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Research Article

Artificial Intelligence in Supply Chain Management: An Integrated Framework

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Abstract

Degree of sophistication of work in the field of Supply Chain Management (SCM) has changed due to emergence of Artificial Intelligent (AI). Therefore, this study aims to explore the recent trends and research opportunities in the field of AI based SCM and develop an integrated framework for the same. The study applies bibliometric techniques to trace the evolution of AI based SCM and proposes the promising themes for future research. The study identified six main research themes through cluster analysis. The identified themes were: *(a) 'Industry Environment Analysis for AI based SCM', (b) 'Challenges and Future Directions of AI based SCM Implementation', (c) 'Optimization Techniques for AI based SCM', (d) 'AI based SCM in Industry 4.0', (e) 'Impact of adopting techniques on AI based SCM', and (f) 'Planning and Decision making in AI based SCM'.* Finally, the researchers proposed the integrated framework revealing the various steps that should be followed for the effective implementation of AI based Supply Chain in Industry 4.0.

Keywords: Supply Chain Management (SCM); Artificial intelligence (AI); Bibliometric Analysis; Industry 4.0; Cluster analysis.

Introduction

The world has been gradually transitioning to a digital future over the past few years, and Industry 4.0 technologies are generally recognized as the trend of the future (Xu *et al.,* 2018). Among these technologies (such as blockchain, IoT, cloud computing, and so on), Artificial Intelligence (AI) is one of the most well-known (Dirican, 2015). AI is described as a machine's capacity to mimic and converse with human abilities (Schutzer, 1990). AI can solve issues more rapidly,

precisely, and efficiently. AI is expanding through process adaptation across a wide range of industries, including Supply Chain Management (SCM) (Jarrahi, 2018; Martinez-Lopez & Casillas, 2013).

AI's presence has changed several fields, including business research. AI is now being studied from a more holistic viewpoint (Canhoto & Clear, 2020; Dirican, 2015), with supply chain management seen as one of the disciplines that stands to profit the most from AI applications. Consequently, given the relative interest in this area from practitioners and researchers (as evidenced by the numerous studies on AI, including Nishant *et al.,* 2020; Jarrahi, 2018; Ransbotham *et al.,* 2017; Vargas *et al.,* 2015; Min, 2010), it is necessary to investigate the role that Artificial Intelligence (AI) plays in operationalizing Supply Chain Management (SCM).

Thus, following are the main objectives of the current study:

RO1: To study the role of Artificial Intelligence in operationalizing Supply Chain Management in the organizations.

RO2: To develop the integrated framework for the effective implementation of AI Based Supply Chain Management in Industry 4.0.

Considering the information presented above, the primary objective of this paper is to conduct an in-depth examination of the existing literature on AI and related fields in conjunction with SCM over the past decade. The study aims to identify the predominant themes related to SCM and discuss the future scope of studies in the field of SCM. The study provides a direction for future research in the area of AI and SCM through the developed integrated framework.

Literature Review

Artificial intelligence (AI) has emerged as a key element needed to successfully implement operational reforms in organizational systems. Implicitly, AI is the premise underpinning how machines think, act, and perform in ways that are either identical to or comparable to those of humans. It has become a necessary activity for commercial organizations (Aloini *et al.,* 2018). This has caused AI to become a prominent topic in the business world. The field of AI was first conceptualized by the scientist McCarthy et al. (2006), and it was publicly introduced at the Dartmouth Conference in 1956 (Moor, 2006).

Today, AI is at the forefront of many corporations' priorities (Balugani, *et al.,* 2018; Sreedharan *et al.,* 2020). The branch of computer science or information technology known as artificial intelligence is responsible for the creation of expert systems, algorithms, and programs (Ahmadi & Abadi, 2020; Shukla & Vijay, 2013). In the field of industrial manufacturing, AI offers a new approach to SCM. With the aid of AI, companies can improve the efficiency and effectiveness of operations, achieving high performance at reduced costs.

AI integration in SCM is a social process as well as a technological one, impacted by how humans perceive and understand AI systems (Hendriksen, 2023). Modern supply chain management combines AI and big data to address many challenges. Artificial intelligence is the application of machine learning, it uses algorithms to automate decision-making and change workflows (Singh, 2023). Supply chain managers are using both AI and big data to optimize their businesses. The goal of AI is to simulate the human brain to make decisions in the same manner that humans do when face with a wide variety of challenges and obstacles (Deshpande *et al.,* 2018; Qamar *et al.,* 2021).

The concept of AI was initially put forward in 1956, although the area has made substantial strides in the last several years (Gil *et al.,* 2020; Jamwal *et al.,* 2021). AI has led to a significant improvement in processing capabilities. The best example that can be provided is the abundance of data related to medical, meteorological, defence, and other similar disciplines that are processed effectively along with a decrease in the time and cost associated with the maintenance of the data (Chaouch, 2022)

In addition to addressing simple issues like scheduling business events and answering customer service questions, AI also encourages the decisiveness of a knowledgeable human to resolve complex issues by applying reasoning and analytical skills similar to those of computers. Computer-based models that function as independent agents are called agent-based systems, or agent-based models. These agents can finish the tasks assigned to them by working independently or in groups. These groupings can be regarded as organizations (Jeble *et al.,* 2018; Jha *et al.,* 2018). Big data analytics is the act of handling large amounts of data, whereas big data itself refers to a significant amount of data.

Research Methodology

This study employs bibliometric methods to examine the current body of research on Artificial intelligence (AI) and its applications in Supply Chain Management (SCM). Advanced mathematical and statistical techniques are utilized to conduct a comprehensive review and assessment of the scientific contributions and impact of research publications. Bibliometric evaluation involves retrieving documents from various bibliographic databases, including Web of Science (WoS), Scopus, and Google Scholar.

Subsequently, the identified documents are analysed using a range of bibliometric techniques and graphical representations to gain a better comprehension of the evolution of a specific intellectual and conceptual framework. These techniques include co-citation, co-word, and co-authorship analysis (Benckendorff & Zehrer, 2013;

Koseoglu et al.,, 2016). Bibliometric metrics such as citation counts per paper, author, and/or country are also used by various scholars (Donthu, *et al.,* 2021; Utkarsh *et al.,* 2021).

This study utilized the Web of Science (WOS) database, a renowned global repository of scholarly articles, to gather publications on SCM. Previous studies, including Pereira *et al.,* (2018), Ferreira *et al.,* (2021), and Evangelista *et al.,* (2018), have carried out numerous studies employing WoS platform. The Web of Science Database was searched, yielding 27,334 studies upon using the keyword "Supply Chain Management." Subsequently, the inclusion criteria "Global Supply Chain & Artificial intelligence" and "Supply Chain & Artificial intelligence" narrowed down the selection to 752 studies eligible for inclusion in the study. Finally, 664 papers with full-text access were considered suitable for this bibliometric analysis.

Based on themes emerged from bibliometric analysis, *an integrated framework for the effective implementation of AI based SCM in Industry 4.0* was developed. Using Vosviewer (Visualizing Scientific Landscapes, 2018), a co-word analysis of keywords appearing in the title, abstract, and author-provided keywords was performed to identify the interlinkages between the keywords and thus understand the key research areas of the published articles. The co-word analysis assumes that the co-occurrence of keywords describes the article's content (Callon *et al.,* 1991). Furthermore, the co-occurrence of keywords in a specific set of articles reflects the inter linkage of keywords (Verma & Gustafsson, 2020; Waltman *et al.,* 2010). As a result, the most occurring keywords are clustered into groups (research themes), and a network map depicting the inter linkages between the research themes is generated.

Findings and Results

Emerging Dimensions in AI based SCM: Keyword-based Analysis

To explore the emerging dimensions in the field of Artificial Intelligence (AI) based Supply Chain Management (SCM), Keyword analysis was conducted and various clusters were formulated using Vosviewer. Post pandemic Covid-19, the focus is on the improvement of SCM's performance by developing various frameworks using neural networks and the application of different technologies in various sectors. The studies during this phase focus on the role of AI in the Context of Industry 4.0. For instance, the research conducted by Gupta *et al.,* (2021) examines and analyses previous research in the realm of Decision Support Systems (DSSs), as well as how Artificial Intelligence (AI) capabilities have been integrated into Operations Research (OR) and demonstrate how AI has aided decision-making in the field of operations research.

Similarly, to assess the SCM in Agriculture Rejeb *et al.,* (2022) perform a bibliometric analysis of Internet of Things (IoT) and agriculture in academic literature. Using a resource-based perspective (RBV), the study identified agricultural resources most influenced by the IoT (seeds, soil, water, fertilizers, pesticides, energy, livestock, human resources, technological infrastructure, and business relations) and offered various areas for further study.

The quantitative study conducted by Cadden *et al.,* (2022) investigates the connections between supply chain culture and AI. It focuses on the generalizability of culture to reveal unique insights regarding AI-driven supply chains that have not been documented in any earlier studies. The findings provide evidence of the crucial role that cultural enablers play in the effective integration of AI technology in supply chain, which has repercussions for both operations management and supply chain management. During the last decade Industry 4.0 revolution has sped up digital transformation, automated production, and improved business decision-making.

Rodríguez *et al.,* (2022) integrate institutional theory, the resource-based approach, and the technology acceptance model to construct a unique behavioural model for risk management using big data, AI, cloud computing, and block chain from the operations manager's perspective. The model was validated for each I4.0 technology using data from 117 UK industrial operations managers. The study highlights the maturity, market pressure, legislation, and resilience of the perceived utility and uptake of these technologies for controlling business risks and also describes how operations managers might utilize I4.0 technology to increase operational productivity.

Richter *et al.,* (2022) conducted a study on Electricity Supply Chain. The Power Supply Chain optimizes electricity generation, transmission, and consumption. The amount of distributed energy sources in the electrical system is rising, which requires greater monitoring to assure the Electricity Supply Chain's stability and quality. Growing data demands automation. Large volumes of heterogeneous data must be handled and processed utilizing forecasting and optimization approaches. AI approaches extend human cognitive powers in certain activities. In this paper, the authors summarize the key implications of AI on Electricity Supply Chain automation and discuss AI automation at every layer of the Smart Grid Architecture Model and showcase cutting-edge techniques.

The study conducted by Zdravkovic *et al.,* (2022) interrogated the AI applications integrated with Customer Relationship Management, Supply Chain Management, Inventory and logistics, Production Planning and Scheduling, Finance and accounting, Product Lifecycle Management, and Human Resources, with a focus on manufacturing firms. The study revealed that AI services

provide enhanced capabilities. AI enablement uses Machine Learning models or logic-based systems to improve decision-making or automation. It's a process of corporate transformation that leads to the confluence of four disruptive technologies: IoT, ADS, Cloud Computing, and AI.

Rathore *et al.,* (2022) in their study identify impediments to Disruptive Technology adoption and examines their interrelationships in logistics. The Fuzzy Delphi Method was used to reduce the number of obstacles from 12 to 10 after a thorough literature assessment. The report points out that Industry 4.0 technologies can improve economic, environmental, and social performance and emphasizes the need for logistics efficiency for an organization's survival in cutthroat markets. Sustainability trade-offs, unclear benefits, environmental lifetime effects, fairness concerns, and technology maturity are some of the issues that still exist. Future studies should concentrate on balancing sustainability metrics across product lifecycles, Human-AI collab, system integration, digital twins, semi-autonomous transportation, & intelligent reverse logistics.

Similarly, the study conducted by Toorajipour *et al.,* (2021) reviews the literature to identify AI's contributions to SCM. This study intended to discover present and potential AI techniques that can improve SCM study and practices. The research identifies prominent areas viz. the most common AI techniques in SCM; the possible AI techniques for SCM; and the AI-improved SCM subfields with high AI enhancement potential. Four SCM sectors (logistics, marketing, supply chain, and production) are identified and evaluated using inclusion and exclusion criteria.

In line with other studies, Aylak (2021) discovered that incorporating Artificial Intelligence (AI) and Machine Learning (ML) into the Agricultural Supply Chain (ASC) improves monitoring, prediction, and decision-making. This research presents a thorough evaluation of the literature on AI and ML applications in the agricultural supply chain. AI and ML applications for agriculture have been proposed for the following phases: crop yield prediction, soil property prediction, and irrigation management; weather prediction, disease detection, and weed detection; demand management and production planning; and finally, transportation, storage, inventory, and retailing.

During 2018-2020 the major concern was on developing various models and decision support systems for managing Supply chains using several computing techniques like neutral networking, fuzzy logic, algorithm, etc.In one such study, Dumitrascu *et al.,* (2020) developed a performance evaluation model that links certain difficulties to the most pertinent Key Performance Indicator (KPI) for every SCM subsystem. The study describes the adoption of data mining to identify the connection between KPIs and issues that occur in any business's supply chain management. The project concludes with a Graphical User Interface (GUI) that forecasts the most dependable KPIs for each selected topic using neural networks and the multilayer perceptron AI algorithm.

Cluster Analysis Based on Keywords

To explore the emerging areas of the various studies conducted at international platforms in supply chain management, the analysis of the keywords was conducted using the Bibliometric software Vosviewer. Overall, five clusters were constituted, which are shown in Fig. 1 The clusters are deciphered in Table 1.

The first cluster consists of studies based on AI and technological frameworks in SCM. The second one discusses the challenges and future of SCM implementation. The third cluster consists of the studies on the design and future of SCM implementation. The fourth cluster elaborates the application of SCM in industry 4.0. The fifth and sixth cluster consists of the impact of adopting algorithm on SCM and decision-making in SCM by employing a variety of methods like Data Envelopment Analysis and Reverse logistics. The attributes of studies under each of the clusters are discussed as Cluster 1-6.

Cluster 1: Industry Environment Analysis for AI based SCM

In this Cluster the focus is on '*Industry Environment analysis, Business Analytics, SCM Practices, Smart Technology, Artificial intelligence*'. Authors in this cluster indicated that Resource-Based View (RBV) could be applied in SCM by focusing on a company's unique resources, capabilities, and competencies to get a competitive edge. This approach emphasizes leveraging internal strengths to optimize supply chain processes, enhance operational efficiency, and create value for customers. A company might utilize its advanced technology, skilled workforce, or specialized knowledge to streamline logistics, improve inventory management, or implement innovative resourcing strategies within the supply chain. The vital step for the implementation of AI based SCM is to identify the various factors and processes, which impact the supply chain in the industry.

Managers must look for the technological changes occurring in the industry and their aftermaths. The empirical study conducted by Chien *et al.,* (2020) on Deep reinforcement learning for selecting demand forecast models to empower Industry 3.5 studied semiconductor component distributors and found that smart technology plays a crucial role in the execution of the effective supply chain. By combining deep learning architecture and RL algorithms, deep RL can learn effective policies from the dynamic and challenging actual world. In line with this, the study conducted by Sobb *et al.,* (2020) revealed that the fourth revolution in SCM systems is Supply Chain 4.0,

which integrates industrial activities with telecommunications and information technology processes.

Although the overarching goal of supply chain 4.0 is to improve production systems within supply chains by leveraging global reach, increasing agility, and emerging technology, with the goal of increasing efficiency, timeliness, and profitability, supply chain 4.0 is plagued by new and emerging operational and cyber risks. In the operation of its industrial and information technology processes, supply chain 4.0 suffers from a lack of semantic standards, inadequate interoperability, and a lack of security. Block chain, smart contracts, AI applications, cyber-physical systems, Internet of Things, and Industrial Internet of Things are among the technologies that underlie supply chain 4.0. Each of these technologies, both alone and in combination, raises cyber security concerns that must be addressed. To implement future research initiatives in AI based SCM, Industry environment analysis must be conducted holistically and through technology-specific perspectives.

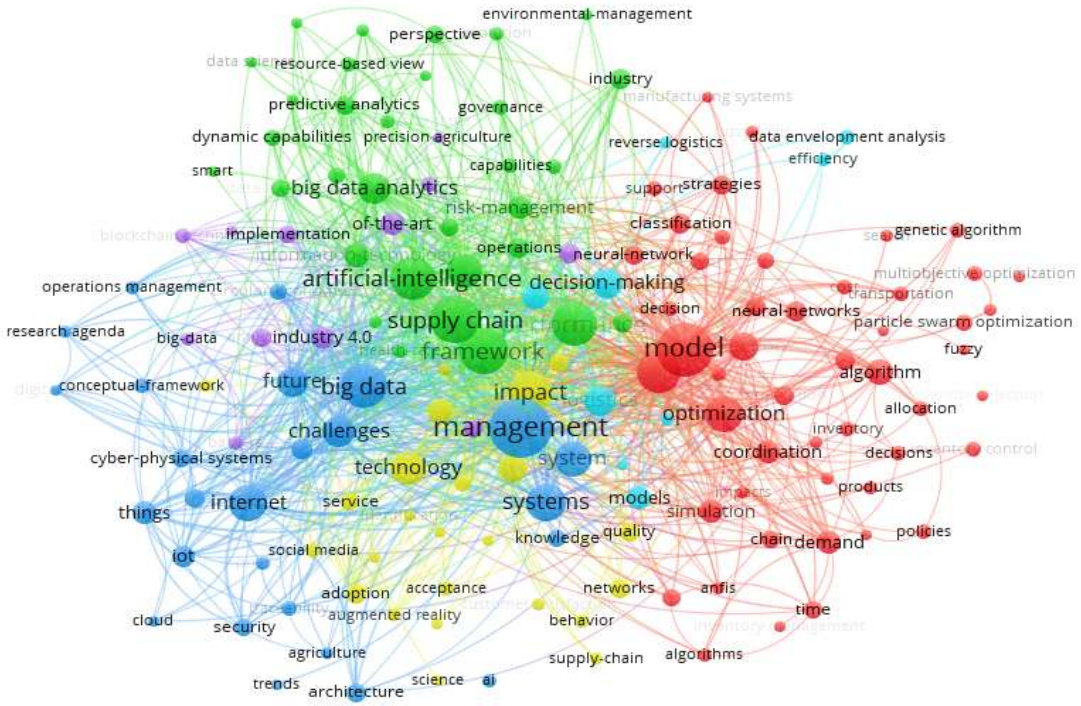

Fig. 1: Keywords Analysis
Source: Vosviewer Output

Table 1: Keywords Cluster Analysis

Clusters	Cluster 1 (Green)	Cluster 2 (Blue)	Cluster 3 (Red)	Cluster 4 (Purple)	Cluster 5 (Yellow)	Cluster 6 (Sky Blue)
Area of Study	Industry Environment Analysis for AI based SCM	Challenges & Future Directions of AI based SCM Implementation	Optimization Techniques for AI based SCM	AI based SCM in Industry 4.0	Impact of adopting techniques on AI based SCM	Planning and Decision making in AI based SCM
Keywords	Industry Environment analysis, Business Analytics, SCM Practices, Smart Technology, Artificial intelligence	Role of Technology and IOT, System Modelling and Architecture SCM	Algorithm(s), Neural Network, Fuzzy Logic, Stimulation, Integration, Regression, Decisions, Swarm Optimisation, Transportation, Manufacturing system	Block Chain, State Art, Business Analytics, Big Data Analytics, Industry 4.0	Adoption, Generic Algorithm, enhancement of knowledge, quality, SCM	Data Envelopment Analysis, Artificial Intelligence, and Reverse Logistics

Source: Author's compilation

Cluster 2: Challenges and Future Directions of AI based SCM Implementation

The second cluster consists of various studies addressing the challenges and future of SCM implementation. To create a smart port supply chain knowledge service model in the rapidly expanding field of big data and AI employing knowledge matching, knowledge fusion, and natural language processing, Bo *et al.,* (2021) emphasizes future trends in knowledge service and big data technology. A port supply chain knowledge service model is built, which includes knowledge acquisition, knowledge organization & knowledge service modules.

Di Vaio *et al.,* (2020) consider the sustainable and socially responsible perspective depending on the level of environmental consciousness that each stakeholder possesses; that can play either a central or a supporting role in the process of value generation for the company. Further, the study concluded that these challenges appear to still be open in some industries, such as the agri-food industry, where the adoption of new technology needs the entire business model to be rethought and redesigned.

The research conducted by Galasso and Thierry (2009) revealed that to increase the performance of supply chains, it is vital to consider the demands of the customers via strategic planning process. Consumers are finding it increasingly challenging to guarantee a specific level of demand over a medium-term time horizon, particularly when their customers have growing demand for customization and rapid adaptation from them. To bring the order process and the bookkeeping process into harmony, it is required to establish methodologies and decision support systems. Within this framework, the primary objective of this study is to establish a connection between making decisions in the face of uncertainty and the perspective of an industry that is predicated on the idea of risk management. This serves as the foundation for the formulation of a strategy that is dedicated to the design of cooperative processes in a customer-supplier relationship and is based on simulation and decision theory.

In line with our current study Kuzior and Sira (2022) using bibliometric analysis revealed that Block Chain has been widely used along with SCM and sustainable development. The visualization generates three sets of clusters. Red incorporates blockchain, SCM, and sustainable development. Blockchains, smart contracts, e-money, Bitcoin, and Ethereum are in the green cluster. The blue cluster covers AI, big data, healthcare, and COVID-19. The study advocated that several factors keep blockchain popular. It has helped digital currencies and other non-crypto currencies flourish in recent years. Researchers are currently exploring further blockchain's possibilities.

Cluster 3: Optimization Techniques for AI based SCM

The study in this cluster discusses the designing and modelling of SCM. For instance, the study conducted by Aalaei and Davoudpour (2017) proposes a bi-objective optimization model for virtual cellular manufacturing and supply chain architecture. The model includes multi-plant and facility locations, multi-market allocations, and multi-period production planning under variable product demand and resource capacities. This model became an auxiliary crisp model. The model is solved using an improved multi-choice goal programming technique. The suggested methodology strives to reduce the entire cost of supply chain design, including holding costs, outsourcing costs, machine maintenance and administrative costs, fixed costs, external transportation costs, and the number of unusual elements and labour movements between active facilities. Computational results are discussed using a real-world case study and the proposed model solution approach.

Mamashli *et al.,* (2021) suggested that considering the rise in the frequency of natural disasters and the substantial amounts of trash that are produced because of these occurrences, it is essential to have a comprehensive structure for the management of this waste during the stages of a catastrophe that involve recovery and response.

A chunk of people who are concerned about environmental and safety issues is enlarging, which has made the topic of sustainable production and consumption an important one in the chemical business. Choy *et al.,* (2016) already raised the issue of sustainable consumption and production in the Chemical industry. The study strongly recommends that companies enhance the quality of chemical goods while simultaneously reducing the negative effects of manufacturing on the surrounding environment. During the process of inception and development of a product, chemists and formulators are tasked with deciding not only which components will go into the final product, but also how each machine's settings will be configured. During the process of developing chemical products, the trial-and-error procedures cause a significant amount of the ingredients, toxic materials, and pollutants to be wasted or emitted. These losses will persist if the operations department lacks suitable methods for controlling sustainable production and consumption. In this study, the recursive operations strategy, or ROS, model is used for attaining sustainable consumption and production in the chemical industry.

Cluster 4: AI based SCM in Industry 4.0

This cluster consists of studies on SCM in the context of Industry 4.0 based on Big Data Analytics. The study carried by Stekelorum *et al.,* (2021) investigated the capabilities of big data predictive analytics and supply chain ambidexterity on the part of suppliers as potential supporting elements for responsible governance mechanisms used by buyer enterprises to strengthen circular economy practices. The

findings of questionnaires administered to a total of 404 businesses indicate that a focal firm's supplier-selection process has a considerable impact, both positively and significantly, on the circular economy practices of the focal firm. The firms should strengthen their supplier selection process criterion while designing the Supply chain.

Ganesh and Kalpana (2022) revealed that Supply Chain Risk Management (SCRM) is a fast-expanding topic of research that encompasses the identification, evaluation, mitigation, and monitoring of the risks of unexpected and unusual occurrences. This field of study is predicted to become increasingly important in the coming years. Although research on SCRM has been ongoing for a considerable amount of time, the sectors continue to struggle with effectively managing the SC risks. In addition, the managers of SC have started to place greater emphasis on decision-making that is based on a variety of data sources, with the goal of more correctly forecasting uncertainties and achieving a proactive and predictive intelligent risk management system. Due to these characteristics, AI and ML are two methodologies that are well-suited for use in the SCRM sector. The implementation of these strategies in SCRM is still in the infant stages of development.

Bhattacharya and Chatterjee (2022) addressed numerous goals in the '*Architecture, Engineering, Construction and Operations*' (AECO) value chain by proposing an integrated framework for digital '*Project-Driven Supply Chains'* (PDSC) and evaluating emerging themes of the Fourth Industrial Revolution (4IR) technologies. Findings of this study indicates that the implementation of 4IR technologies has the potential to utterly transform the AECO supply chain industry and launch the field into an entirely new paradigm. The tremendous computational capacity that has been liberated has the potential to contribute to an increase in the efficiency in delivery. Technologies with enormous promise for the future include the Internet of Things, Internet of Services, cloud computing, big data, smart factories, 3D printing, cyber-physical systems or embedded systems, augmented reality, virtual reality, and robotics. The study suggested that an integrated framework should be developed to satisfy the numerous goals namely - enhanced project delivery, greater productivity and cost savings, activity monitoring, reporting and agility, improved workflow procedures, and reduced wastage. Consequences and restrictions of the research provide suggestions for the comprehensive integration of the AECO supply chain to provide value to the end consumers.

Cluster 5: Impact of adopting technologies on AI based SCM

Min (2022) carried out research on rapid technological improvements that have been sparked by the Fourth Industrial Revolution (also known as Industry 4.0). The seaports of today are under significant amounts of pressure to modify how they function to accommodate the traffic flows. The study revealed that a smart port can decrease the amount of time it takes for users of the port to respond, improve the utilization of port assets, and increase the visibility of maritime logistics by digitally automating and integrating all stages of port operations without the need for humans. Another study conducted by Krupitzer and Stein (2021) advocated that the increasing number of people on the planet, the changing attitudes and behaviours they have regarding food consumption, and the recent surge in knowledge surrounding the importance of food sustainability all contribute to the emergence of new challenges for the industry that deals with the production of food.

Recent advancements in Internet of Things (IoT) and Artificial Intelligence (AI) technology, such as Machine Learning (ML) and Data Analytics, could be able to help mitigate some of the negative consequences of these challenges. With regards to the Aim and the Approach because of the rise of digitization, there are a variety of various research methodologies that have already opened new doors of possibility. Precision agriculture, the internet of food, the industrial internet of things, and smart health are a few examples of these technologies. An additional concept that should be considered is food informatics, which has been recognized largely as a strategy that is mostly data-driven and aims to aid in the production of food.

In this review paper, authors propose and discuss a new perspective on the concept of Food Informatics as a supportive discipline that subsumes the incorporation of information technology, primarily the IoT and AI, to support the variety of aspects tangent to the food production process and differentiate it from other, existing research streams in the domain. The study describes food informatics as a supporting subject that encompasses the inclusion of information technology, namely the IoT and AI.

Cluster 6: Planning and Decision making in AI based SCM

In this cluster, the studies address '*Data Envelopment Analysis*' (DEA), AI and Reverse logistics in SCM. The study conducted by Hsu *et al.,* (2019) developed a conceptual framework for decision-making analyses of '*Decision-Making Units*' (DMUs) from a variety of perspectives. The data were shown using '*Multi-Dimensional Scaling'* (MDS), which was done so that the results would be more understandable to those who are not professionals in the field. The study uses two soft indicators viz. '*Supply Chain Indicator'* (SCI) and '*Sentiment Indicator'* (STI) for developing the forecasting model. SCI is computed by combining the use of text mining and Social

Network Analysis (SNA). The results of the analysis are then included in a method that is based on AI, which is used to build the forecasting model.

Loske and Klumpp (2021) utilized fuzzy '*Data Envelopment Analysis'* (DEA), fuzzy DEA with '*Slack-Based Measurement*' (SBM), and fuzzy DEA with '*Analytic Hierarchy Process'* (AHP). In both the Fuzzy DEA and the SBM fuzzy DEA models, it is possible to demonstrate that there are efficiencies to be gained for the two depots that are utilizing AI-based routing. Results further indicate that the methodological approach used is appropriate for the problem that was analysed and that the combination with AHP is an interesting addition as, for example, the perspective of sales managers supersedes that of logistics managers for route planning efficiency.

Integrated framework for Implementing AI based SCM in Industry 4.0

Based on the Bibliometric Analysis the present study proposes an integrated framework for the effective implementation of Artificial Intelligence (AI) based Supply Chain Management (SCM) in the era of Industry 4.0 as shown in Fig. 2.

Fig. 2 decipher an integrated framework representing the various steps and key considerations for the implementation of AI based Supply Chain in Industry 4.0. During the last decades there is huge transformation in the field of Logistics. The first and foremost steps for the effective implementation of the Supply Chain is to conduct the industry environment analysis using *Business Analytics, Smart Technology and Artificial Intelligence.* After industry environment analysis, planning and decision making is the crucial step. The decision can be reached using Data Envelope Analysis and Reverse Logistics considerations. The next step is to optimize the Supply Chain Technology using the various optimisation techniques applying tools like *Algorithm(s), Neural Network, Fuzzy Logic, Stimulation, Integration, & Regression Analysis.* It is necessary to evaluate the effects of SCM deployment in terms of knowledge enhancement and quality of AI based SCM. The last step is to address the challenges in the adoption of AI based SCM. The previous literatures revealed that the challenges should be addressed in the light of *Role of Technology, Internet of Things (IOT), System Modelling and Architecting Supply Chain.* These actions will eventually result in the successful deployment of an AI-based supply chain under Industry 4.0.

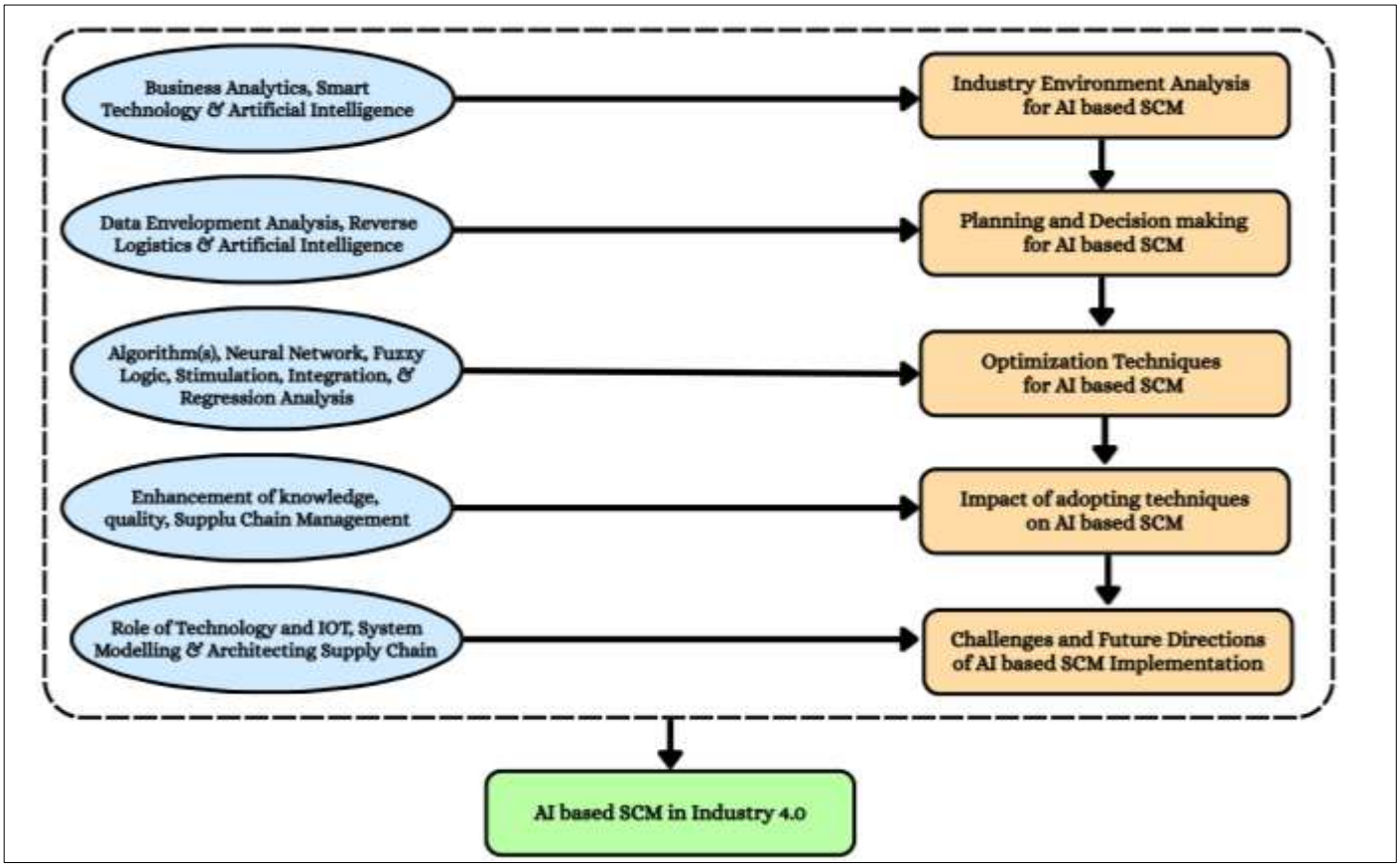

Fig. 2: An Integrated Framework for the Effective Implementation of AI based SCM
Source: Authors' compilation

Managerial and Academic Implications

AI has significant potential to support supply chains. The supply chains must quickly analyze large data using effective solutions that offer real-time decision-making insights to keep a competitive edge which can be easily done through AI. The present study reviewed 664 detailed research papers on AI based SCM published in the last decade. The study outlined important patterns emerging in the field of SCM which would enhance the research interest among academicians. The study is novel as it utilizes Bibliometric analysis for developing theoretical framework. Further, the study employed scientific mapping techniques for categorising the reviewed literature.

In present study, AI and global supply chain management keywords are utilised for the Bibliometric and Cluster Analysis, which organised AI Based SCM studies into six major categories: '*Industry Environment Analysis of AI based SCM', 'Challenges and Future Directions of AI based SCM Implementation', 'Optimization Techniques for AI based SCM', 'AI based SCM in Industry 4.0', 'Impact of adopting technologies on AI based SCM' and 'Planning & Decision making in AI based SCM'.* Bibliometric Analysis followed by a detailed data visualization through network analysis captured the key features of literature. The present study adds several theoretical contributions in the field of AI based SCM literature. The study provides new insights to the academic scholars regarding the effective implementation of AI based SCM using the developed framework that can be validated through future empirical studies across various sectors and countries.

The study has several useful ramifications for managers. The present study highlights the interconnections and complexities of supply chain networks & Artificial Intelligence and also develops an integrated framework for effective implementation of AI based SCM in Industry 4.0. Organisations can implement this integrated framework for effective and efficient implementation of AI based SCM, which will lead to higher productivity and profitability in the present complex business environment. Organizational learning can speed up AI outcomes in operations and SCM, according to Wamba *et al.,* (2023). Businesses now a days earns profit by making their SCM resilient against disruptive and unexpected occurrences through information system management efficiently using AI which is statistical-based, predictive, and self-learning algorithms.

The developed framework helps infuse AI in SCM and hence help the managers to improve their supply chain performance metrics in the dynamic and unpredictable business environment. The developed framework emphasises implementation of AI as an emerging technology, which provides long-term competitive advantage to the organizations. AI improves the sensing and grabbing capabilities and makes supply chain more competitive (Pournader *et al.,* 2021). The AI based SCM framework plays a significant role in boosting SC productivity. AI can be combined with other developing technologies and can be utilised to improve real-time supply chain performance and minimise waste, opening the path for more sustainable manufacturing systems.

In terms of behavioural operations, real-time information exchange offered by AI systems can improve SC interactions, SC integration, and stakeholder coordination (Helo and Hao 2022). Through the application of proposed framework practitioners can focus on the enablers for effective AI integration in supply chains. AI approaches might also be considered as a socio-technical benefit in production and operations management. AI deployment will not only cut mistakes and setup times, but it will also increase worker safety by improving human-robot interactions.

Conclusions

The study concludes that after the year 2020, there was a surge in research area of AI based SCM, and this trend is continuing strongly even today. The increase in the number of papers relating to the AI Supply Chain demonstrates that the field has progressed to a more sophisticated level. The keywords analysis concluded that the studies based on Industry Environment Analysis for AI based SCM, the challenges & future directions of AI based SCM implementation, the designing and modelling of AI based SCM, Application of AI based SCM in industry 4.0, Assessing the impact of adopting technologies on AI based SCM and AI based SCM Decision making using various techniques like Data Envelopment Analysis, and Reverse logistics are the emerging dimensions in Supply chain management. The proposed integrated framework for effective implementation of AI based Supply Chain Management provides guideline for organizations to achieve profitability, longevity and sustainability in Industry 4.0.

Authors' Contribution

All authors contributed equally at all stages of research and preparation of the manuscript. Final form of the manuscripts was approved by all authors.

Competing Interest Declaration

The authors declared no potential competing interest with respect to research, authorship and (or) publication of this article. All authors have equally contributed to this article.

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