DOI: 10.46541/978-86-7233-416-6_56

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A LITERATURE REVIEW ON ARTIFICIAL INTELLIGENCE IN GLOBAL SUPPLY CHAIN MANAGEMENT

Abstract: Artificial intelligence (AI) can significantly improve the efficiency and resilience of supply chains due to its potential to forecast future demand, reduce costs, optimize logistics, enhance quality control, improve inventory management, as well as to increase both customer satisfaction and overall effectiveness of global supply chain management (global SCM). Despite these benefits and popularity, research to date on the contributions of AI to global SCM is rather dispersed. This paper aims to synthetize this relevant body of knowledge and assess the current context of AI in supply chain literature.

Keywords: literature review, synthesis, artificial intelligence, global supply chain management

1. INTRODUCTION

Over the last few years, the world is increasingly moving towards a digital era and Industry 4.0. Technology is steadily emerging as a crucial provider of adequate solutions for complex problems in business operations, while supply chains are certainly no exception to such trends. Against this backdrop, artificial intelligence has long been recognized as one of the leading technologies capable of enabling communication between machines and devices (Guzman & Lewis, 2020; Dwivedi et al., 2021). In point of fact, artificial intelligence, as a highly disruptive technology, has drastically changed the way decisions are made and also affects the progress of both businesses and industries. More than a decade ago, a major decline in trade followed by a number of transmission mechanisms was seen as one of the most prominent features of the 2007-2008 financial crisis (Kostoska, Stojkoski & Kocarev, 2020). Among these mechanisms, an exceptional role has been assigned to the emergence of global supply chains, and also to the differing compositional effects of the demand shock on trade and GDP (Altomonte et al., 2012). In short, the global financial crisis has already had a strong impact on global supply chains with potentials to permanently change some of the fundamental supply relationships. Many companies that have offshored their sources of supply, have encountered severe disruptions in the ability to procure materials and products. "The sudden drop in orders in developed countries spread rapidly through global supply chains, resulting in severe cutbacks in production in the multiple tiers of the supply chain. In some cases, suppliers failed due to lack of financial capacity to survive the sudden fall in orders. In other cases, they cut quality or lengthened delivery times in a desperate attempt to reduce costs" (Mefford, 2009, p.9). In the coming decade, global value chains will experience an even greater transformation. The change will be prompted by the need for greater supply chain resilience on account of Covid-19, which in turn is compounded by existing pressures from the technological revolution (Baldwin, 2019; Bolwijn et al., 2019; Brun et al., 2019), rising economic nationalism (Blanchard, 2019; Bellora & Fontagnè, 2019; Zhan, 2019) and the imperative for sustainability (De Backer & Flaig, 2017; Kolk et al., 2017). Corona virus pandemic costed both millions of lives and significant disruptions in supply chains of various industries. Indeed, poor supply chain information has caused a series of unforeseen delays in receiving materials from certain locations (Paul & Chowdhury, 2021), whilst some other factors such as reduction of production costs, consolidation of suppliers and risk minimization have reduced the available inventories leading to the current state of knotty shortages (Dolgui & Ivanov, 2020; Wang-Mlynek & Foerstl, 2020). What is extremely important is to highlight the challenges in today's supply chains that have caused this level of crisis for companies. Namely,

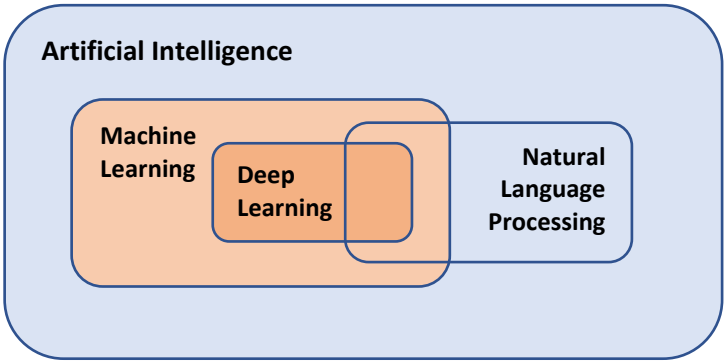
manufacturing has become very complex with respect to outsourcing components from multiple locations to produce a single product. In other words, there is an exceptional dependence on logistics, import and export, which in turn requires smart solutions to address the harmful disruptions (Choi, 2020; Wamba et al, 2020a, Wamba et al., 2020b). In a time of Covid-19, shortfalls in the network, and especially the risk of distribution (for example responsive allocation, direct distribution and stuffing of warehouses) represent an even greater challenge (de Koster & Warffemius, 2005; Butt, 2021). For this reason, logistics professionals should consider integrating the cutting-edge systems, especially those pivoted around artificial intelligence to fill the gap that the human resources cannot effectively manage. By combining AI tools with human control, managers will be able to better protect supply chains from current and future challenges. For example, machine learning is a system that might examine a huge amount of data and also acknowledge the signals, patterns and trends in data, providing for adjustments in the supply chain when necessary. Internet of Things devices, on the other hand, can assist in monitoring supply chains by collecting the necessary data to notify supply chains professionals when the machine needs maintenance or replacement. In short, what is important is that artificial intelligence does not refer to a specific technology, but rather a paradigm shift in respect to how we think over the technology itself. We often think of artificial intelligence as something that allows for automation, but this view, by its nature, is too limited. "The true role of artificial intelligence in the supply chain is to enhance and augment human intelligence and decision making, as opposed to being something that makes it obsolete…Ultimately, the role of AI in supply chains is two-fold: the automation of repetitive tasks and processes across supply chain functions; the realization of new forms of strategic decision-making and collaboration" (Bradic, 2020, paras.5,7). With all this being said, it is clear that artificial intelligence is taking an increasing presence in the scholarly discourse of global SCM. Hence, the purpose of this paper is to contribute to a systematized understanding of AI's contribution to global supply chain management studies.

The rest of the paper is organized as follows. The section 2 refers to artificial intelligence and its (sub)fields. The section 3 and section 4 are focused on pros and cons of AI-powered global supply chains. The last section concludes and recommends.

2. ARTIFICIAL INTELLIGENCE AND ITS (SUB)FIELDS

The concept of artificial intelligence focuses on the capacity of modern technologies to interpret different types of data, learn from data and flexibly adapt to different situations (Angeleski et al., 2022). It is a technology that uses modern algorithms and historical data to develop systems capable of performing tasks analogous to those performed by humans. The primary goal of this technology is to create advanced tools that use available data and offer opportunities to efficiently solve various business problems (Angeleski & Kostoska, 2022). So, artificial intelligence refers to systems that demonstrate intelligent behavior by examining and interpreting their environment, and then independently taking actions, with a certain degree of autonomy, to achieve certain goals (Boucher, 2020).

Artificial intelligence includes a number of research fields such as: machine learning (ML), deep learning (DL), natural languages processing (NLP), expert systems, evolution algorithms, search algorithms, knowledge graphs and many others (Xu et al., 2021) that can find application in various fields. Considering that machine learning (ML), its subfield deep learning (DL) and natural languages processing (NLP) are the most exploited fields of AI and whose algorithms are mostly used in SCM, a brief introduction to all of them will follow (Picture 1).



Picture 1: Artificial Intelligence and its (sub)fields overlapping: Machine Learning, Deep Learning and Natural Language
Source: Author's representation

Machine learning is a branch of artificial intelligence (AI) which focuses on the use of data and algorithms to imitate the way that humans learn and behave, gradually improving its accuracy from experience without being explicitly programmed and that can access data and use it to learn for themselves (Expert.ai, 2022; IBM, 2022). There are three main classes of machine learning techniques: Supervised learning, Unsupervised learning and Reinforcement learning (Simeone, 2018). Supervised learning is simply a formalization of the idea of learning from examples (Dey, 2017). In the learning process of Supervised learning, two sets of data are defined, that is a training set and a test set. The

algorithm learns to make predictions or decisions based on labeled data in the training set. Labeled data is data that has been previously tagged with the correct output. Supervised learning algorithms generate models from the training data set which can be used to classify other unlabeled data (Cunningham et al., 2008), or to predict some continuous numerical value. “In other words, in supervised learning we have labeled data in the sense that each data point has an input and an output which explicitly explains ‘what we see in the data’” (Lindholm et al., 2019, p.7). In unsupervised learning, the algorithm works with input data that does not have labeled targets or desired outcomes. Instead, the algorithm analyzes the patterns and relationships within the unlabeled data and clusters the data into distinct groups based on their similarities underlying structure and patterns in the data on its own (Haldorai et al., 2020). Reinforcement learning is based on feedback of actions, that is the opportunity to learn in an interactive environment by trial and error, using feedback from its own actions and experiences (Bhatt, 2018; Wuest et al., 2016). Deep Learning is a specialized area within the broader field of machine learning that involves the use of artificial neural networks, which are designed to mimic the structure and function of the human brain. These networks are composed of multiple layers that enable them to process and analyze complex data sets, using nonlinear methods to extract valuable insights and patterns (Brownlee, 2020; Graupe, 2016). Natural Language Processing (NLP) is an Artificial Intelligence discipline that enables machines to understand, interpret, and extract logical meaning from human languages. In other words, “NLP is the use of computers to understand and then process human language in the form of text or speech” (Toorajipour et al., 2021, p.509).

3. ADVANTAGES OF AI APPLICATIONS IN GLOBAL SUPPLY CHAIN MANAGEMENT

Global supply chain management is a key component of business operations as it involves the coordination, planning and control of the delivery of goods and services from suppliers to customers. The optimal utilization of resources in supply chain processes has become a special challenge for businesses, especially in a global environment. Fortunately, the use of artificial intelligence has the great potential to revolutionize such processes and contribute to their optimization. AI applications can help companies predict demand, manage inventory, and automate processes. Artificial intelligence models find application in almost all processes related to Supply Chain Management (planning, sourcing, manufacturing, inventory and warehousing, delivering and logistics, returning) including all actors of the supply chain (suppliers, producers (manufacturer), intermediaries (distributors), retailers, customers). Since global supply chain management encompasses activities from sourcing raw materials, manufacturing, inventory to distribution to end consumers, artificial intelligence can greatly help in increasing efficiency, minimizing costs, improving customer satisfaction and constant monitoring and optimization of the inventory levels. “Inventory bottlenecks lead to delays and reductions in revenue. With the help of AI, businesses can gain complete visibility of supply chain variables and identify the processes that act as bottlenecks” (Cin7, 2022, para.26). Besides, research shows that "marketing and sales, and supply-chain management and manufacturing are among the functions where AI can create the most incremental value" (Chui et al., 2018, p.1).
The next few paragraphs will provide an analysis of several SCM processes that benefit from AI integration (Picture 2).

3.1. Forecasting in Global SCM

One of the rapidly growing technologies in global SCM that offers numerous benefits to businesses is the prediction of various SCM processes. Predictive Analytics enables companies to improve and refine their supply chains in ways that were not feasible before. As the creation of artificial intelligence models is based on large data sets, and the use of ICT in SCM processes makes data increasingly accessible, the use of Predictive Analytics and other AI-based solutions for forecasting and planning within supply chain processes is growing. This will certainly improve production processes, reduce inventory cost, fulfill customer demands, enhance consumer service and expand market share (Naz et al., 2022). Predictive analytics, using historical and current data to identify patterns and make predictions, can improve supply chain analytics, accurately predict demand for products and services, optimize inventory levels, and reduce costs through downsizing of waste (Kassies, 2022). In fact, AI can be used to extract useful information from data in the manufacturing process where large data sets generated without the use of AI algorithms are often difficult to analyze. This means that AI-driven machines are capable of performing a variety of tasks, such as identifying complex patterns, combining data, and predicting outcomes (Wuest et al., 2016). Since artificial intelligence has the ability to automatically process, analyze and make predictions based on data, the application of its algorithms can schedule production to optimize resources and improve demand forecasting (Younis et al., 2022). This allows businesses to optimize the procurement of raw materials resulting in lower costs related to transportation, storage and supply chain management in general (Dash et al., 2019). Predictive analytics, using machine learning, can reduce the time required to solve design problems for manufacturers, reducing the cost of iterations and testing (Bughin et al., 2017).

3.2. SCM processes simulation

The simulation, that is, creating a virtual model of SCM processes, allows for generating different scenarios that will lead to a deeper understanding of SCM operations, better decision-making, and an increase in the overall supply chain

performance. Digital twins assisted by AI algorithms can largely be included in this kind of simulation. A Digital Twin is a dynamic and real-time digital model of a physical entity, such as a product, process, or system. “A digital twin is a virtual replica of the supply chain that can include assets, warehouses and materials. The advantage of a digital twin is it allows supply chain professionals to simulate the flow of materials, acting out a multitude of possible ‘what-if’ scenarios. For example, a digital twin could predict how a supply chain will be impacted if there is unrest in a location where warehouses are located, or if materials get lost due to extreme weather conditions. Creating potential scenarios and watching how each will impact the supply chain provides a unique vantage point to effectively judge risk and efficiency” (Civil, 2022, paras. 3-4). It is built using a combination of sensors, data analytics, and simulation software to capture and monitor real-time data and the behavior of the physical object. The purpose of the digital twin is to develop precise virtual replicas providing capabilities for assessment, improvement, and forecasting (Graessler & Poehler, 2018). A Supply Chain digital twin is a computer model that represents various components and processes involved in the supply chain such as warehouses, transportation networks, and production facilities (Saci, 2022). For example, a digital twin of a manufacturing process can be used to simulate different scenarios and identify potential areas for optimization. When combined, AI and digital twins can create a powerful tool for analyzing and optimizing complex systems and to support product design, equipment manufacturing, medical analysis, aerospace and other fields (Lv & Xie, 2022).

3.3. Quality control

The data collected in the production process can be used to identify product anomalies that will lead to "prevention of critical quality faults" (Schlegl et al., 2021, p.1547), but also to identify equipment malfunctions that can serve as a basis for creating estimates of future system performance (Wuest et al., 2016). Collecting predictive data in the manufacturing process uses various sensors that detect various factors such as vibration, temperature, humidity or sound, and whose data can be used to predict potential defects. As the volume of data from a particular sensor grows, manual monitoring and analysis becomes impractical and unfeasible, making machine learning, and especially deep learning, ideal for predictive data processing (Klein & Bergmann, 2018). Namely, machine learning enables the automated examination of defects in machines and detection of damage through the recognition of certain conditions (image, sound, etc.) on which the ML models were previously trained. This automation results in a reduced probability of delivering defective products to end consumers, leading to improved customer satisfaction.

3.4. Customer services

Artificial intelligence fundamentally changes the way businesses interact with their customers (Pasonen, 2020) and can lead in improving response times to customers and increase customer satisfaction (Hosseinnia Shavaki & Ebrahimi Ghahnavieh, 2022). The findings show that AI allows customers to track their goods across the global supply chain until the final delivery stage and can provide the customers with real-time feedback on product details (Nozari et al., 2022). On the other hand, the use of AI can enhance customer experience by customizing it according to individual preferences (Kaptanoğlu, 2020). Businesses have the option to utilize AI-powered chatbots, which are automated communication systems designed to respond to inquiries and offer customer service. The use of chatbots in customer service applications leads to optimizing customer service and reducing costs for companies (Kinsey, 2019). Instead of manned call centers, AI-powered chatbots with 24/7 support and using NLP standards can answer customer questions in a number of different languages about the status of their orders, delivery and other details providing fast and efficient customer support (Choudhuri, 2021), creating interactions that can be personalized by AI-driven bots (Modgil et al., 2021).

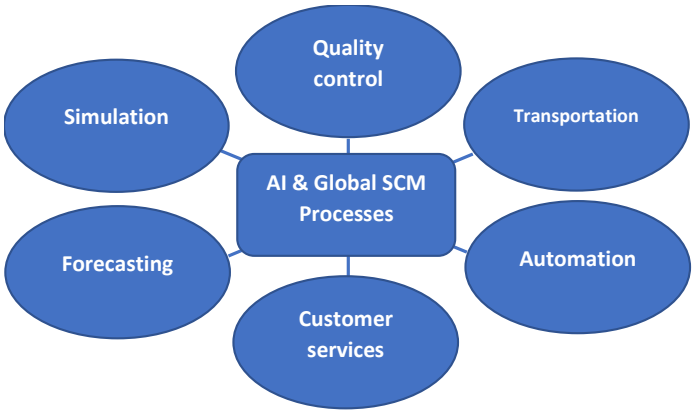
3.5. Transportation

Autonomous delivery solutions have a goal to tackle some of the most complex logistical obstacles, such as reducing the ecological impact of parcel delivery, decreasing the expenses associated with driver’s wages and benefits, overcoming the challenges of reaching remote regions, navigating through the congested traffic of urban centers and improving safety in the supply chain (Everything Supply Chain, 2023). In this context, there are four different types of autonomous delivery solution or autonomous vehicles: autonomous delivery drones; autonomous trucks; autonomous delivery cars or vans and autonomous delivery robots (Lmad.eu, 2022). AI is a critical technology for efficient autonomous vehicles functionality and has significantly enhanced the design, development, validation, and real-time monitoring of Autonomous Vehicles. AI enables effective achievement of perception, path planning, and decision-making in Autonomous Vehicles. The use of AI in Autonomous Vehicles involves determining their routes based on predictive models; learning from past experiences to decide on the optimal speed and path; enhancing the transportation system's efficiency and providing real-time data by various types of sensors (Bathla et al., 2022).

3.6. Automation of the processes

The advancement of AI technologies has resulted in significant progress in the automation process of the global SCM. “Supply chain automation is a broad term that refers to technology that reduces or eliminates human involvement in supply chain activities” (Sherrer, 2022, para.1). The range of automation solutions covers a variety of technologies that can range from solving basic rule-based tasks to sophisticated intelligent systems. Rule-based automation uses

structured data and predetermined rules and responses to generate results. In contrast, intelligent automation uses cognitive technologies to process unstructured and semi-structured data from various sources. It can handle complex tasks by imitating human decision-making processes and constructing new rules to adapt to different situations (The Consumer Goods Forum, 2018). The impact of automation on global supply chain management is most evident in the manufacturing industry. Given the constant fluctuations in demand, manufacturers must frequently adjust their production strategies to remain competitive. Automation has simplified the process by automating much of the documentation involved in global SCM. This allowed factories to produce more goods with less labor and less downtime, resulting in greater efficiency and productivity. For example, an automated warehouse powered by AI, predominantly depends on robotic systems for the storage, identification, and retrieval of goods. These machines are pre-programmed to carry out these duties on a regular basis, resulting in faster packaging procedures and increased levels of productivity. Despite the reduced human involvement, the enterprise operates without any disruptions and business runs more smoothly. Simply put, the businesses can use robotics to perform repetitive, labor-intensive tasks with logical processes empowering their supply chain teams to concentrate on more strategic and decision-making responsibilities. By doing so, they can foster a culture of continuous innovation, keeping their teams motivated and satisfied with their work (Virbahu, 2019).



Picture 2: Applications of AI in Global Supply Chain Management
Source: Author's representation

4. DRAWBACKS OF AI-POWERED GLOBAL SUPPLY CHAINS

Artificial intelligence is still developing, with constant research and development initiatives happening around the world. "But when algorithms begin to create other algorithms, which are then auto-executed, this presents a "black box" scenario. Researchers and AI engineers may not be able to quickly untangle the nuts and bolts of these AI-generated algorithms" (Thomas Insights, 2018, para.6). In other words, alongside the benefits, there are also disadvantages of implementing artificial intelligence in global supply chain management. First, the costs of implementing AI can be very high. Moreover, it is not simple to replace the old technologies and put the focus entirely on artificial intelligence. The whole process requires time and expert knowledge (from software development to data science) in order to implement the system without errors from the very beginning. Besides, artificial intelligence is not a self-sufficient system but humans still need to control it and provide inputs to ensure effortless functioning. The technology is still relatively new and not sufficiently tested, so many unpredictable problems can occur. Moreover, AI needs a lot of data to function properly, so if there is any kind of data problem, it can induce disruptions in the supply chains. Artificial intelligence does not only process information, but the system also learns and becomes more intelligent. AI systems can be very complex and obscure, hence difficult to manage and monitor. AI is a digital system that administers a wealth of sensitive business information. This issue can be extremely important if one does not invest in high-quality protection systems with sophisticated safety mechanisms. Finally, as it automates and replaces tasks currently performed by human resources, AI may impose a number of risks to jobs in the supply chain management industry. Overall, "AI within the supply chain should be carefully considered within a comprehensive risk, contingency, and mitigation matrix. And remember: AI is a tool, and is best used in conjunction with human skills and decision-making processes — not simply as a replacement for human labor" (Thomas Insights, 2018, para.8).

5. CONCLUSION

Global supply chains are imbued with several elements that increase their complexity, viz. government regulations, rising transportation costs, changing customer demands, and some global shocks delivered from events such as pandemics. As already stated, artificial intelligence is one of innovations that aids in optimizing the supply chains by

better predicting customer preferences and reducing costs by automating some recurrent manual tasks. In point of fact, the AI-powered supply chains benefit from several key points that can help transform and develop the businesses around the globe. The (warehouse) automation is one of the foremost benefits of applying AI to control supply chains. Aside from accelerating the work and saving time, AI automation can diminish the number of warehousing staff and save money that would have been spent on salaries. Given the capacity to accumulate, filter, and analyze huge dataset, artificial intelligence is increasingly advancing in inventory management. Reduction of the operational costs is yet another advantage of AI inclusion into supply chains. Most of the work is now automated, which would imply the engagement of fewer people. Besides, technology, unlike humans, can work 24/7 with maximum productivity and reduced number of workplace incidents and mistakes. The application of artificial intelligence in supply chains can also lead to better shipping control. Satisfied customers will not only buy again in the future, but will actively participate in brand promotion. How can AI be used to boost customer service? The answer lies in chatbot technologies - artificial operators are available around the clock and are likely to completely replace humans in the near future. Through machine learning companies can also use predicative analytics. In such manner, firms can identify patterns from historical data and current purchasing patterns for better forecasting. Nevertheless, artificial intelligence comes with some intrinsic risks and drawbacks - the systems can be expensive to implement and hard to manage, and could also cause both potential disruptions to existing workflows and job losses in the global supply chain management industry. While artificial intelligence will surely prove to have more benefits than disadvantages, AI is still only a tool, and as such can best be used only in combination with human skills and decision-making processes.

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