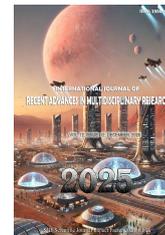




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RESEARCH ARTICLE

ARTIFICIAL INTELLIGENCE IN SUPPLY CHAIN MANAGEMENT

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ABSTRACT

The rapid development of artificial intelligence (AI) technology has revolutionized various industries, including supply chain management. This paper aims to explore the application of AI in the supply chain and how it has transformed traditional operations by improving efficiency, reducing costs, and optimising decision making process. Through an in-depth analysis of AI technologies such as machine learning, robotics and natural language processing., this study provides an extensive overview of their implementation across different stages of the supply chain. Moreover, potential challenges and ethical considerations associated with AI adoption in the supply chain are discussed. Overall, this study underscores the immense potential of AI to enhance supply chain practices, pave the way for intelligent automation, and drive unprecedented levels of operational excellence.

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INTRODUCTION

A supply chain is defined as "a set of three or more entities (organizations or individuals)" also known as parties, "directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer" (Mentzer *et al.*, 2001). The supply chain involves all parties that work to fulfil a customer request, directly or indirectly. Examples of parties included are manufacturers, suppliers, transporters, warehouses, retailers and eventually the customers themselves. One organization can be a part of numerous supply chains, emphasizing the network nature of a supply chain. In the last four decades, advances in technology have shaped supply chains (MacCarthy *et al.*, 2022). Digitization, or the process of converting information to a digital format, allows for a strong digital thread connecting and mirroring physical supply chains, while improving efficiency. The movement towards cloud based systems is affecting how data, computing infrastructure, and software are accessed and used across a supply chain (MacCarthy *et al.*, 2022). Supply chains provide opportunities for the use of different technologies such as using sensors for monitoring, access to cheap cloud-computing infrastructure that increases computing power, and real time data for tracking deliveries and managing inventory. The five parts of the supply chain are planning, sourcing, manufacturing, delivering, and returning (Fernando, 2022). The planning stage allows supply to match customer and manufacturing demands. Firms must predict what their future requires and plan accordingly, specifically what raw materials will be needed during each stage of manufacturing. The next stage is sourcing which involves working with vendors to supply the raw materials needed. The vendor should have the flexibility to deliver emergency materials if necessary and it

should have a proven track record of delivering goods on time and in good quality. Firms have to be cognizant of lead time and how a supplier can comply with those needs. The manufacturing stage of the supply chain means transforming the raw materials to a final product by using machinery and labour. The manufacturing sector can be divided into various tasks, including assembly, testing, inspection, and packaging. Once the product is made, the company must get it into the hands of the customer, also considered the distribution process. Good supply chain management involves robust delivery channels that ensure timely delivery of final products. The supply chain process ends with providing customers support for any returns or errors on the company's part. The company must have the necessary capabilities to receive returned products and rectify the situation with the customer. Effective management of the supply chain is crucial to building and sustaining a competitive advantage in the product and services of the firms. But what is supply chain management (SCM)? SCM as a philosophy takes a systems approach to viewing the supply chain as a whole, with the goal of managing the total flow of goods from the supplier to the end customer. The main goal of SCM is to have the greatest customer satisfaction by utilizing cooperative efforts to converge operational and strategic capabilities into a unified whole (Mentzer *et al.*, 2001). Digital supply chains provide opportunities to develop and deploy artificial intelligence tools for better supply chain management as compared with traditional supply chains.

Here's a more detailed look at how AI is being implemented:

- **Demand Forecasting:** AI algorithms analyse vast datasets, including historical sales data, market trends, and external

factors like weather and social media, to predict future demand with greater accuracy. This helps businesses optimize inventory levels, minimize stockouts and overstocking, and reduce waste.

- **Inventory Management:** AI-powered systems can automate inventory tracking, optimize warehouse layouts, and predict when restocking is needed, preventing shortages and overstocking. For example, Amazon uses AI-driven robots in its fulfilment centres.
- **Warehouse Automation:** AI-driven robots and automation technologies are used to automate tasks like sorting, picking, and packing, increasing efficiency and reducing labour costs.
- **Logistics and Transportation Optimization:** AI algorithms optimize routes, predict delivery delays, and manage transportation fleets in real-time, leading to faster and more reliable delivery. For instance, AI can analyse sensor data from trucks to predict potential equipment failures and enable proactive maintenance.
- **Predictive Maintenance:** AI can analyse data from sensors on equipment to predict potential failures, allowing for preventative maintenance and reducing downtime.
- **Risk Management:** AI helps identify and mitigate potential disruptions in the supply chain by analysing data and identifying vulnerabilities.
- **Supply Chain Evolution:** AI is driving the evolution of supply chains towards greater agility and responsiveness, enabling businesses to adapt to changing market conditions and customer demands.

Benefits of AI in SCM:

- Reduced operational costs
- Improved demand forecasting accuracy
- Reduced lead times
- Increased supply chain flexibility and resilience
- Enhanced efficiency and productivity
- Improved decision-making

Artificial Intelligence in Supply Chains: Advances in data analytics have led to transformative trends in the field of supply chain management, especially in areas like manufacturing, quality control, and logistics. These trends involve the integration of machine learning, IoT technologies, artificial intelligence, and artificial neural networks, allowing for increased efficiency and capabilities to enhance SCM applications (MacCarthy *et al.*, 2022). Artificial Intelligence (AI) Artificial Intelligence involves the use of computers for reasoning, recognising patterns, and developing knowledge to solve problems in decision-making situations (Sharma *et al.* 2022). AI provides a machine with the capability to carry out any cognitive functions that mimic human behavioural patterns. AI is essential for the automation and digitalization of supply chain activities and can drastically change current business practices. AI is the umbrella term for software that mimics human behaviour to complete tasks. Because of artificial intelligence and cloud computing technologies, it is possible to connect and integrate different parts of the supply chain model (Garay-Rondera *et al.*, 2020). This enables different parts of the supply chain to work together in real time and create groups of related processes/activities. Cloud computing is especially influential in allowing this – it helps analyse data, learn from it, and make decisions – which leads to new ways of managing processes and behaviours in the supply chain. Businesses are using AI to overcome information processing constraints to allow supply chain innovation (SCI) (Belhadi, 2021). This results in new ways of designing products, solving supply chain issues, and pleasing customers. So, supply chain firms will be able to create new profit streams quickly while decreasing costs. AI-driven SCI, like self-driving systems, can be beneficial to stimulate logistics and transportation functions. AI as a whole supports decision-making in wholesale distribution and has the potential to decrease economic loss due to out-of-stock occurrences by around 56% (Bottani, 2019). AI also helps with analysing data and extracting helpful information. AI can decrypt, interpret, and learn from convoluted information from various

sources to eliminate uncertainties surrounding operations. Without it, firms have to rely on human capabilities to manage a responsive supply chain, which slows efficiency and reduces profit margins. AI allows firms to develop information processing capabilities which directly improve supply chain performance (Belhadi, 2021).

Machine Learning (ML): Machine learning mimics human nature based on the knowledge and experience that is collected. Machine learning was introduced to provide computers the ability to learn without being explicitly programmed through gathering knowledge directly from the data to learn to solve problems (Ratner, 2000). Machine learning can be classified by category – concept learning which is designed to recognize concepts for future decision making, decision tree learning which classifies all objects by testing their values for certain properties, perception learning which aims to acquire knowledge and solve problems using a single layer of network, and reinforcement learning which trains the computer by giving constant feedback (Min 2008). ML is a subfield of AI that uses algorithms that are trained using data to complete complex tasks. ML can be useful for understanding the motivation behind the behaviour of supply chain partners for sharing information and ultimately strengthening the partnership among the partners. For example, machine learning can be used to forecast the distorted demand information at the end of the supply chain, known as the bullwhip effect (Carbonneau, 2008). Distorted demand is harmful for companies because it can lead to excess or not enough inventory which causes a stock shortage or an increase in prices. SCM is a complex operation so it is crucial to keep productivity high and machine learning techniques are often integrated into models to increase efficiency and replicate control processes that would otherwise require human element (Ali *et al.*, 2021). Machine learning methods in conjunction with optimization algorithms create robust solutions in supply chains. A fusion-based approach driven by K-Nearest Neighbour and Support Vector Machines when integrated with the cloud can increase supply chain coordination and improve the entire process. ML, specifically automation, can help increase the efficiency of processes within supply chain partners. Machine learning provides significant help when it comes to supply chain collaboration because machines can produce more reliable outcomes than humans (Ali *et al.*, 2021).

Artificial Neural Networks (ANN): Artificial Neural Networks are based on the way brain cells or neuron's function. ANN can learn from experience, recognize patterns, and process information using the interconnected network of computer memories. ANN consists of nodes connected by links, which are the primary means of long-term memory storage. The output of one neuron is an input to another neuron linked to it. The ANN can respond to assorted data patterns and can be trained in either unsupervised or supervised environments (Min, 2008). ANN is useful for semantic modelling and for manoeuvring autonomous vehicles using its unique image processing capabilities (Min, 2008). ANN was used to mimic the behaviour of a human driver by steering a land vehicle along a lane on a highway (Pomerleau, 1993). ANN was also successfully used to develop hierarchical supply chain planning that allowed for accurate determination of time/capacity needed for setups, linked inventory and scheduling decisions, and estimation of optimal lot-size between supply chain processes (Rohde, 2004). Overall, ANN reflects the interconnectivity and interdependence of supply chain planning. SCM often requires making decisions when the information is not complete or accurate, and artificial neural networks can help with this (Silva *et al.*, 2017). A group of experts used ANN to understand how supply chains change when the system changes and to figure out the best way to organize supply chains to reduce costs. ANN can also be used to predict potential disruptions in supply chains.

Blockchain: Blockchain technology uses the power of the Internet to record data in a decentralized manner, creating blocks of information that form a chain (MacCarthy *et al.*, 2022). One of Blockchain's defining characteristics is immutability – all network nodes, or the connection point among network devices that receive and send data, can see the chain and a consensus is required to add new blocks,

creating an unchangeable digital record. Blockchain can be useful for supply chains because it offers a reliable immutable digital ledger. Supply chains involve multiple organizations, leading to fragmented information about operations. Blockchain can hold information about products, processes, operations, etc. in an unchangeable and verifiable record. This would allow easy tracing of product origins, verify authenticity, and ensure sustainability (MacCarthy *et al.*, 2022). Amazon uses this type of technology to manage inventory in real time and later to track the delivery in route and adjust accordingly. Blockchain has the potential for changing business models by shifting trust from organizations to analytics, developing automated smart contracts, and facilitating sharing economy applications (Esmacilian *et al.*, 2020). Blockchain technology can also reduce barriers toward sustainability through data collection, data analytics, and decision-making capabilities. The four main blockchain capabilities that support sustainable supply chains are that they help reduce product recall due to tracking abilities, they make it easy to trace the footprint of products, they facilitate recycling behaviour, and they improve efficiency of emission trading schemes. Sensor technologies enable data collection and open the way for software tools that analyse data in real time. The level of information that is shared increases over the entire supply chain, making the product life cycle more transparent.

Internet of Things (IoT): IoT, internet of things, refers to the network of physical devices which are embedded with sensors and software that exchange data with other devices over the internet. For example, Nest thermostats are embedded with sensors that monitor the air in a space and are connected to the internet to allow a person or a program to monitor and update the temperature. IoT connects the real world with the digital realm throughout the entire journey from design and manufacturing to transportation, customer usage, and service, thus shaping the future supply chain (Mahamuni, 2018). The manufacturing sector is experiencing significant bottom-line reduction due to real-time monitoring into business Key Performance Indicators because of IoT (Mahamuni, 2018). The transportation and logistics sector also benefits from lower downtime due to real-time monitoring of trucks, on-time arrivals because of location tracking and intelligent routing, and reduction in liabilities of driver behaviour and in-transit damages. Connecting the entire supply chain in a seamless digital thread allows shipments to be automatically planned and communicated to third-party logistics companies. Most importantly, IoT technologies enable new business models, such as servitization, or selling products as a service. Companies are able to sell a service with a pay-as-you-go model because of IoT technologies. As a result, customers shift their expense models and change their consumption patterns significantly (Mahamuni, 2018). IoT can also be applied for condition monitoring, effective management of cold chain logistics, managing energy consumption, and addressing sustainability issues (MacCarthy *et al.*, 2022). Due to IoT technologies, there was a 48% reduction in unplanned downtime. IoT data can be used for event detection, predictions, root-cause analysis, and anomaly detection. Sensor data is employed for monitoring conditions like temperature, inventory levels, generating events, and triggering automated workflows in SCM applications for mitigation. Using predictive models, organizations can proactively take steps to mitigate the impact of any potential problems because of the real-time predictions. Sensor data is used with contextual data from SCM applications to find the root-cause of challenges in supply chain operations. IoT can help analyse this data in the context of business applications. IoT also enables firms to identify any non-standard deviations from normal patterns, which reduces the probability of potential issues in the supply chain (Mahamuni, 2018).

CONCLUSIONS

Artificial intelligence is a powerful technology that can be used to improve supply chain management in many ways. However, there are also some challenges that need to be addressed. As the technology continues to develop, these challenges will likely be overcome, and AI will become an even more important tool for businesses. Some

more details about the conclusion of the paper on the application of artificial intelligence in supply chain management are as follows:

- The use of AI in supply chain management is still in its early stages, but it is growing rapidly.
- AI has the potential to revolutionize the way businesses manage their supply chains, leading to significant improvements in efficiency, productivity, and profitability.
- There are some challenges that need to be addressed before AI can be fully adopted in supply chain management, such as data availability, data quality, and complexity.
- However, as the technology continues to develop, these challenges are likely to be overcome. M. Khadem *et al.* international journal of industrial engineering and operational research 26
- The future of AI in supply chain management is very promising. AI has the potential to become an essential tool for businesses that want to stay competitive in the global marketplace. Here are some specific examples of how AI is being used in supply chain management today:
- **Demand forecasting:** AI is being used to predict future demand for products and services. This information can be used to optimize inventory levels, production schedules, and transportation routes.
- **Risk management:** AI is being used to identify and mitigate risks in the supply chain. This can include risks such as natural disasters, cyberattacks, and supplier disruptions.
- **Warehouse management:** AI is being used to automate tasks such as picking, packing, and shipping. This can improve efficiency and accuracy.
- **Transportation management:** AI is being used to optimize transportation routes and schedules. This can reduce costs and improve delivery times.
- **Customer service:** AI is being used to provide real-time customer support. This can improve customer satisfaction and loyalty. These are just a few examples of how AI is being used in supply chain management today. As the technology continues to develop, we can expect to see even more innovative and creative applications of AI in this field. The future of AI in supply chain management is very promising. AI has the potential to revolutionize the way businesses manage their supply chains, leading to significant improvements in efficiency, productivity, and profitability. Businesses that are early adopters of AI are likely to have a competitive advantage in the years to come.

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