Artificial Intelligence in Supply Chain Management

Shyla Awasthi

BASIS Independent Silicon Valley, USA

ABSTRACT

Given the recent surge in AI technology, companies are increasingly using it as part of their supply chain. This paper explores how different types of Artificial Intelligence can be used to improve supply chain activities. AI can help overall functions or specific parts of the supply chain including planning, sourcing, manufacturing, delivering and returning. The paper analyzes Amazon as a case study, as they have implemented AI in almost all aspects of their supply chain, from ordering a product to receiving it at your doorstep. Finally, limitations and challenges to implementing the AI are discussed.

Supply Chains

What are Supply Chains?

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 fulfill 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.

What are the Stages?

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 labor. 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.

What is Supply Chain Management (SCM)?

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.

Types of Machine Learning / 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 behavioral 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 behavior 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 tougher in real time and create groups of related processes/activities. Cloud computing is especially influential in allowing this – it helps analyze data, learn from it, and make decisions – which leads to new ways of managing processes and behaviors 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 analyzing 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 behavior 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 Neighbor 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 neurons 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 modeling and for maneuvering autonomous vehicles using its unique image processing capabilities (Min, 2008). ANN was used to mimic the behavior 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, verifying authenticity, and ensuring 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 (Esmaeilian 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 behavior, and they improve efficiency of emission trading schemes.

Sensor technologies enable data collection and open the way for software tools that analyze 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 behavior 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 analyze 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).

Case Study

An example of a company that utilizes AI in their supply chain is Amazon. AI is used in almost every interaction from accounting to energy usage to logistics in order to instantly analyze a situation and help users make the best decision.

Amazon looks at past demand and online-shopping habits of their customers to write algorithms and models that teach the AI to forecast demand. Amazon's AI models have detected surges in shopping around the winter holidays and spring breaks. Inside Amazon's warehouses itself, AI powers their Kiva robots, which carry shelves of products. AI keeps track of all items in the warehouses and rearranges the shelves accordingly. Traditionally, people would walk to the shelves, but the Kiva robots, powered by AI, now carry them. Amazon's AI can also discern and interpret people's hand movements to recognize when a person places an item inside a shelf or when they want to scan items they are holding (Drury, 2023).

AI is especially used in Amazon's delivery process through an app called "Flex." The AI constantly calculates how many drivers are needed while considering the weight, number of packages, and locations of the delivery (Selyukh, 2018). Getting a package from point A to B is very crucial to do correctly since it accounts for about 50% of the delivery costs. Amazon Web Services (AWS), the leader in cloud computing, are used to ensure that the best, most efficient route is taken. The model continually learns in real time as delivery drivers follow their routes and reoptimizes the route. This technology in general helps the service industry optimize which locations it services to allow for maximum efficiency (Drury, 2023).

AWS is also used to cut down on waste from expired products. Amazon's AI to help manage stock depletion utilizes factors like promotions and local events and determines whether to mark down prices or move them to other facilities (Drury, 2023).

Limitations / Challenges

One of the limitations of using AI in supply chains is that AI requires large volumes of accurate data to train the algorithm and predict efficiently, However, many companies lack this quality of data which makes the forecasting models less accurate. In addition, the data is often scattered among internal and external partners which leads to poor results due to the missed opportunities for optimization and execution. The entire supply chain should be connected to a real-time network to strengthen the reliability of the data. Another issue with AI technology is bias in the algorithms. For example, Amazon used the AI system to hire employees but researchers pointed out that the system had a bias for hiring males. This was because the algorithms were trained on mainly male data. Companies should ensure the data that the algorithm is being trained with is not biased like this (Duckworth, 2019).

Conclusion

AI, ML, ANN, Blockchain, and IoT each uniquely improve supply chain activities. AI helps with digitization, automation, and information processing and effective reorganization. ML is used to predict demand so companies can be adequately prepared with the right amount of inventory. ANN is helpful for providing unique image processing capabilities, while blockchain can reliably store product information and IoT can be used for event detection or prediction. Despite the challenges associated with AI with regards to the large amount of accurate

data required, Amazon has successfully implemented AI technology to optimize the delivery and inventory tracking process.

Acknowledgments

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