Improving Model Business Efficiency by Integrating Innovative AI Technology in Supply Chain Management Systems

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Abstract
The purpose of this paper is to identify the means and potential of Artificial Intelligence technology used to increase the performance of supply chain management. A pertinent literature review was done to understand what SCM is about, what are its components, how are they digitalized, and then how is digitalisation helping supply chains integrate AI into their business models. Since different areas of a supply chain are co-dependent but independently developed, this paper describes digitalization and AI models integration and at the same time what are the practical application as well as benefits of adopting this technology into the business model.

Keywords
Supply Chain Management; digitalization; Industry 4.0; Artificial Intelligence; Supply Chain Network; Digital Supply Chain.

Introduction

The marketplace is very competitive and dynamic nowadays due to the rapid technological advancements and globalization and customers' everchanging expectations. In consequence, traditional competition between companies is turning into a competition between supply chains (Farahani et al., 2014). This makes it only natural for organizations to better manage their material flows and logistics throughout the whole network structure (Farahani et al., 2014). Competing supply chains are thus the entities of modern days markets and will also be in the future (Farahani, 2014). This competitiveness remodels how supply chains structures are developed and be considered as single entity networks that work as a whole in the context of a certain industry (Shen, 2007).

The focus has turned from developing a single company or supply chain to creating a supply network through a process called “supply chain network design” or SCND (Shen, 2007). It impacts the strategy and future tactical decisions of the chain and how it will function (Faharani, 2014). Supply chain networks (SCN), as described by Klibi and Martel (2012) are composed of five main types of entities: external suppliers, production centers, distribution centers, demand zones, and transportation assets. Due to competition, supply chain networks must realign often with the future requirements of the business market, meaning that strategic decisions must be taken to keep performing (Klibi & Martel, 2012).

A popular defining term in business, the supply chain is presented by many authors as being the whole network of companies involved in the process of manufacturing a product and delivering it in the hands of the end-user, including every assembler, reseller, and transportation that play their part among the process (La Londe & Masters, 1994). This standard definition can be found in many authors' books and articles where most of them include the final consumer of the product or service alongside the upstream and downstream network of stakeholders. Mentzer et al. (2001) simply define a supply chain as being a minimum of three or more entities that are connected directly in the upstream and downstream flow of products, services finances, and information from the start point of the product to the customer. Introducing the notion of management into the equation (Supply Chain Management) transforms the understanding of the whole chain into a single entity rather than a sum of parts although all components are legally different enterprises (Mentzer et al., 2001). In this manner, every company that takes part in the supply chain more or less directly influences the performance of all the other participants from the chain and the overall effectiveness and efficiency of the supply chain (Cooper et al., 1997). Supply chain management is also described by Harland (1996) as the management of every business activity and relations within all the areas of a company like internally, with every supplier (first level, second level), and even with customers and the rest of the actors involved in the supply chain. Another definition about supply chain management, given by Scott and Westbrook (1991), explains that every element of the manufacturing and distribution process including the transformation of raw materials into products and up to end-user including every organization boundary along the way is covered by the term supply chain management. This encompasses all the value chain from the very beginning of the raw materials follows through with their transformation into a product and ends up in the hands of the end-user (Tan, 2001). Another author completes the definition of supply chain management and introduces a new layer which is recycling and re-use (Baatz, 1995).

Having all the organizational value chain integrated, the system of suppliers improves the performance and activity of the chain (Tan, 2001). Transportation and logistics play a strategic role in defining supply chain management, even more than that of transformation of the product as specific literature puts it (New & Payne, 1995).

An example of a supply chain can be seen in Figure 1.

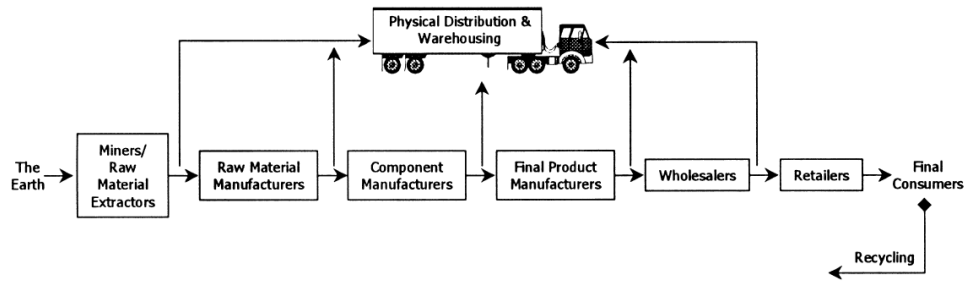

Figure. 1. Activities and actors in a supply chain
(New & Payne, 1995)

Main components of SCM

As Wisener et al. (2014) discuss in their research, there are four main components that a supply chain management is comprised of. They refer to every activity that goes upstream and downstream and throughout the company and the suppliers and logistics segments involved. These components are Supply, Operations, Logistics, and Integration.

Supply is the strategic component referring to the relational ecosystem of partners involved in supplying raw materials for the development of the product or services that a company delivers to its customers. Supplier management allows companies to select use the most performing partners and build strong relationships with them to deliver the most profitable and qualitative solutions for the intended market. Suppliers are an important part of the early-stage product design and cost selection, making up even for innovation in production to compete better in the global market (Monczka et al., 1994). Better relations and higher purchase volumes make for a lower unit purchase cost and in return better delivery. This strictly impacts the company's competitive abilities. Important factors include supply base reduction, supplier alliances, supply relationship management, global sourcing, and ethical and sustainable sourcing (Joel et al., 2011).

Operations come into play as a factor for organizing all the activities that come after buying components or raw materials. Some processes such as assembling or processing the acquired materials into finished products, demand management strategies have the objective of matching demand with the targeted capacity. Managing the inventory has to be done with high precision and in the modern age and software such as material requirements planning (MRP) working in connection with an enterprise resource planning system provide real-time data for decision making factors in the company. A similar way to handle inventory is the lean production system or just-in-time creates a fast connection between production and end-user demand resulting in a more accurate stock creation. Quality control is a key factor in managing a lean production system (Joel et al., 2011).

Logistics must ensure that customer requirements are met through planning, implementing, and controlling forward of and revers flow and storage of goods, services, and information flow between production processes and consumption points (Ballow, 2017). This requires a dedicated amount of planning and has to reach the desired outcome for quality customer service. Transportation methods must be adapted for the specific needs of the customers. Companies keep in touch with them through the use of a customer relationship management system providing delivery dates, important information, and successful logistic service. A distribution network is designed to operate order fulfillment and factory warehousing transportation (Joel et al., 2011). To save money on transportation, storage costs, and operating, companies might opt for building a few highly dispersed warehouses to reach better customer service, instead of using a network of local or regional partners for inventory holding and delivery (Joel et al., 2011).

Integration or supply chain integration (SCI) is the part of a supply chain where an organization sets up strategic collaborations between internal functions or external partners (Qi et al., 2017). Through steady management, the integration process, processes like production, services, information exchange, and decision making are ensured to be effective and efficient to deliver good value to customers. The two types of integration – internal and external – are two different dimensions to SCI. Internal refers to the departments of a company that should function as an integrated process and external emphasizes the importance of creating a solid relation with external partners (Qi et al., 2017).

Table 1. Understanding SCM from academic literature

Synthesis of Supply Chain Management composing elements		
1	Supply element	Monczka et al., 1994 ; Joel et al., 2011
2	Operations element	Joel et al., 2011
3	Logistics element	Ballow, 2017 ; Joel et al., 2011
4	Integration element	Qi et al., 2017

Digitalization of SCM

The main driver nowadays for change in modern businesses is the digitalization of the processes and infrastructure, and as MacCarthy et al. (2016) put it, digital technologies represent a mixture of information, processing, communication, and technology. Listing the main digital innovations for the past 10 years include mobile technology, cloud computing, social media, and big data analytics, they are commonly abbreviated as SMAC. Lately, there is a constant increase in the use of another cluster of technology such as blockchain, artificial intelligence, the internet of things, and 3D and 4D printing (Nowicka, 2019). These new developments are due to ongoing improvements and performance achieved in networking and interoperability and the lowering cost for computing power that became accessible everywhere.

In supply chains, digitalization follows both digital products and services and the process of managing and handling supply chain processes that are transforming very fast (Büyüközkan & Göçer, 2018). It allows companies to take advantage of new sets of features like online services, barcode/QR code scanning, NFC (near field communication), or RFID (radio frequency identification) that improves operability and allows for faster centralization of data (Ström et al., 2014). Smart technologies allow for smarter processes which in turn leads to an improvement in competitive advantage. As Yoo (2010) describes devices, they are now programmable addressable, sensible, communicable, memorable, and associable, making more activities in the supply chain adjustable to the specifics of the business and customizing towards more efficient systems. Companies now are subject to faster and faster changes in business infrastructure. Their business models are also challenged by digitalization and managers are under the pressure to find an optimal solution to adapt to the changes. The previous existing supply chain procedures, tools, strategies, and tactics must be redesigned and developed to meet the needs of a modern, digitalized supply chain (Nasiri et al., 2020).

Interactions became quicker and communication almost instantaneous which leads to superior agility and productiveness (Büyüközkan & Göçer, 2018). The same way social media changed how people communicate while still using the same devices, digital transformation revolutionizes the manner in which companies handle and approach external collaboration and reduces engagement costs (Crittenden et al., 2019). Customer service is consequentially improved as large data amounts can be acquired from various sources and such solid networks of partners are constructed (Berman, 2012). Adding to the performance of the supply chain is the automation of processes alongside data processing and practices refining creates both challenges and opportunities for all involved actors (Nasiri et al., 2020). Riemer and Schellhammer (2019) talk about how collaboration and information exchange between actors have created new forms of work and also virtual organizations, and this, in turn, created strategic changes throughout the industry.

Benefits of a Digital Supply Chain

According to Raab and Griffin-Cryan (2011) in a report from Capgemini that was exploring the benefits of digitalization and automation in supply chains, they remark that a digital operating model is based on how well the organizational layers of governance, processes, data & performance management and IT have standardized and integrated processes. The report divides the benefits of their model into three categories that can also be seen in Figure 2:

- Business process automation makes personnel more efficient and enables companies to manage assets, customers, and product portfolios more effectively.
- Organizational flexibility creates higher value when centralizing specific functions through improved productivity.
- Digital management of corporate assets creates better visibility of resources in a company and results in efficient integration of operational and financial data.

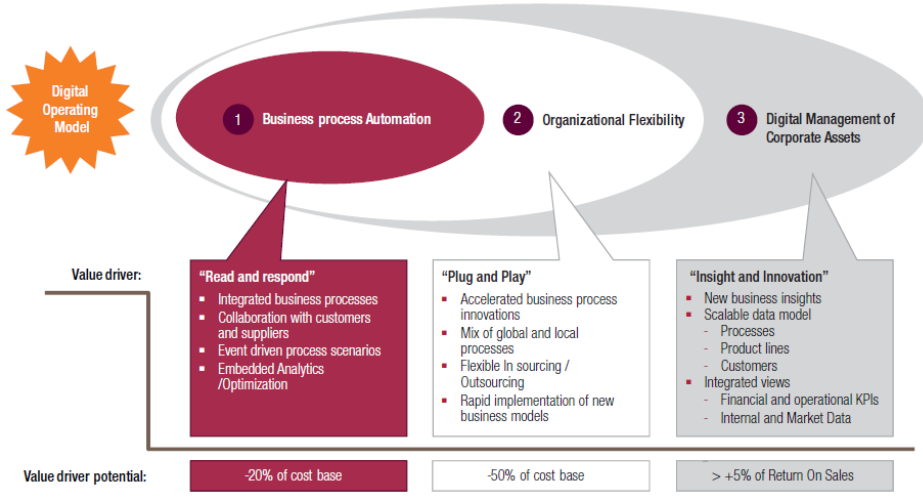

Figure 2. Value enhancing through service orientation
(Raab & Griffin-Cryan, 2011)

A digitalized supply chain is defined by Büyüközkan and Göçer (2018) as "an intelligent best-fit technological system that is based on the capability of massive data disposal and excellent cooperation and communication for digital hardware, software, and networks to support and synchronize interaction between organizations by making services more valuable, accessible and affordable with consistent, agile and effective outcomes". The impact of the digital supply chains (or DSC's) at the organizational level implies benefits in different areas of the chain-like buyer-supplier relationship which can enhance transactions by using ICT (Queiroz et al., 2019).

Integrating blockchain technology into a supply chain, for example, improves security and can reduce the cost of transactions (Korpela et al., 2017). DSC's also impact product development through providing more information which in turn integrates more efficiently with customer needs both upstream and downstream (Büyüközkan & Göçer, 2018).

Being part of a digitalized supply chain means moving goods in a shorter period because of more organized stock information as well as quicker access to it (Büyüközkan & Göçer, 2018). Quick reaction to demand is one of the most important sides of a supply and can happen better thanks to effective information circulation and with the use of AI predictive models demand patterns can be handled in a better way. Global connectivity allows organizations to react better at local levels and adjust supply hubs to complete orders from the closest source, translating in cost savings for transportation if it were to ship products from further away (Schrauff & Bertram, 2016).

Digital supply chains have the advantage of managing the inventory in real-time across stakeholders' warehouses with the help of smart sensor arrays or other technologies such as RFID. As customer behavior changes the stocks can adapt in consequence and also, having global knowledge of stocks, orders can take place from any warehouse, everywhere in the world (Schrauff & Bertram, 2016). Smart technologies enable the production of smart products equipped with powerful computing capabilities that allow for self-learning and autonomous decision-making algorithms based on the data gathered. Features like these make available a whole range of automation processes and support innovation at the operations level (Büyüközkan & Göçer, 2018). Smart technologies are effectively reducing costs in the majority of operating areas even if they come with a high cost of implementation (Büyüközkan & Göçer, 2018).

Artificial Intelligence Algorithms used in Supply Chains

There are many use cases for Artificial Intelligence in supply chain management and they refer to different implementations for different types of situations. Scientific literature findings done by Toorajipour et al. (2021) suggest a number of 21 AI techniques that are used for the marketing, logistics, production, and supply chain segments as presented below, in Figure 4.

Marketing	1.Artificial neural networks (4) 2. Genetic algorithm (4) 3. FL/modelling (3) 4. Agent-based/multi-agent systems (2) 5. Swarm intelligence (1) 6. Simulated annealing (1) 7.Association rule (1) 8.Tree-based models (1) 9.Support vector machines (1) 10.General forms of AI (1) 11.k-means clustering (1) 12. Hill climbing (1)
Logistics	1.Artificial neural networks (1) 2.Agent-based/multi-agent systems (1) 3.Data mining (1) 4.Simulated annealing (1) 5.Automated planning (1) 6. Robot programming (1) 7. General forms of AI (1) 8. Heuristics (1)
Production	1.Artificial neural networks (8) 2.FL/modelling (5) 3. Case-based reasoning (4) 4. Genetic algorithm (3) 5.Agent-based/multi-agent systems (2) 6. Data mining (2) 7.Decision trees (2) 8.General forms of AI (1) 9. Gaussian (1) 10. Rule-based reasoning (1) 11. Automated planning (1) 12.Swarm intelligence (1) 13.Expert systems (1)
Supply chain	1.Artificial neural networks (5) 2.FL/modelling (4) 3. Agent-based/multi-agent systems (4) 4. General forms of AI (4) 5.Physarum model (1) 6. Bayesian networks (1) 7.Swarm intelligence (1) 8.Data mining (1) 9.Support vector machines (1) 10. Stochastic simulation (1)

Figure 3. Classification of AI techniques based on fields
(Toorajipour et al, 2021)

Using a technique called Artificial Neural Networks, applications such as sales forecasting, marketing decision support systems, pricing, and customer segmentation, production forecasting, supplier selection, demand management, and consumption forecasting benefit from algorithmic information processing techniques to find predictive patterns (Toorajipour et al., 2021). ANN's main capability is solving data-intensive problems in which the algorithm rules are very difficult to identify or even unknown (Toorajipour et al., 2021). Another type of AI model used in AI is an agent-

based model that trains AI agents to simulate actions and interactions of an environment while considering the influences of the system in general. They are used in SCM in applications that include distributed supply chain planning, design and simulation of supply chain systems, analysis of complex behavior supply chains, and negotiation-based collaborative modeling (Toorajipour et al., 2021). Generic Algorithms (GAs) are evolution-inspired models that are regarded as function optimizers that address various categories of combinatorial decision problems (Whitley, 1994). GAs are extensively used in SCM in developing managerial decision-making processes improving the efficiency of the supply chain and other applications regarding multi-objective optimization of the supply chain networks, partner selection in green SCM problems, and problem-solving approach to closed-loop supply chains (Min, 2015).

One new practice that is enabled by digitalization and widespread connectivity is data mining that is stimulated by the development of huge databases (Hand, 2013). The value of the big and structured databases is that they contain information that can provide strategic insights into decision making and processes and these types of insights improve SCM components such as controlling and monitoring warehouses, food supply chains knowledge management, and supply chain innovative capabilities (Toorajipour et al., 2021).

Support vector machines, an AI technique that uses a linear classifier to classify data and decipher subtle patterns (Hongmao, 2016) have been used in several SCM applications regarding forecasting, time-series classification, supplier selection, and SCM systems design (Toorajipour et al., 2021).

Practical applications of AI in SCM

Sales, as a component of a supply chain, refers to communicating with the client a valid quotation of the specific product that is in accordance with the production specifications (Helo & Hao, 2021). Tools used for sales configurations make for a clear integration of the sales department with the production one to maintain an efficient channel with the customer. This type of software saves products in a specific format that can be integrated with external tools such as ERP for production planning and scheduling. AI applied in this process uses the configuration history to cluster product selections and make a “shopping cart analysis” and bundle this information so it can be used by the research department to reduce speed for quotation process, improve quality of documents and reduce labor work (Helo & Hao, 2021).

Production planning and control consist of matching up production and manufactory instructions, controlling dependencies, and design activities ensuring customer satisfaction and order fulfillment. Using a genetic algorithm module, a production company can implement an AI to support planners with automated decision support. This AI connects to a cloud-based AI that optimizes any changes in the production activity based on the customer order list. It will optimize to suggest production schedule modifications, material change as well as production tools, working on fulfilling its main objectives that are improving the capacity of machinery and increasing resource planning efficiency (Helo & Hao, 2021).

Quality control is a good example of how AI, using computer vision, is able to automatically determine the product quality or packaging status, similar to a real quality inspector. The AI uses deep neural networks (or DNNs) to analyze video streams from the production line and detect possible errors in the products. This analysis works by training the algorithm with a library of images of good and damaged products to know how to make the distinction and flag the occurring errors in real-time. Using computer vision in QA can fulfill a series of tasks that increase control productivity without adding personnel, develop a systematic learning loop for the analyzed products and reduce resulting waste in the process (Helo & Hao, 2021).

Inventory management and storage can represent somewhere between 15%-35% costs of an entire business value and the goal is to increase product variety to fulfill customer needs while decreasing costs (Ni et al., 2020). Most of the decisions to estimate and predict required stocks are made based on the experience of the managers and warehouses are filled with uncertain inventory input. For this issue, machine learning algorithms are utilized to quickly check and adapt inventory input from determined patterns from comparable data sets (Ni et al., 2020). With the help of neural networks this information can lead to accurate forecasting in a multi-echelon supply chain (Ni et al., 2020).

Transportation and distribution are key elements for any supply chain and mainly refer to the vehicle routing problem. Finding the optimal routes out of multiple choices for a transporting vehicle impacts both operational and financial supply chains. Machine learning algorithms are used in this case to analyze big chunks of data sets to model the routing planning a problem that surpasses the ability of a person to optimize instantaneously and take into account variables from real-time data. To solve, an adaptive neural network is trained to assess the performance of the whole supply network, integrate with the ERPs and calculate the best possible option (Ni et al., 2020). In this manner, ML is generating better options for delivery routes by looking into consumer behavior patterns, vehicles, and transportation patterns, and infrastructure performance (Ni et al., 2020).

Conclusions

The supply chain is a living ecosystem of stakeholders and processes where products are developed, planned, and distributed through various methods which are being improved constantly. To become more efficient, a supply chain must improve the connections and communications between suppliers, manufacturers, logistics companies, retailers, and finally consumers. The cost to operate between all these stakeholders must be effectively and efficiently handled, as for any one of them affects the balance of the whole chain. Important success factors to achieve a high-performing supply chain are quick information sharing, collaboration, and process integration (Fatorachian & Kazemi, 2020). Digitalization is and will be the modern solution that supply chains have to undergo, even if it creates a dependency on technology in the shape of ERPs, sensors to collect data, and algorithms to process it (Ni et al., 2020).

Artificial Intelligence algorithms are the means to process the different types of data that a supply chain consists of throughout all of its components. Studies show that the manufactory industry stands out as the most prevalent branch of a chain where AI creates value (Chui & Malhotra, 2018). With integrating more and more AI technology, supply chain management transforms slowly into a self-governing, self-optimizing, and self-aware entity (Ni et al., 2020). This literature review looks into the basic understanding of how a supply chain functions, what are the benefits of digitalization, and how it is transformed through Artificial Intelligence. Automatization and integrating sensors have started to become a new layer of a supply chain and also the new standard for competitiveness. Leaving room for AI algorithms to lead to new performances.

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