Application of Information and Technology in Supply Chain Management: Case Study of Artificial Intelligence – A Mini Review

Hieu Bui Trong and Uyen Bui Thi Kim

***Abstract* — It is wide known that the world has been moving towards a digital future over the years, and Industry 4.0 technologies are considered to be the way of the future. One of the most prominent of these technologies (including Block Chain, Internet of Things, Cloud Computing, Big Data, etc.) is Artificial Intelligence (AI), was introduced to develop and create "thinking machines" that are capable of mimicking, learning, and replacing human intelligence. However, its widespread acceptance as a decision-aid tool, AI has seen limited application in supply chain management (SCM). The purpose of this work is to identify the contributions of AI to SCM through a brief review of the existing literature. Besides, this paper reviews the past record of success in AI applications to SCM and identifies the most subfields of SCM in which to apply AI.**

***Index Terms* — Artificial Intelligence, Supply Chain Management, Literature Review, Overview.**

I. INTRODUCTION

The digital transformation has driven hyper-connected organizations. An example of this is Industry 4.0, which represents a concept of intelligent manufacturing networks in which machines and products interact with each other without human control. In this context, the new Information and Communication Technologies (ICT) allow obtaining precise data in real time [1]. Since SCM requires the comprehension of complex and interrelated decision making processes, their integration with the above technologies can improve their efficiency, sustainability, flexibility, agility, robustness and resilience. The supply chain (SC) operations planning is crucial for this. However, the increasing uncertainty and the dynamic environment make the synchronized planning necessary. Synchronized planning describes a state in which a constant flow of data from the supply network enables organizations to accurately plan production to match the actual demand. But this new paradigm of SC planning will require transforming data, facilitating real-time decision making using online data, automating decision making and making it smarter, not only for pre-programmed decisions but also with some learning capability. These necessary capabilities can be achieved using techniques that fall within the broad spectrum of AI [2]. In general, the application of AI techniques to not only analyze data or automate decision-making but also to optimize the whole supply chain is considered to be highly relevant and an enabler for a supply chain's digital transformation. Nonetheless, the question on what exactly AI is and which methods do belong to the set of AI techniques remains and has not been answered by scientific literature yet. Instead, the term AI is viewed and defined from different angles focusing e.g. on "agents that receive percepts from the environment and perform actions" or on "computational systems that perform tasks commonly viewed as requiring intelligence". It can be subsumed, that there is no common definition of what AI is. Moreover, the understanding of "intelligent" has been changing over the years, which is described by the AI effect. It describes the circumstance that the notion of AI changes due to advancements in the field as well as the emergence of new technologies. If something a computer can do becomes common enough that a majority of the people are used to it, it is no longer considered as AI. So while approaches such as genetic algorithms or expert systems are no longer considered to belong to the set of AI techniques anymore, recent progress in the fields of information processing or sensing technology as well as the shift to a data-driven paradigm have led to major advances in the field of AI such as deep learning, reinforcement learning, robotics, computer vision or natural language processing. Therefore, it is necessary to answer the questions which approaches from the field of AI are applied within the SCM domain as well as which SCM problems or tasks are addressed with AI approaches [3].

II. BACKGROUND

A. An Overview of Supply Chain Management

Successful firms have made a focused and clear idea of value creation, no matter if it is related from high-end products to custom-tailored services or generic and cheap commodities. However, how good your marketing is, no one may buy it if the product or service cannot be delivered to the consumer at an acceptable cost. Many companies should improve their SCM because their products spend time in inventories at least six months to a year or more. Since the products spend a lot of time in inventory, there is a huge opportunity to increase flexibility, reduce costs, make better deliveries, reduce cycle time, and lead to a more corresponding reduction in inventory. Several companies have improved their supply chain with internal operations. They have recognized that it has a relation to external

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Hieu Bui Trong, Faculty of Information Technology, Ho Chi Minh City University of Transport, Vietnam.
(e-mail: hieu.bui@ut.edu.vn).
Uyen Bui Thi Kim, International Trade School, College of Foreign Economic Relations (Cofer), Vietnam.
(e-mail: uyenbtk2007@yahoo.com).

customers and suppliers and with it they can gain further improvements in operations. Krichen & Ben [] described SCM to the decision-making process which manages different activities that create beneficial profits to suppliers, retailers, and customers. The efficient planning of activities can be cost-effective for production, sourcing, product development, logistical solution and for all flows that is linked between these activities. It can also be a process which optimizes a set of decisions. The process generates profitable solutions to provide efficient plans for acting on numerous levels while considering all decision-making standpoints. Krichen & Ben [4], Jacobs & Chase [5] advise that operations and SCM is critical for everyone to learn, no matter what your major is. They stated that even if your interest is in financial field, convert all values to the currency of your choice and after that, you will understand that it is about currency moving, storing, and exchanging the value. SCM is a vital aspect of making business today. For reader to understand what supply chain is, the research provides a formal definition of supply chain. There is a set of entities and relationships which are called supply network. In this supply network information and material flows are called downstream and upstream. Downstream goes towards the customer and upstream towards to the first supplier [6].

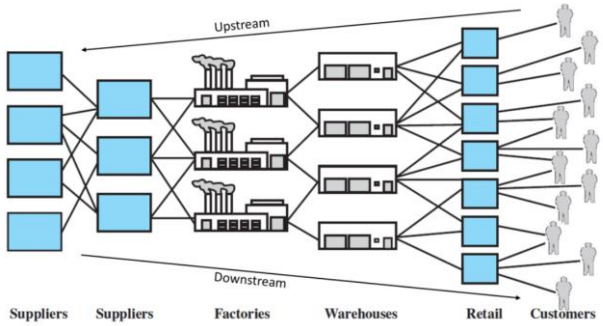

Fig. 1. Supply Chain Overview.

According to Fig. 1, SCM is a vital aspect of making-business today. For reader to understand what supply chain is, the research provides a formal definition of supply chain. There is a set of entities and relationships which are called supply network. In this supply network information and material flows are called downstream and upstream. Downstream goes towards the customer and upstream towards to the first supplier. Downstream from the supplier to the customer consists of materials and requisite information, for example, usage instructions, invoices, inventory levels etc. and it flows until materials are transformed to the final product and sold to the end-customer. Upstream from the customer to the first supplier consists returned materials like defective units, customer returns, recyclables etc. and requisite information like forecasts and demands. With information of forecasts and demands, it is easier for suppliers to plan capacity and inventory level [6].

B. An Overview of Artificial Intelligence

According to [6], recent years have shown that artificial intelligence has raised curiosity in SCM area. Since the late 1970's, development of AI has focused on to increase business productivity and ability to understand phenomena and patterns of business. Time-consuming and routine work tasks can be done by robotic process and machine learning as algorithms learn from data and analytics. With these, customer relationship management solutions reveal information for company to serve a customer with better knowledge. According Bughin et al. [7] report for McKinsey Global Institute, companies invested $26-$39 billion on AI in 2016 and high-tech companies used 90 percent of their investment in AI in the research and development (R&D) and deployment sector and 10 percent to AI acquisitions. AI is defined as computers' ability to solve problems independently when they have not been programmed explicitly to do particular task. The modern AI platforms have ability to gather information from surroundings. This kind of AI is made to use logicality and probability to choose and act within the highest likelihood of success. AI uses big-data sets, objects and sounds to act intelligently and recognize with distinguished precision [8]. AI gives ability for machines to feel environment in the same way as human being. This means completely new way for businesses to interact with their customers and offer them more holistic experiences such as intelligent products, service, and automated processes. AI is the most powerful technology of mankind. In the most basic form, AI exploits data for calculations or algorithms and makes decisions or predictions. This basic form runs into difficulties when calculating algorithms and calculations are more complex or user cannot describe the rules. In modern AI, for example, face recognition from different angles replicates this by using neural networks. Instead that human creates the rules for algorithms and calculations, machines program the rules themselves [9]. As a conclusion, definition of AI can be explained as machines that use big data to compare it to algorithms and calculations and make predictions of what is the most successful result. It can be used in many ways and today's AI technology is capable to do individual, holistic and complex decisions considering many aspects.

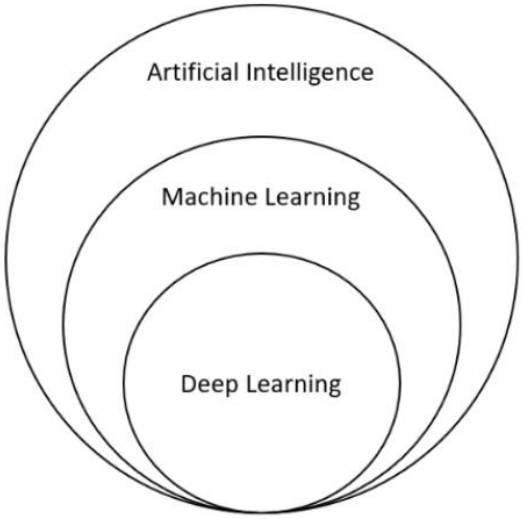

Fig. 2. Basic structure of artificial intelligence.

C. An Overview of Artificial Intelligence in Supply Chain Management

According Dash et al. [8] in their research "Application of Artificial Intelligence in Automation of Supply Chain

Management", they have classified AI helping businesses in four areas. These four value creation areas are vital for gaining competitive advantage. Those areas consist aspects as:

1. Reach almost 100% accurate forecasts including customer demanding and projection.
2. Gain production with decreasing costs and increase quality with optimizing their R&D.
3. Helping in promotion as defining the price, demography, recognizing target customers and create the right message etc.
4. Provide better experience for customers.

SCM is one of the most competitive areas in business which emphasize the interaction with different sectors, marketing, production, and logistics. In recent years, AI has been proven to be vital aspect for SCM. Modern machines with AI platforms can gather information from available data and use it to choose most probable and logical act with likelihood success.

According Min's [10] research, AI integration to SCM can be divided into three sections. Expert systems contain inventory planning, make-or-buy decision, and supplier selection. Genetic algorithm containing network design and agent-based systems takes over demand planning, forecasting, customer relationship management, negotiations, and order picking. AI is presented as a useful decision tool to help companies connect with customers, suppliers, and network partners to change informational knowledge [10]. Especially areas where forecasting is highly needed such as replenishment, the use of AI is scientifically and practically highly developed. The pioneers of AI have integrated broad spectrum of applications in their everyday businesses, while the competitors invest strongly in new ideas. However, some of the companies does not actively use or do any effort to adopt such technology [11]. According to [8], to make better optimization of processes and assets, AI has made a significant impact in production. AI can organize and design the best solutions of robots and people to make reliable and high-quality production. Also, prevention of downtime for maintenance can be predicted by AI. Automation, robots, and robotic solutions led to advanced technology implementations which can recognize objects and materials with camera-equipped robots and taught to recognize empty shelf place. This dramatically increases the speed of picking objects compared to conventional methods. Jacobs and Chase [5] describes that logistics visionaries have talked many years that the role of inventory in modern supply chain will be eliminated or at least affect radically. In the future, inventories would not need any buffer because supply and demand will be in a perfect sync. This means dramatical reduction of logistical costs. Most companies have not honed their technologies and networks to the point where they could abandon one's principles, inventory. For end consumers, inventory might be the most visible action of SCM. The most important operations management's responsibility is inventory management because inventory ties up capital and affects to the delivery of goods to customers. Inventory management affects to many business functions [6].

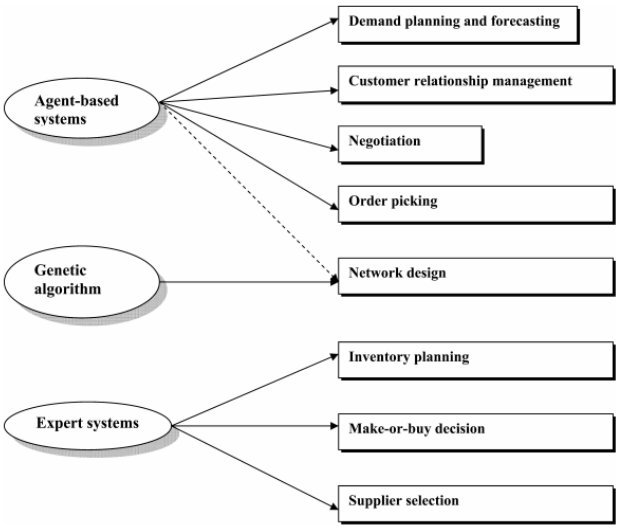

Fig. 3. Link between popular AI tools and their SCM applications areas.

D. Challenges and Opportunities to Implement AI in SCM

1. Challenges

AI as robots, IoT (Internet of Things) or supporting decision-making as intelligent agents can enrich human experience. Otherwise, it can fail and cause physical injuries, financial loss, and more subtle harms such as instantiating human bias and damaging individual dignity. These failures can cause unreliability because strange, unpredictable, and new dangers can lead to general inconvenience and abandoning AI. It is deeply transformative technology which is fast developed omnipresent in everyone's life. AI approach must be holistic, and it must reflect to many ways which AI can fail. Mannes [12] stated in their research that data reliability is top of challenges of AI. The data and technology are not mature yet enough to implement AI solutions.

According to Min [10], challenges of AI-tools integration in SCM are currently following:

• User has no free will and that is why it leads strongly to computer program which can cause wrong decisions if it is programmed wrongly.
• Implementations are not easy to establish because they are esoteric and for ordinary decision-makers hard to follow.
• Cross-border and cross-functional SC decision environments where AI may not be capable to function properly which is due to its knowledge acquisition bottlenecks.

According to The World Economic Forum (2016), optimizing machines to serve peoples' needs with AI has attracted attention to the ethical questions and risk assessments which are related to AI:

• Does AI increase unemployment?
• Does AI lead to bigger gap between wealthy and poor people?
• Does AI and robots influence in peoples' behaviour and intercourse?
• How can we get protection against mistakes?
• Do machines learn to be biased?
• How do we guard AI systems from adversaries?
• Can AI occur negative side effects?
• How do we control a complex intelligent system?
• How the humane treatment can be defined for AI?

2. Opportunities

Recent studies have shown that well-structured AI-tools in SCM are limited to tactical and operational problems. Agent-based systems have the most potential in SCM to solve strategic issues in customer relationship management, relationships of outsourcing, B2B negotiations, strategic alliances among SC partners and collaborative demand planning to eliminate bullwhip effect [10].

To understand the drivers of new demand patterns, companies can exploit AI to take over decision-making, routine planning and activities in SC. Demand planning usually suffers of inefficiency when reacting in unpredictable demand patterns. Deep learning automatically recognizes patterns from external signals and can distinguishes inappropriate signals to relevant signals. With signals it can fine-tune demand forecasts. Advances of AI consist tracking weather, spot market capacity, identify key variables of demand drivers, feedback from product quality, and gather data from production machines to make better planning. Genetic algorithms can identify batches related to SC planning and decision-making cycles. These reroute orders and address near-term supply delays. Identifying batches with genetic algorithms helps to recognize in-house expenses and automate procurement of alternative capacities. The solution is not to buy latest planning software from AI-company. AI solution is a holistic ecosystem with the right algorithms, - mix of internal and external data and rights of decisions. Sustain solutions lead to strong end-to-end change management. To achieve successful SC planning, companies must identify new technological solutions that helps them in complex business environment [13].

E. Summary of Artificial Intelligence in Supply Chain Management

According to [6], in a planning level, AI concentrates in SCM field to forecasting, demand planning and optimization. These areas increase customer experience and make better assessments for processes and assets. The most potential areas of AI in SCM can be considered agent based systems as it can operate in many SCM areas. AI can operate on strategical-, tactical -, and operational decision-making levels, but mostly on operational levels as forecasting, production, and warehouse actions. Increasing competitiveness, demand uncertainty and higher supply risks make companies invest enormous amounts of money to R&D when modern AI technology is implemented, and they are trying to find best AI solutions for business actions. However, companies should not be blind-folded when investing to AI solutions but consider exactly what serves them in the most sustainable and comprehensive way. Also, they must think what challenges AI may bring for the company in ethical and data maturity point of view. SCM value creation via AI are to reach almost perfectly accurate forecasts and decreasing costs of production. It also increases quality by optimizing their R&D and helps recognize target customers and provide better customer experience. With accurate forecasts, companies can minimize the waste and thus be more sustainable. They also can reduce costs and optimize sourcing. Weather-related solutions can predict the best supply and demand variation based on local weather forecasts. This solution could be great key for retail stores to optimize their sales e.g. in hot summer days. In production, AI can predict maintenance downtime and make production more reliable and high-quality. Camera-equipped robots can recognize objects and materials and increase speed of picking. AI can make remarkable impact for inventories when supply and demand are being in perfect sync. This leads to decreasing capacity of inventories and satisfies customer needs rapidly.

III. Discussion

In [10], since SCM requires the comprehension of complex, interrelated decision-making processes and the creation of intelligent knowledge bases essential for joint problem-solving, SCM has evolved into knowledge management. In other words, it is increasingly important for SC partners to learn from the increased knowledge bases and automate the SC decision-making processes. Thus, AI has been put forward as a useful decision-aid tool that helps the firm connect its customers, suppliers, and SC partners by facilitating information exchange among various business entities across the SC, while replacing assets (e.g., inventory, facilities, transportation equipment) with information. Despite the presence of AI for the last half-century and its recent emergence in the SCM area, AI has not been fully exploited to solve SC problems whose solutions are either too expensive or difficult to produce due to their inherent complexity and ill-structured nature. However, some recent AI studies have shown the great potential of AI tools (especially agent-based systems) for addressing a variety of soft but strategic issues involving CRM, outsourcing relationships, strategic alliances among SC partners, SC coordination, collaborative demand planning, and business-to business negotiations that have often been overlooked by more traditional analytical models (Min and Zhou 2002). Another finding is that an agent-based system has emerged as one of the most popular AI tools for tackling various aspects of SC problems (Fig. 3).

IV. Conclusion and Future Directions

According to [6], the primary suggestion for future research could wait until quantum computers become more common and are usable for companies. They can exploit it to make more accurate calculations because AI needs a lot processing power. Also, when quantum computers become more common, AI solutions can develop more intelligence. As results presented narrow scale of AI applications, the future research should be done with SCM professionals and IT-experts because they can combine expertise together and make clear and comprehensive understanding of the topic area. Respondents must have more experience of AI in the future. As discussion presented the number of employees with knowledge of AI and data-analytics is low. The future researcher should find the suitable employees and make data collection by interviewing them. Thus, they can answer for the questions with more knowledge. However, suggestion is to do future research when AI applications are more common, and companies are not at the planning stage. At

planning stage, they are afraid to lose competitive advantage if someone steal their idea. As education for AI functions becomes more common, it produces skilled employees to the job markets. This means more implementations of AI and increasing maturity levels. Even though AI is on the frame all the time, the future research should be done when human and machines interaction become more fluent and data is mature enough to implement sophisticated AI. After all, this study has been done too early and in difficult time, no question about that.

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