The role of artificial intelligence in supply chain optimization

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Abstract. Artificial intelligence is becoming the best solution for an efficient supply chain. Its integration into supply chain activities within these systems brings substantial benefits, and is essential for improving overall performance. However, the supply chain is a group of activities that enables raw materials to be transformed into finished products and delivered to the end customer. In recent years, however, it has become very difficult and complex to deliver a product efficiently and on time. This can lead to numerous disruptions that can bring operations to a standstill. That's why all companies need to improve and optimize their supply chain to meet the challenges ahead. At this stage, artificial intelligence is very important for optimization. It can improve productivity, supply chain resilience, visibility and flexibility. It can also reduce costs and lead times. The aim of this article is to explore the possibilities offered by AI for improving supply chain operations

Keywords: Industry 4.0, supply chain, Artificial Intelligence, Machine Learning, Deep Learning.

1 Introduction:

In recent years, companies have been focusing on improving their operational efficiency and competitiveness. Supply chain management is one of the key elements of this optimization.

However, the traditional supply chain process is a static chain that operates manually or semi-automatically. It relies on predictions based on historical data. These methods show that this chain can be confronted with certain disruptions that can lead to business stoppages and discontinuity, and its limits in the face of business uncertainty.

With the rise of Industry 4.0 and digitization, the aim of all companies is to optimize their activities. The use of Industry 4.0 technologies, such as AI, is an important element

in improving the supply chain. According [1] to applying artificial intelligence technology in supply chain can be the current way for ensure stability. Thanks to advanced AI technologies, such as machine learning (ML), deep learning (DL), it is possible to improve procurement, production, transportation and distribution, and minimize overstocking and underutilization of resources [2], which also makes it possible to best anticipate needs and optimize inventory. It's enable intelligent and adaptive decision-making [3]. According to [4] all industries are beginning to integrate AI for optimizing there production processes, reducing costs and improve efficiency. More than that, it allows to improve SC sustainability and efficiency [2]. According to [5] AI can solve problems quickly and accurately.

Integrating AI into the supply chain enables a digital supply chain that can operate automatically. This integration is not limited to logistics or inventory management. It can be integrated into supplier management, route planning.

The aim of this article is to explore what artificial intelligence and its technologies? And how can AI transform TSC into a digital supply chain?

To answer these questions, this article will follow the following outline. The main topics to be covered in this article are:

- An overview of AI and its benefits;
- AI integration in the supply chain.

2 Basic concepts:

2.1 An overview on Artificial Intelligence:

Artificial Intelligent (AI) is one of the most important industry 4.0 technologies, which their objective is to use intelligent and automatic process instead to use manual process. AI is a branch of computer science that replaces human behavior with intelligent behavior that has the same characteristics as human behavior, i.e. the ability to think, learn and solve problems in order to work on complex tasks [4]. According to [6], Artificial intelligence (AI) makes reference to the automation of intelligent performance , is the ability of a system to properly read external data, to learn from it. It's developing to more powerful digital area to facilitate information access and intelligent decision [2]. Is using group of technologies and automated learning to improve and optimize process [7]. According to [8] is defined as a sub-field of computer science specializing in tasks that require human learning and reasoning.

Artificial intelligence algorithms are a set of techniques that used in different areas, which allow machines to be capable to effect tasks that require human intelligence.

2.2 AI technologies:

AI has different technologies that play an important role in enhancing supply chain. Applying AI technologies in supply chain in objective to improve her efficiency, resilient and flexibility. There are some important AI technologies using in supply chain management (SCM) (figure 1):

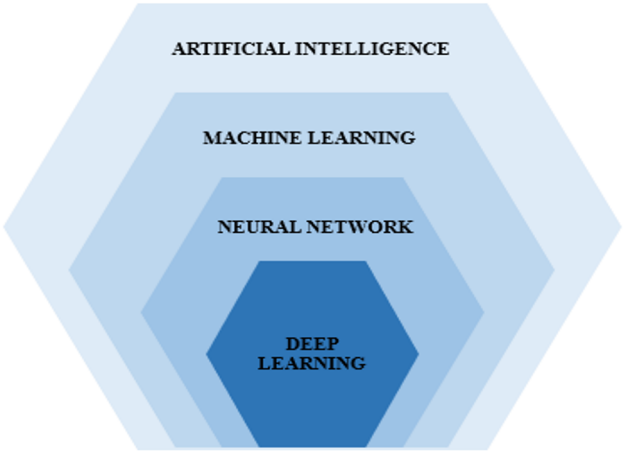

Fig.1.Different artificial intelligence technologies

- Machine Learning (ML): is one of the technologies of artificial intelligence, which enables computers to work automatically and improve through experience. There are different algorithms that work in the same way as human learning [9]. According to [10] supervised learning and unsupervised learning are the types of ML; In supervised learning data consists of inputs partnered with outputs. In the other hand unsupervised models can learn patterns from unlabeled data.
- Artificial neural networks (ANNs) are a powerful mathematical tool that can be used in various fields to analyse difficult and complex models, particularly physical models.[11].
- Deep Learning (DL): is technology that becomes an important element in data analysis and image processing [12]. it is a learning method that processes complex data[13].

Using these technologies in supply chain allow improving efficiency of SC.

In this context, traditional supply chain (TSC) is a group of activities manual or semi-automatic, which can transform a raw product to final product and delivery it to final customer. In addition, Supply chain management is the management of delivering products of higher value to customers at low cost, it lies between suppliers and customers. TSC is becoming complex and difficult. The TSC faces a number of challenges which can obstacle supply chain activities such as increase in costs and delays. According to [14] these challenges are manifested in: Complexity of Supply Chains, Lack of raw materials, Higher transport costs, Forecasting demand… . In addition, according to [15], the TSC can face certain challenges that disrupt the supply chain. among these challenges there are pandemics, natural disasters, price increases.... These challenges lead to low efficiency and quality of products.

At this stage, companies need to have the ability to avoid these challenges, or at least to have methods for dealing with them.

Artificial intelligence is one of the most important industry 4.0 technologies The application of Artificial Intelligence (AI) is important for tackling the complex challenges of the Supply Chain because of its ability to process vast volumes of data in

real time, automate processes and optimize decision-making. It can prepare companies for any situation, ensuring the company's long-term future and automate routine activities and operations to minimize human error [16]. According to [17] Integration, AI can reduce costs through many operations such as optimizing resource allocation, more than that, it can improve the operations group by personalizing the experience to increase operational efficiency, moreover, it can open up businesses to new revenue streams by enabling innovative services. According to [16] application of AI and ML in supply chain may improve productivity by reducing repetitive activities and tasks.

2.3 Application AI in supply chain:

AI is the key of enhancing supply chain management by reducing costs and improving efficiency.

It can be integrating in different domains or activities.

According to [18] applying AI it can replace human labor and automate production processes, In addition, it can enhance inventory management by minimizing overstocking and out-of-stocks, and can predict the risk of disruption. [19] Using AI in supply chain is crucial to improve supply chain productivity, automate and digitizing supply chain activities.

According to [20], the integration of AI into the supply chain is important because it enables stock levels to be monitored to avoid over-stocking and stock-outs, and even to track production. According to [21], AI is crucial in stock management, it can help companies plan stock levels efficiently, avoid stock-outs or overstocking, it can help them make better decisions and optimise logistics. Using AI refers to use techniques for data analysis process optimization, that allow companies can take decisions more informed and effictive, that allow to reduce response time [22].

Applying AI to the supply chain can transform a traditional supply chain into a digital supply chain, meaning that instead of having manual processes, it can be intelligent and automatic, allows reducing errors or breakdowns and reducing the time taken to deal with problems. (figure 2) explains the integration of AI's application into the supply chain.

To create AI systems, it's need to tree parts (figure 3): inputs (data), models (AI algorithms) and output (decision) [21] :

Fig.2. Integration AI model

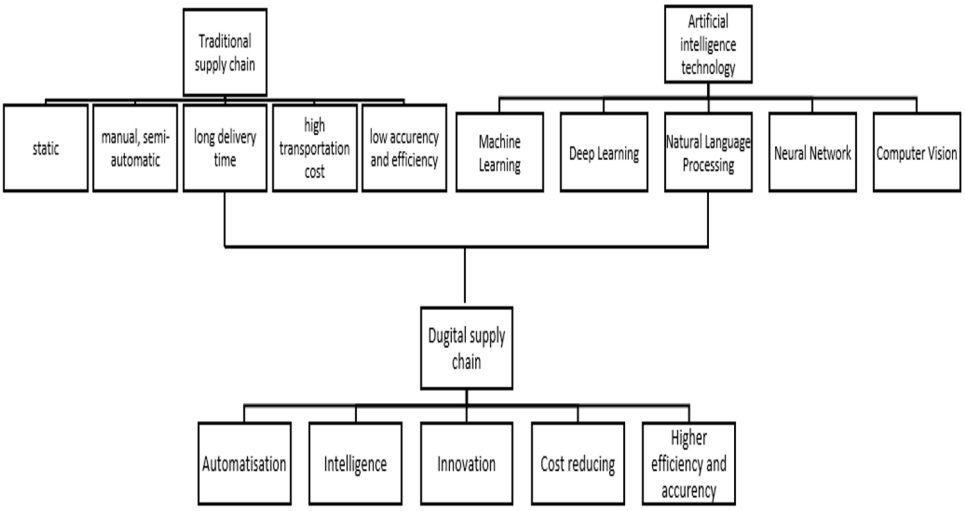

Fig.3. The importance of AI in supply chain

After collecting data such as order history or Iot sensors …, it should be storage and procession then cleaning in order to delete the unusable data. After that, it was necessary to choose algorithm depend to data model such as Machine learning, deep learning or AI optimization. Using these algorithms allows to have the expected result such as redusing costs, process automation … (figure 4)

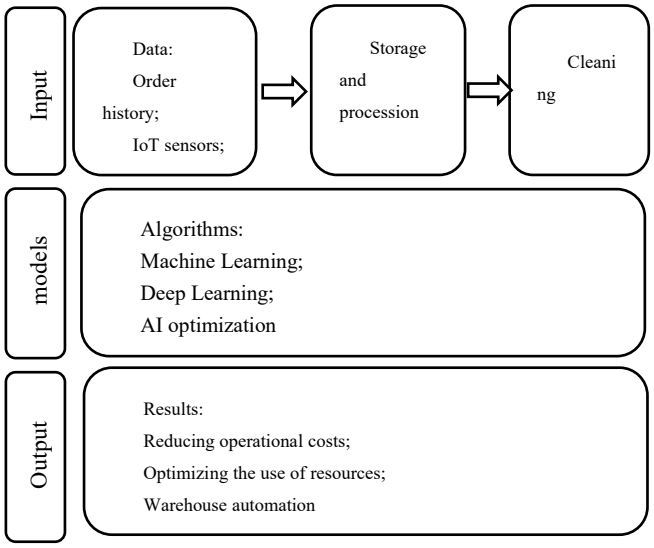

Fig.4. Steps for integration AI in supply chain

3 Challenges and obstacles of integration IA in supply chain:

Integration of artificial intelligence has many positive effects on the supply chain. But despite its importance and these expected benefits, it has its challenges and obstacles. In this context, [23] identified challenges and obstacles to the integration of intelligence, such as the immaturity of processes and people, and insufficient data to optimize algorithms. He has also shown that these obstacles manifest themselves in job displacement or lack of confidence in technology.

In the same context, [24] mentioned that the challenges of artificial intelligence manifest themselves in the complexity of this integration the quality of the data, as they are often incomplete, moreover he affirms that the lack of qualified personnel and the risk in terms of cybersecurity and confidentiality are among the obstacles that put this integration more difficult and more complex.

In addition, [25] found that these obstacles are not only technological, but there are other obstacles on the organizational side, for instance, challenges include the absence of a clear alignment between vision and strategic execution, a lack of organizational culture that promotes information sharing, and, on the environmental side, insufficient regulatory frameworks and compliance requirements.

In the same context, 4 asserted that there are several obstacles to the integration of artificial intelligence, including poor support from senior management, limited resources, high installation costs, and data confidentiality and security.

4 Methodology:

In this study, we have chosen to adopt a literature review approach to examine the role of artificial intelligence and the importance of integration in the supply chain. In this stage, we selected articles and scientific publications from databases such as scopus and web science, using keywords (artificial intelligence, industry 4.0, supply chain, artificial intelligence technologies), ... We consulted articles and journals specialising in digitisation and supply chain innovation.

The aim of this article is to find out about the importance of artificial intelligence and its impact on businesses, and to identify the main technologies used, such as machine learning and deep learning. We have highlighted current trends by selecting articles published between 2018 and 2025. This analysis has enabled us to identify future research opportunities to improve the integration of these technologies into logistics processes.

In this study, research effected using the key words like (supply AND chain OR industry 4.0 OR supply AND chain 4.0 OR traditional AND supply AND chain OR digital AND supply AND chain) in databases such as scopus (figure 5) . This research allows to have a total of 2577 articles from 2018 to 2025 (figure 6).

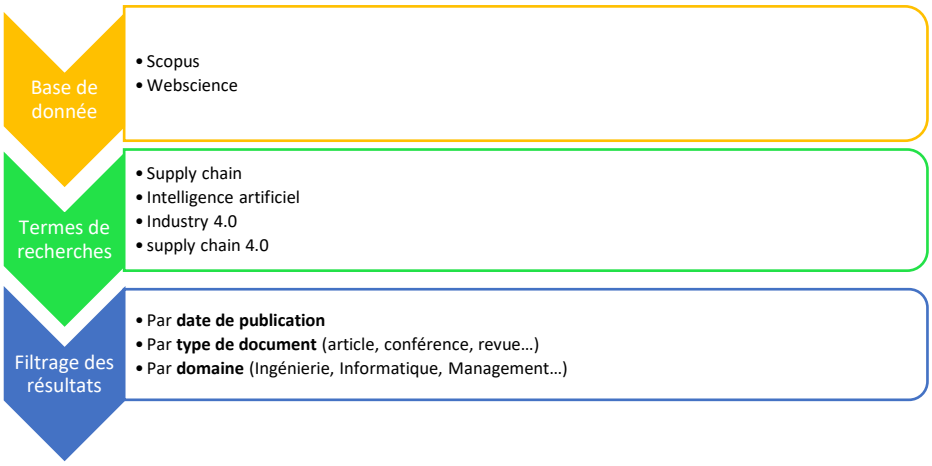

Fig.5. Structure for importing articles from databases

We can constate that searchers about supply chain and industry 4.0 technologies such as artificial intelligence augmented year after year. This trend is indicative of the growing importance of these key words in the field of academic research and in the industrial sector in general

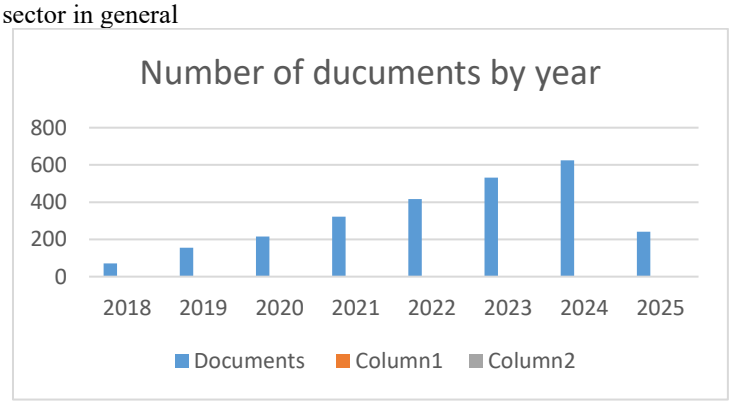

Fig.6. Number of documents by year

5 Discussion:

The traditional business model based on human decisions was sometimes subjective. But the integration of artificial intelligence into supply chain is playing an important role in the transformation of the logistics process. This transition to the digital supply chain is becoming important, as it offers many opportunities. It can make the supply chain more agile and resilient, and it is also leading us towards an automated and autonomous supply chain.

Thanks to advanced AI technologies such as ML (Machine Learning), DL (Deep learning)... companies can avoid supply chain disruptions, anticipate demand fluctuations and automate supply chain activities to avoid errors due to repetition and

the same routine; moreover, thanks to AI, companies can optimize logistics routes in real time. This technology is one of the most important in Industry 4.0, its user is not looking to improve operational efficiency but to be able to confront and build resilience to disruption, whether external or internal.

The future of the supply chain is interested in the integration of industry 4.0 technologies such as artificial intelligence, IoT, ... these technologies will make work easier and reduce work stoppages and breakdowns, in fact they will help solve problems without work stoppages.

6 Conclusion:

The integration of artificial intelligence in the supply chain is crucial to improve their efficiency, resilience, flexibility and sustainability. The use of artificial intelligence technologies such as machine learning, deep learning, ... companies will have an opportunity to reduce the cost and time whether it is transport, production, ... Moreover, it can manage the stock to avoid having overstock or stock shortages.

Despite these advantages, there are challenges and obstacles that make this integration more difficult and complex. In this context, the integration of artificial intelligence requires a very high cost for installation and even for the transformation of the supply chain from traditional to digital. In addition, data is very important for efficiency, which can lead to problems such as data errors, or even the need to ensure data security. But despite the obstacles, integrating artificial intelligence in particular, or Industry 4.0 technologies in general, can improve business and increase supply chain efficiency and flexibility.

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