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supply chain risk management using artificial intelligence learning techniques

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Abstract: Today, with globalisation, companies are confronted with many disruptions that can affect their supply chain management, more complexity due to unpredictable weather conditions and external sources of risk. In effect, the COVID-19 pandemic has exposed these vulnerabilities and created many new challenges for supply chain management. This has led researchers to focus on the study of supply chain risk management issues. Within this framework, supply chain risk management is the main focus of research that involves several strategies to identify, assess, mitigate and monitor unforeseen events or conditions that could adversely affect any part of a supply chain. Although research on SCRM has been ongoing for a long time, industries still face difficulties in monitoring all SC. In addition, SC managers have started to focus on decision making based on multiple data sources to predict uncertainties more accurately to achieve an intelligent, proactive and predictive risk management mechanism. These attributes make artificial intelligence (AI) and learning techniques appropriate in the SCRM domain. By analyzing large amounts of data, AI can identify potential risks and propose strategies to mitigate them. With this purpose, this paper aims to address the use of AI learning techniques in the different phases related to SCRM and discuss the impact of supply chain automation for decision making and business process improvement. This review focuses on research articles related to SCRM and the application of AI techniques published between 2018 and 2023. Finally, this review provides the benefits but also the challenges and limitations of implementing AI technologies in supply chain risk management.

Key-words: artificial intelligence, supply chain risk management, risk management, learning techniques

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1. Introduction

The supply chain (SC) includes all companies and distributors involved in all stages of the production and marketing process of a product or service. The success of any business across the supply chain. is directly related to the management of the supply chain and customer satisfaction. Thereby, it is essential to plan, implement, motivate and control effectively all activities of the process such as: transportation, production, storage of raw materials and materials, as well as storage of finished products, from the first supplier to the last customer, which adds value to the product or service [1]. Indeed, in order to have a smooth and uninterrupted supply of products and materials while minimizing costs, it is crucial to set up an efficient supply chain management. Hence the importance of SC is translated by the level of contribution of each link in the chain, suppliers, production, carriers and customers in order to increase the value and efficiency of the chain of the company [2].

Today's supply chain is very different from those of just a few years ago [3]. With globalization and outsourcing trends, digitization, competitive conditions, ever-increasing relationships between supply chain partners, and the development of technology, supply chains have become interconnected and complex with each passing day [1]. Companies master the actors located in the first two levels of their supply chain, but their visibility gradually decreases for the following levels [4]. These trends put a strong pressure on the operations without having interruptions, and produces a vulnerability to disruptions consequently increasing the financial impact of the supply chain [5]. As 56 percent of the world's companies face disruptions each year including product diversity, fewer suppliers, increased dependency on each other, rising customer expectations and shorter delivery times, they are now paying increased attention to these issues. However, it is essential to design resilient supply chains and prepare contingency plans [5]. These companies face risks such as production and delivery delays and supply disruptions. Practitioners and researchers are therefore interested in investigating the causes of these events in order to mitigate the impact of the associated risks to achieve an excellent management, fast, flexible and effective. At this stage the SCRM is treated in several research works, indeed an important part is dedicated to the identification of these risks, their effective assessment, their proactive management and monitoring of their continuous progress[2].

Supply chain risk management is based on a wide range of strategies that aim to identify, assess, monitor and mitigate potential threats that may compromise the effective and efficient execution of supply chain processes. These can include operational disruptions (breakdowns, stock-outs), geopolitical risks (political instability, conflicts) or environmental risks (natural disasters), and economic fluctuations (price changes, currencies), terrorism, war and pandemics, have taught business organizations to optimize their supply chains out of necessity[6] . The importance of supply chain risk management in today's business landscape is clear: recent health and economic crises have demonstrated how reactive companies must be to ensure their sustainability [3]. At this point, SCRM is addressed in several research works. Significant disruptions in SC occurred with the covid pandemic19 which justified the ineffectiveness of SC risk management strategies. This pandemic has affected millions of people and has resulted in enormous costs, depending on its impact and speed of spread. For this reason, companies must consider such a situation as a risk in the management of their SC [1]. This outbreak of COVID-19 indicates the need to transform the existing SC in terms of adaptability (flexibility), recoverability (resilience) and resistance capacity (robustness) to disruptions in this dynamic environment [2]. In this context, it is important for companies to anticipate the risks in supply chains and take the necessary measures. Although several strategies have been adopted by companies, managers still find it difficult to manage these risks and think of mastering a predictive plan whereby they prepare a contingency plan in anticipation of changes that can potentially prevent signs of significant loss to the organization. Indeed, proactive strategies rely on the ability to accurately predict the probability of occurrence and potential impact of risks. It is an intelligent SC that integrates a planning plan to create a visible, responsive and agile network using digital technologies. The application of AI learning techniques to manage SC risks is in its infancy [2] [1], with few research adopting this notion, several researchers have used multi-criteria decision making (MCDM), mathematical optimization programming and AI techniques to achieve the objectives of SCRM [7].

In the well-known quote of Herbert Simon in 1965 "machines will be able to do any job, any job a man can do" [8], an approach that has developed over time, since early 2010 the use of AI applications in-

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creases more and more in business management, the latter start to invest in AI solutions to improve supply chain operations [8]. In addition, research indicates that SCRM is an unexplored area lacking holistic approaches such as end-to-end visibility and real-time perception. Recent articles show that researchers are increasingly interested in using AI techniques to accurately predict uncertain events [3]. In this context, AI provides continuous monitoring, which improves the resilience of SCs and minimizes the influence of sudden disruptions. Therefore, the research highlights the need to introduce a new transformation paradigm to improve decision making using automated technologies that can analyze advanced and predictive data. However, it is relevant to leverage AI and these techniques such as Machine Learning (ML), Deep Learning (DL), and natural language processing (NLP) in SCRM [2].

Based on a qualitative study, we discuss the applications and uniqueness of AI adoption in SCRM and propose a research model on the adoption, implementation, and routinization intent of AI in SCRM at the organizational level. After that, we discuss the implications of the study and the benefits for policy makers and supply chain planners in designing effective strategies when adopting AI in SCRM. The main purpose of this paper is to conduct a systematic review of SCRM-related research that uses AI learning methods to achieve the objectives, by classifying and synthesizing the results of selected papers over the past five years. The research questions this study aims to address are:

-Does the SCRM domain leverage AI capabilities such as decision making, prediction, learning, and the ability to manage complex and uncertain environments?

-What is the current state of research on using AI to predict SC risks?

-What are the relevant drivers for using AI tools in SCRM?

-what is the relationship between AI and risk management?

-what is the influence of AI on decision making?

- What are the issues for the future use of AI learning techniques in SCRM?

In order to effectively answer these questions, a comparison and evaluation of the relevant literature is carried out, indeed, a review of selected articles from the SCRM literature related to AI, namely decision making, prediction and learning. However, the article is organized as follows: An introduction is followed by a research methodology, then in another section we will discuss the AI learning techniques used for SCRM and the advantage of their application. In a separate section from the previous one we will discuss the results according to the identified themes. Finally, we end with a conclusion that addresses the future of AI and SCRM that are drawn, and future research directions are suggested.

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2. Methodology

The purpose of this literature review is to summarize and rank existing work on the use of AI techniques in Supply Chain Risk Management (SCRM) since 2018. This study uses a content analysis methodology, or we will compare different points of view found in several articles in order to be able to select the relevant work related to our research theme. The main purpose of this article is to: keep the work associated with the application of artificial intelligence techniques in supply chain risk management and reject work that. is solely related to SCRM without considering the application of artificial intelligence techniques. The review methodology used for this problem consists of 4 steps: (1) selecting articles, (2) sorting articles according to relevance, (3) then highlighting the essential ideas (4) in order to compare between these works.

2.1. research

Initially, the keywords "AI" AND "SCRM" were the search query used to extract articles from the 3 indexed databases Scopus and Direct Science and SpringerLink (limited to the article title, abstracts and keywords).

2.2. selection of articles

Article selection was only for English articles, open-source articles, and what has been published in the previous five years (2018-2022). 20 items were selected from about 40 items initially found, after keeping that work in the following area: industrial and computer engineering, management, business, accounting, system for decision support. The relevant papers are interested in the application of AI in SCRM in the context of engineering and mathematics which led to a final selection of 14 papers

3. supply chain risk management "SCRM"

3.1. understanding the importance of managing supply chain risk

Supply chain management aims to optimize the flow of materials, information and money in order to reduce costs and satisfy the customer, as companies are always faced with disruptions that can influence the continuity of supply chain activities. Disruptions are defined as the possibility of error, damage or loss resulting from unexpected events. Any disruption in one link of the supply chain affects the whole chain [9]. This is why supply chain risk management is becoming more and more important every day to ensure competitive advantage and sustainable success

Supply chain risk management is about identifying potential risks and putting in place measures to mitigate those risks, while focusing on three activities [2]: risk identification, risk quantification and identification of potential solutions to mitigate the impact of risks, ensure business continuity and customer satisfaction.

From raw material procurement to final product delivery, the supply chain comprises several stages and is confronted with several disruptions that can occur at each stage of the chain, including: mis-statement of requirements, poorly established specifications, delivery delays, poor quality of the raw material or materials purchased, transport and logistics constraints, system and equipment failures, product quality problems, natural disasters, quality problems, etc [5]. These disruptions can cause delays, additional costs and even loss of revenue and production. Problems can affect the customer and their safety, which can damage the company's reputation, so it is important to be prepared for such unforeseen events and to seek to improve performance, but also to reduce costs.

Given the complexity of the global supply chain, which is increasing due to unpredictable weather conditions and external sources of risk, including climate change, natural disasters, political instability, financial turmoil and pandemics [10]. Indeed, as the COVID-19 pandemic has highlighted these vulnerabilities and created many new challenges for supply chain management, supply chain risk management is the subject of a number of research projects that include several strategies to identify, assess, mitigate and control unforeseen events or conditions that could have a hostile, more or less fatal influence on the continuity and profitability of any part of a supply chain, thereby minimizing disruption and maintaining business continuity [7]. In addition, SCRM is concerned with both proactive management of risk prediction and response and is the sub-field of supply chain management that manages the risks of instability due to the complex and uncertain environment of supply chain operations.

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3.2. SCRM process: how can supply chain risks be managed?

The supply chain risk management process needs to be developed proactively due to its complexity. Indeed, in order to implement an effective SCRM approach, it is necessary to follow the following process [9]:

-Phase 1: Identify potential risks:

This phase consists of identifying the events that can influence the proper operation of the chain, in fact it is important to address each link in the supply chain and determine the main causes of the problems.

-Phase 2: Evaluate the impact of the identified risks:

In order to give priority to the risks identified above, we measure the impact of each risk on the activities of the chain and on the company as a whole. Indeed, this evaluation can answer certain questions such as: which stakeholder is most affected by these risks? What is the probability of occurrence of these risks? What are the costs generated by these risks?

-Phase 3: Develop risk reduction strategies:

an effective strategy that seeks to reduce the impact of the risk such as using alternative suppliers, setting up contingency plans for the most critical risks, setting up action plans, and setting up control procedures, etc.

Phase 4: Control and monitor risks and contingency plans to identify potential risks before they become increasingly critical, in order to reduce downtime and costs. By using risk dashboards, alerts and data analysis to effectively monitor risks and contingency plans.

Phase 5: Continuously improve risk management

The results of risk management should be regularly monitored to identify necessary improvements and strengthen the resilience of the supply chain. Indeed, artificial intelligence learning techniques can help improve supply chain risk management by providing predictive analysis and helping to identify trends. A proactive approach allows companies to optimise their performance and improve their processes [2].

In summary, the outcomes of SCRM have two objectives: to mitigate the negative consequences of risks or to enhance the positive attributes to improve profitability, competitiveness and business resilience to the unexpected. Rather than trying to mitigate the damage after the impact, the most effective solution to the risk management process is to anticipate and prepare solutions by adopting an effective strategy to ensure optimal management of resources and seize market opportunities[11].

4. Supply chain risk management and artificial intelligence: role and application

4.1. Artificial intelligence: definition

Artificial intelligence (AI) is a branch of computer science that focuses on the development of machines capable of performing tasks that are usually the province of human intelligence, including perception, understanding, decision-making, learning and problem-solving [3]. To achieve this, AI uses algorithms and mathematical models that allow machines to learn from data and gradually improve without direct human intervention. AI can be applied in various fields, such as image recognition, machine translation, speech recognition, robotics, data analysis, security, etc [3].

There are many studies on artificial intelligence. In their paper, Mehrdokht et al, 2021 state that the term "artificial intelligence" was coined by John McCarthy in 1955 to solve problems using the ability of the machine to use language usually reserved for humans. Since its initial conceptualisation in the 1960s, AI research has varied greatly, however, it is only recently that AI has begun to deliver the promised value to business. Examples include IBM Watson, which is used for medical diagnostics, and Fleet Learning, developed by Tesla, which enables vehicles to predict their changing condition by continuously sharing fleet data [8].

In general, AI is increasingly used in many fields, such as medicine, finance, logistics and production. It has also become a concern for some, who fear that AI will take over humanity in the future.

4.2. SCRM and the application of artificial intelligence

Artificial intelligence has been developed to permit computers to think logically and function like humans in terms of decision making. Artificial intelligence is a multidisciplinary research field. It works in partnership with many independent branches such as mathematics, computer science, manufacturing and services, retail, public institutions and law [1].

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Through artificial intelligence techniques, companies gain efficiency, productivity and competitive advantage in supply chain management. Artificial intelligence techniques enable the development of new problem-solving methods and facilitate the resolution of chronic problems in supply chain management business processes [12]. Artificial intelligence techniques allow companies to implement decision support systems that enable them to operate at low cost and with high profitability in supply chain management. Artificial intelligence techniques are used in supply chain risk management, inventory control and management, transport network design, purchasing, demand planning and forecasting, and order picking [11][13][7].

In general, it can be used to help manage supply chain risk in a number of ways [6]:

-Risk prediction: AI can be used to forecast potential risks by analyzing supply chain data, weather data, economic data, etc. Predictions can help companies take preventive measures to minimize negative impacts.

-Risk monitoring: AI can continuously monitor supply chain operations for any changes or potential risks. Using machine learning, AI can learn to recognize the warning signs of specific risks and alert managers in real time.

-Supply chain optimization: AI can be used to optimize supply chain operations, providing recommendations to improve efficiency and resilience. Using machine learning, AI can identify potential bottlenecks, inefficiencies and risks, and propose solutions to address them.

However, AI can help to anticipate risks through machine learning methods, enabling faster and more accurate risk management decisions. AI algorithms can analyze supply chain data in real time to detect anomalies or potential errors and alert businesses before a problem occurs [6]. AI can also be used to predict supply chain disruptions and make decisions to minimize the impact of these disruptions. It can also be used to predict future risks using predictive models based on historical data. AI learning techniques, such as supervised learning, unsupervised learning and deep learning, can be used to improve supply chain risk management.

For example, supervised learning can be used to detect fraud in invoices or payments, these techniques can be used as follows:

- Regression: Used to predict a continuous variable in the supply chain, such as delivery time. Popular regression algorithms include linear regression and logistic regression.

- Classification: Used to classify data into categories. In the supply chain, it can be used to classify suppliers by performance or to detect anomalies in deliveries. Popular classification algorithms include decision trees, random forests and support vector machines (SVMs)

- Decision trees: Used to determine what action to take in the event of detected risks. For example, choosing an alternative supplier in case of failure of the main supplier. A decision tree is a series of decisions that lead to specific actions based on the current state of the supply chain. Decision trees can be used for classification and regression.

In addition, unsupervised learning can also be used to detect anomalies in supply chain data such as:

- Clustering : is an unsupervised learning technique used to group similar suppliers according to specific characteristics. Popular clustering algorithms include kmeans and hierarchical clustering. Commonly used characteristics for clustering suppliers include:

-Geographic location

-Product type

-Order volume

-Price

-Quality.

- Association: is an unsupervised learning technique used to identify relationships between different suppliers, for example whether certain suppliers are more likely to cause delays. Popular association algorithms include apriori and Sparkle. The association process involves finding association rules that correlate sets of items. For example, if many customers who buy milk also buy cereals, an association rule could be established between these two items.

- Sentiment analysis: is an unsupervised learning technique used to analyse customer feedback on delivered products to detect quality or customer satisfaction issues. The sentiment analysis process involves classifying each comment as positive, neutral or negative in tone. Negative comments can then be examined in more detail to identify specific problems reported by customers.

Finally, Deep Learning can be used to improve the quality of supply chain forecasts by applying the following techniques:

- Neural networks: are used for pattern recognition, supply chain optimisation and real-time decision making. They are based on an information processing structure similar to that of the human brain. Neural networks are able to learn autonomously, and are

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particularly suitable for complex tasks such as image recognition and prediction.

- Convolutional neural networks: are a variant of neural networks, specifically designed for image analysis. They are used for tasks such as detecting damage or defects in delivered products. Convolutional neural networks work by identifying key features of images and using them to classify images into different categories.

- Recurrent neural networks: are used for natural language analysis and prediction of possible outcomes in the supply chain, such as order returns or cancellations. They are able to work with sequential data, i.e. data that has a temporal structure, such as text or a time series. Recurrent neural networks use recurrent connections to process sequences of inputs, using previous results to influence subsequent results.

In summary, it is important to note that the use of AI to manage supply chain risks should not be seen as a quick fix. AI results should be interpreted with caution and validated by human experts. Furthermore, AI cannot completely replace human expertise in risk management. Instead, AI can be used as a tool to help human experts make informed decisions and improve supply chain resilience.

5. Discussions and results

Artificial intelligence can play an important role in supply chain risk management. In today's technology-driven world, supply chain risks are increasingly increasing. In addition, supply volume risks are mainly due to unforeseen demand, but also to production failures, material shortages, environmental factors, economic, social or political problems, or the viability of key suppliers [9]. Furthermore, increasing globalization leads to increased delays. Other risks are related to the global nature of the supply chain, such as communication problems, exchange rate fluctuations or regulatory or legislative issues. In 2021, the disruption caused by the UK leaving the EU provided a timely example of the type of disruption that can be caused by changes in legislative requirements. For example, lack of control over the supply chain or organizations makes it difficult to manage supply chain risks. The use of AI in supply chain risk management has several advantages. Firstly, AI can help identify potential risks proactively, allowing companies to take steps to mitigate these risks before they materialize. Second, AI can be used to predict supply chain disruptions and make decisions to minimize the impact of these disruptions. Finally, AI can help companies make faster and more accurate supply chain risk management decisions [2]. By combining AI with human expertise, companies can significantly improve their efficiency in supply chain risk management. There are many studies in the literature that use artificial intelligence techniques in supply chain risk management. The following are some of these studies [1]:

-Jing et al.(2009): In their study, developed a neural network based early warning model was developed on food quality safety.

-Wu et al (2013): developed a multi-objective stochastic fuzzy programming model for supply chain outsourcing risk management. In their study, they considered quantitative risk factors (price, quality, logistics, etc.), each of which is a risk factor. which is expressed by stochastic data with a probability distribution, and qualitative supplier selection risk factors (economic environmental factors, supplier evaluations, etc.) with a fuzzy structure .

-Yu and Goh (2014): developed a multi-objective integer fuzzy programming model for supplier selection with three objectives: maximise supply chain visibility, minimise risk and minimise cost. They examined the effect of supply chain visibility and risk on supply chain performance. According to their results, decision makers should focus on risk reduction before improving supply chain visibility.

-Ye et al (2015): Risk identification is also studied by Ye et al, using Big Data analysis, however focusing on financial risks. Public data on the economic performance of Chinese companies is collected and used to train multi-class support vector machine classifiers. These models are able to determine whether a firm is subject to supply, demand, product or external disruptions.

-Fan et al. (2015): in their recent study, generic Big Data-based supply chain risk management frameworks are proposed by Fan et al, based on monitoring data inside and outside the supply chain.

-Papadopoulos et al (2017): use Big Data to determine how best to ensure supply chain resilience in the event of a disaster.

-Ojha et al (2018): perform risk propagation analysis using Bayes networks, automatically learning the interconnections between several risk factors for different supply chain stakeholders and using this knowledge to determine the probability of occurrence and cost of risks.

-Baryannis et al (2019): proposed a framework for estimating supply chain risks with the machine learning

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technique. The survey method is a widely used technique for risk analysis in studies.

-Yang(2019): also proposed an ontology of logistics financial risk and fit the variability of risk using a model with machine learning technique.

-Fu and Chien(2019): present a data-driven analysis framework that incorporates machine learning technologies and temporal aggregation mechanisms to predict intermittent electronic component requirements and, thus, reduce supply risks. The empirical study was conducted in an electronic components distribution company.

-Constante et al (2020): use machine learning techniques to predict fraud in an intelligent supply chain. They assess and classify a transaction as normal or fraudulent in order to reduce product quality risks.

-Park (2021): In his study, Park analysed the data generated in the supply chain using a machine learning algorithm and attempted to manage the flexibility of the supply chain to ensure the sustainability of the supply chain model consisting of manufacturers, distributors and wholesalers.

-Femi et al (2021): In their study, Femi et al. argue that developing algorithms and analytical tools to predict where potential risks lie in supply networks and operations using artificial intelligence techniques reduces financial risks.

In general, the use of AI has several benefits for supply chain risk management, including [2] [1]:

-Improved demand forecasting: AI can improve the accuracy of forecasts by analyzing large volumes of historical data and identifying hidden trends and patterns. This helps to anticipate future needs and optimize stock planning.

-Early detection of risks: By monitoring world events, weather conditions, economic fluctuations and other factors, AI can help identify potential risks before they become problematic. Companies can then take preventive measures to minimize these risks.

-Transport optimization: AI can analyze data on traffic, road conditions and schedules, helping to optimize delivery routes and reduce transport costs.

-Proactive supplier management: By assessing supplier performance in real time, AI can help identify high-risk suppliers and take steps to mitigate that risk, such as increasing monitoring or seeking alternative sources of supply.

-Real-time tracking: The use of smart sensors and other IoT technologies in combination with AI enables real-time tracking of assets throughout the supply chain. This helps to ensure better visibility and proactive management of risks, such as delivery delays, shortages or quality issues.

-Rapid adaptation to market changes: With its ability to analyze and learn continuously, AI can help companies adapt quickly to market changes and make informed decisions to minimize the impact of unforeseen events.

Finally, integrating AI into supply chain risk management allows for greater visibility, faster and more accurate decision making, and reduced costs and potential disruption. Each student is responsible for obtaining copyright permissions, if necessary, to include published material in the thesis. This applies typically to third-party material published by someone else.

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6. Conclusions

Today, companies in many sectors are evolving thanks to new information and communication technologies. This approach goes beyond the dematerialization of work processes to adapt new management methods and tools, so that companies can optimize their operations and gain in performance and efficiency. Indeed, emerging technologies such as artificial intelligence offer an exciting and promising opportunity for supply chain risk management. By understanding the various learning techniques, companies can better utilize these technologies and identify, mitigate risks, improve visibility, efficiency and resilience of their supply chain to optimize their business and production processes.

Furthermore, Although AI has many benefits in supply chain risk management, there are also challenges and limitations to its use. One of the main challenges is data quality. AI can only make accurate decisions if the data used is accurate and complete. Another challenge is the need to combine AI with human expertise for effective decision making, indeed, it is important to note that the use of AI in supply chain risk management should not entirely replace existing risk management processes. The data collected by AI must be complemented by human assessments and traditional risk management processes to ensure effective and responsible supply chain risk management. Finally, AI can be expensive to implement and maintain.

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