The Use of Machine Learning in Supply Chain Management, A Systematic Review

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Abstract

This paper aims to analyze and review the most recent scientific literature regarding the implementation of Machine Learning (ML) in Supply Chain Management (SCM). Moreover, an examination was conducted to find out what areas and industries were addressed in the use cases, and how ML may impact SCM. A Systematic Literature Review (SLR) was conducted for this purpose. It was found that the applied examples mainly used ML's prediction capabilities, and some industries such as health care and logistics were the main focus areas. Then, discussions were developed based on the results of the systematic literature analysis, which can be used as motivation for future research.

Keywords
Machine Learning, Supply Chain Management, Process Management, Industrial Engineering, Disruptive Technologies, Supply Chain, Systematic Review.

Introduction
Supply Chain (SC) and SCM
Russell & Taylor (2019) defines SC as "the facilities, functions, and activities involved in producing and delivering a product or service from suppliers (and their suppliers) to customers (and their customers)." SCM has become a key strategy for managing quality, satisfying customers, and maintaining competitiveness in the face of globalization and the evolution of information technology. An SC is an overview of all activities involved in the flow and transformation of goods and services from raw materials to the end user (customer), including the information flows that accompany it. All the assets, information, and processes that provide supply are referred to as the supply chain. In addition to raw material suppliers, it includes suppliers of parts and components, suppliers of subassemblies, producers and distributors of products and services, and finally customers. Suppliers, such as raw material suppliers, are the first link in the chain. In the supply chain, upstream players are known as suppliers, whereas downstream players are distributors, warehouses, and eventual end-users. Flows of goods and services (i.e., demand) represent the flow of goods and services as the SC moves downstream. (Figure 1.1.) (Russell & Taylor 2019, p. 416). A SC is primarily focused on increasing a customer's willingness to pay for the product or service. Considering this challenge, efficiency improvements to the SC process are inevitable (Sarkar & Kim 2021a).

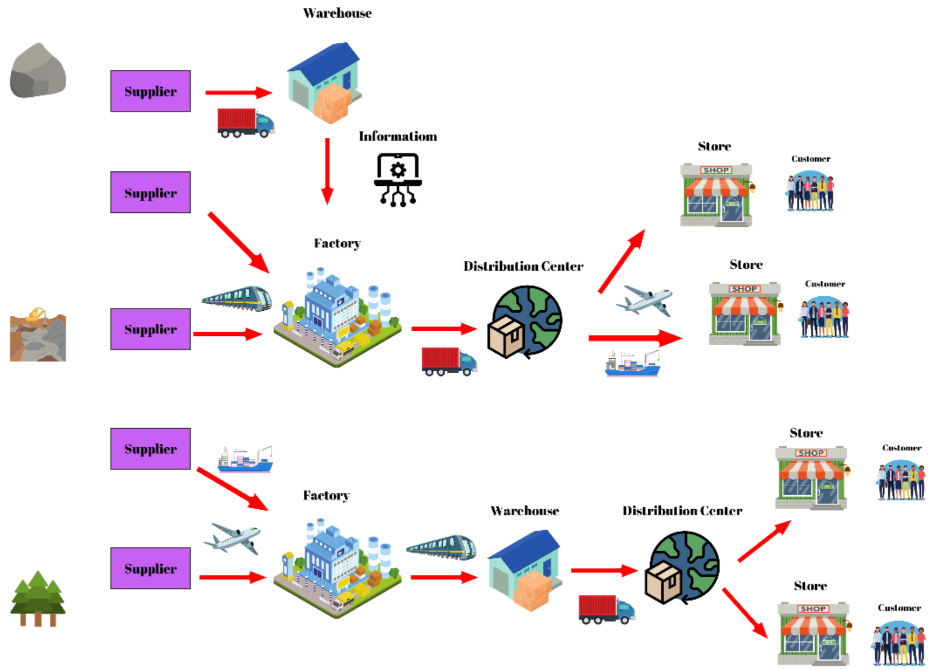

Figure 1.1. An illustration of an SC

The term SCM refers both to logistics operations and to the acquisition and procurement of products. Channel partners can be suppliers, mediators, external professional establishments, and customers. The theory of SCM incorporates partnership as well. To implement one-to-one logistics processes for products and data streams, it is important to do so. Various data sources within and outside an organization as well as within firms are considered here. Fig 2.1. Shows an overall illustration of SCM (Singh et al. 2020a). An SCM system integrates and manages the flow of goods and services through an organization's SC to reduce costs and make it responsive to customers' needs. Each segment of the SC used to be managed separately (as a stand-alone entity) aiming to accomplish its own goals. The 'supply chain' must be coordinated and combined to compete in today's global marketplace. In order to be effective, supply chains must be tightly coordinated, cooperative, and communicated among the members. For suppliers and customers to work together, information must be shared. An SCM system today relies on a rapid flow of information among customers, suppliers, distributors, and producers. The goals of suppliers and customers must also be the same. A supplier's products and services must meet customers' quality and timeliness expectations. It is also essential that suppliers and customers collaborate in the design of the SC to achieve their shared goals and facilitate communication (Russell & Taylor 2019, p.421).

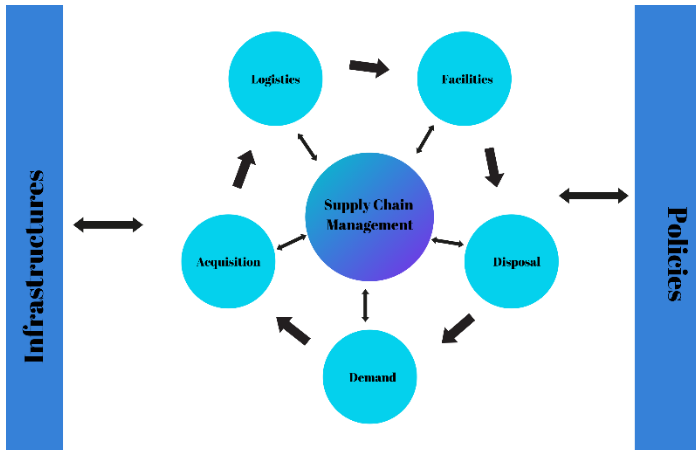

Figure 2.1. Overall view of SCM

A sustainable SC refers to an organization's efforts to meet its social, environmental, and economic goals. Organizations and communities also benefit from these goals. It is beneficial to society to decrease the number of shipments and use larger shipments to decrease the number of traffic jams. As a result of fewer shipments, CO2 emissions can be reduced (Alnahhal et al. 2021). In today's global marketplace, suppliers, manufacturers, logistics, clients, customers, and end-users are spread throughout multiple countries and time zones, requiring careful coordination, cooperation, and management. Several of the key challenges and issues associated with SCM have come to notice, including quality customer service, costing, risk management, qualified personnel, unforeseen delays, and just-in-time manufacturing. Therefore, identifying consumer demand in advance and planning into supply & manufacturing cycles, managing inventory in a way that balances availability and cost, and prototyping and developing new products at a speed that is fast is an essential parts of sustainable SC (Singh et al. 2020b). Moreover, because of the surging demand for products and services and the use of e-commerce to place orders and receive goods at customers' doorsteps, the SCM needs to be enhanced to meet the increasing demands of consumers. A significant part of the business process involves procuring materials from the suppliers, processing them, and returning them to the distributors so they can be distributed to customers.

As a result, SCM must be improved to maximize an organization's potential (Wisetsri et al. 2022a). Traditionally, retailers provide inaccurate inventory information to manufacturers due to their unreliability. Therefore, SC players suffer from information asymmetry. Future production is not precisely forecasted by the manufacturer. Stockholders are likely to experience either overstock or understock situations if demand is uncertain. This situation requires the involvement of SC players. Players who are unreliable or who do not exchange information properly can cause demand uncertainty It is crucial for the modern SC model to forecast demand. Uncertainty arises when retailers fail to provide accurate demand information to manufacturers. Due to this, manufacturers cannot predict exact market demand. When this happens, the SCM system's total profit decreases, as it has an increased holding cost or shortage cost (Sarkar & Kim 2021b). SCM faces many challenges today, so to enhance the business' competitiveness, the management must understand its various complexities and implement tools that will reduce the cost and time involved in moving goods and services in order to enhance the business' competitiveness (Wisetsri et al. 2022b).

Disruptive Technologies and SCM

As technology advances, disruptive innovations are changing how businesses operate. Clay Christensen, a professor, entrepreneur, and author, coined the term disruptive innovation in 1995. McKinsey Global Institute (MGI) has identified twelve technology areas with the greatest economic impact and disruption potential by 2025. It includes mobile internet, artificial intelligence and ML, the Internet of Things (IoT), cloud computing, advanced robotics, autonomous and near-autonomous vehicles, next-generation genomics, energy storage, 3D printing, advanced materials, and advanced oil and gas exploration. Market growth, employment, and inequality could be affected by these disruptive technologies. Using other technologies, such as Radio-frequency Identification (RFID), also provides an advantage for accessing real-time information about the products in the inventory. Compared with traditional SCM systems, implementing these features and technologies takes it to a higher level SCM of industries is impacted by disruptive technologies to improve or maximize total generated value (Yani et al. 2019a; Sarkar & Kim 2021c).

ML

ML uses algorithms and statistical models to analyze and interpret data in order to learn and adapt. Recently, it has evolved rapidly to optimize the process and efficiency for SCM. ML can be applied in a variety of stages of SCM since it can automatically develop from the previous data set. For example, big data can be used in ML to make a better forecast model due to the wide availability of big data for the company. Moreover, by increasing the capacity of a flexible business process, it can reduce overall costs. Management can use technology education (ML) tools to track purchasing orders, simplify shipping, and comply with regulations. Consumers are now able to purchase goods and services online, which has increased sales and profits for the company (Wisetsri et al. 2022c; Yani et al. 2019b). By leveraging ML-based tools, firms have been able to better engage their customers, and produce more accurate results as they expand to new markets or channels. Because ML can handle complex interdependencies between so many causal factors with non-linear relationship patterns, it can improve SC performance because it can handle complex interdependencies (Feizabadi 2020). Therefore, the research community has urged an in-depth understanding of ML and how to tailor it to enhance efficiencies and minimize disruptions in supply chains (Akhtar et al. 2022).

Objectives

The current and future role of ML in SCM, considering the development stage of this topic, is explored by answering the following research questions:
Q1: How is ML used in SCM??
Q2: How could ML contribute to the SCM's success?
Q3: In which industries has research been conducted more often than in others?
SLR provides a detailed examination of relevant and pertinent discourse in the area of focus, allowing for a structured and robust approach to answering the questions above. Additionally, the approach allows exploration of past, current, and future opportunities for ML in SCM. Only twelve literature reviews pertinent to ML in SCM have been published to date.
Presented in Section 2 is the methodology for designing the SLR protocol, collecting data, and classifying the papers. In Section 3, The results and relevant analysis to answer the questions, are presented. A discussion of future research potential is presented in Section 4. As a final step, conclusions are drawn to identify any gaps for future research.

Literature Review

Literature reviews are essential to any future research that will result in synthesized knowledge that researchers and managers can use to establish strategic practices in any field. SLRs are described as reproducible methods for studying and analyzing existing disciplines (Tranfield et al., 2003). This paper organizes the literature on ML in SCM in a systematic way.
This research was conducted using Google Scholar (https://scholar.google.com/) and MavScholar (https://library.mnsu.edu/) as the main sources.

Methodology

An approach of three steps has been followed in this paper:
Step 1: The first step was to search for articles with titles including "Machine Learning Supply Chain Management". Results included 56 articles in the 1995 to 2022 range. Table 1.2. shows the number of articles published each year between 2016 and 2022. Also, a distribution of articles from 2016 to 2022 can be viewed in Figure 1.2.

Table 1.3. Number of published articles per year

Year	Number of Published Articles
2016	1
2017	0

2018	0
2019	7
2020	10
2021	16
2022	22

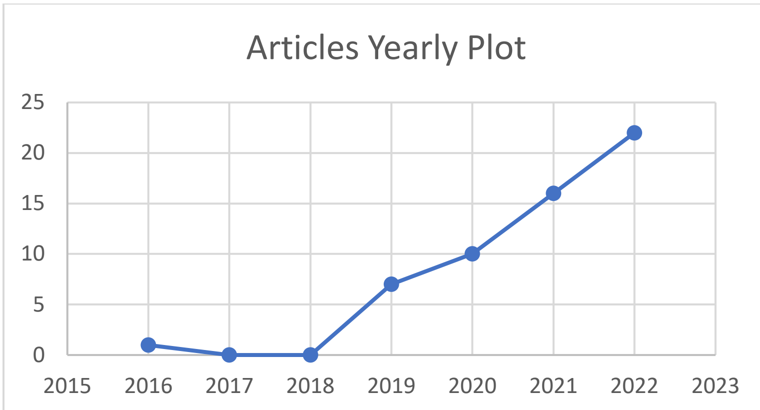

Figure 1.3. Yearly distribution of articles

SLRs also review relevant journals and identify the ones that are most focused on the research topic. Table 2.2. shows the journals with the number of published articles about the research topic.

Table 2.3. List of journals

Title of Journal	Volume	Articles	Pages
Benchmarking: An International Journal		2	
International Journal of Business Insights & Transformation	13	1	
International Journal of Innovative Research in Science, Engineering and Technology	42	1	
International Journal of Intelligent Engineering and Systems		1	464-478
International Journal of Machine Learning and Cybernetics	11	1	1463-1482
International Journal of Supply and Operations Management	9	1	398-416
Journal of Innovation & Knowledge	7	1	100276
Journal of Optoelectronics Laser	41	1	985-991
Operations and Supply Chain Management: An International Journal	14	1	13-Jan

Step 2: Review articles were excluded from the search criteria due to the fact that they are based on original research articles, and therefore they are seen as secondary sources. Then the search period was narrowed down from 2016 to 2022. There were 40 articles left as a result.

Step 3: Then, a further narrowing of the search was achieved by filtering out articles that were not peer-reviewed.

Using peer-reviewed articles for research is the appropriate approach. In peer-reviewed articles, the process of peer review has been applied. The peer review process involves the evaluation of an article by an impartial panel of two or more experts in the field. It is the responsibility of peer reviewers to ensure an article does not contain errors or biases in experimental procedures or analyses, that its findings make a substantial contribution to its field, and that it provides new information within the field in question (Heimerman, n.d.). A detailed description of the development and implementation of the Methodology steps can be found in Figure 2.2. In addition, Table 2.3. includes a list of the 13 articles that remained after all the Methodology steps had been applied.

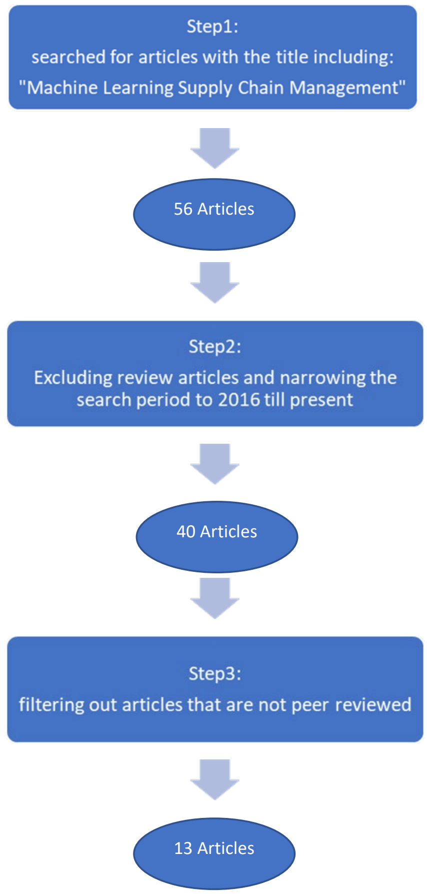

Figure 3.3. Structured literature review steps

Table 3.3. List of final articles

No	Authors	Title	Publication	Year
1	Abbas, Khizar; Afaq, Muhammad; Ahmed Khan, Talha; Song, Wang-Cheol;	A blockchain and machine learning-based drug supply chain management and recommendation system for smart pharmaceutical industry	Electronics	2020
2	Hirata, Enna; Lambrou, Maria; Watanabe, Daisuke;	Blockchain technology in supply chain management: insights from machine learning algorithms	Maritime Business Review	2020
3	Abbasi, Babak; Babaei, Toktam; Hosseinifard, Zahra; Smith-Miles, Kate; Dehghani, Maryam;	Predicting solutions of large-scale optimization problems via machine learning: A case study in blood supply chain management	Computers & Operations Research	2020
4	Wong, Simon; Yeung, John-Kun-Woon; Lau, Yui-Yip; So, Joseph;	Technical sustainability of cloud-based blockchain integrated with machine learning for supply chain management	Sustainability	2021

5	Sardar, Suman Kalyan; Sarkar, Biswajit; Kim, Byunghoon;	Integrating machine learning, radio frequency identification, and consignment policy for reducing unreliability in smart supply chain management	Processes	2021
6	Han, Chaoliang; Zhang, Qi;	Optimization of supply chain efficiency management based on machine learning and neural network	Neural Computing and Applications	2021
7	Yuan, Guanghui; Wu, Shan; Wang, Bin;	Supply chain management model based on machine learning	Neural Computing and Applications	2022
8	Wisetsri, Worakamol; Donthu, Somasekhar; Mehbodniya, Abolfazl; Vyas, Sonali; Quiñonez-Choquecota, Jose; Neware, Rahul;	An Investigation on the Impact of Digital Revolution and Machine Learning in Supply Chain Management	Materials Today: Proceedings	2022
9	Li, Lan;	Predicting the Investment Risk in Supply Chain Management Using BPNN and Machine Learning	Wireless Communications and Mobile Computing	2022
10	Li, Jing; Zhang, Ruifeng; Jin, Yanfeng; Zhang, Haiyan;	Optimal Path of Internet of Things Service in Supply Chain Management Based on Machine Learning Algorithms	Computational Intelligence and Neuroscience	2022
11	Wei, Yuqian;	A Machine Learning Algorithm for SCRAssessment Based on Supply Chain Management	International Transactions on Electrical Energy Systems	2022
12	Reddy, A Rajasekhar; Chandana, A;	Classification of Cyber Threat Using Machine Learning Models in Supply Chain Management		2022
13	Chaubey, Pavan Kumar; Yadav, Ajay Singh; Arora, Tarun Kumar; Ahlawat, Navin; Purohit, Priyambada; Swami, Anupam; Agarwal, Priyanka;	Machine Learning and Deep Learning Based Optimization Algorithms for Covid-19 Pharmaceutical Industry Supply Chain Management		2022

Results and Discussion

In this literature review, results are categorized according to the research questions they mostly address.

RQ1, RQ2

To answer the research questions, a review of scientific articles was conducted. It is often the aim of the research to optimize the SCM using ML approaches.

Since ML enables companies to predict dependent variables (outputs) in terms of independent variables (inputs), In some studies, this ability is used to predict SC variables and improve SCM processes. Currently, SC efficiency management is unable to control the risk caused by inefficient SCM. Consequently, some of the research works are focused on solving investment risks in the SCM process of companies. The risk prediction analysis of SC samples is therefore performed using ML algorithms. Moreover, this study evaluates the risk indicator system based on the current status of SCM (Han & Zhang 2020a; Abbasi et al. 2020a; Yani et al. 2019c). Forecasting SC risks, as well as demand and sales estimations, are critical factors in enhancing SCM and ensuring the sustainability of the system. It would be possible to devise solutions to their many problems if SCs were classified since they face a wide range of risks.

Some of the research papers focus on the assessment of supplier credit risk (SCR) to identify supplier system problems before they negatively affect the business. The goal is to prepare the company to handle new issues and threats as a result of its well-developed distribution network forecasting system (Wei 2022a). Another studied risk is threat threats (unknown attacks). ML algorithms are used to learn the behavior of a dataset and predict cyber threats (unknown attacks) on CS platforms (Reddy & Chandana 2022). Some researchers have attempted to improve on-demand forecasting using ML algorithms in modern SCM systems. Forecasting demand can also improve the sustainability of SCM models and increase environmental effects (Sardar et al. 2021). Based on the results, the ML models were able to effectively predict various risks during the SCM process (Abbasi et al. 2020b; Han & Zhang, 2020; Wei 2022b). However, evaluating the prediction of mixed risks can reveal some gaps between predicted and actual results (Li 2022).

To improve SCM systems efficiency, many researchers are combining ML with other disruptive technologies. Blockchain technology has attracted a lot of attention in recent years. It was created by Satoshi Nakamoto in 2008 and is based on his consensus protocol. It is primarily designed to store the historical log of transactions for the well-known cryptocurrency known as Bitcoin (Abbas et al. 2020c). Research on the benefits of SC networks under IoT technology is another interdisciplinary topic as SC networks are becoming larger and larger. Based on the complexity and evolution of SC networks, ML algorithms can be used to analyze IoT modes of service. RFID technology, EDI technology, and enterprise resource planning ERP are among these modes of service (Yuan et al. 2022; Li et al. 2022a).

RQ3
During the study period, the most notable occurrence was Pandemic Covid 19. While the quarantine measures and virus have not directly affected factories in a particular area, it is still possible that the raw material is captured by the area where the virus was discovered. Due to the complex SC across the world, the crisis, which has taken over half of the world, is likely to affect the rest of the region as well. The effects of this crisis have led many researchers in recent years to focus on the pharmaceutical, medical, and other service industries (Chaubey et al. 2022; Abbasi et al. 2020d). Several other industries were also studied, including shipping (Wong et al., 2021), manufacturing, e-commerce, and offline sales (Li et al. 2022b).

Proposed Improvements
Every country on every continent is affected by climate change. Lives are being affected and national economies are disrupted. Companies are implementing new approaches to reduce the rise of global temperatures this century below pre-industrial levels in response to climate change. The SCM process is also moving toward sustainability as a critical part of the industrial process. ML and digital transformation can greatly enhance SC sustainability. Yet, only a few research papers have explored ML's role in green SC management. The potential of this topic can be explored in future studies.

The predictive power of ML models has been applied in many studies to increase the efficiency of supply chains and manage possible risks. In most cases, however, only simple risks are accurately predicted with high accuracy. Finding the most accurate ML models to predict more complicated risks with more variables could also be a potential topic for future studies.

Conclusion
ML in SCM research for the past 6 years is summarized in this paper. Furthermore, this systematic review highlights current trends, opportunities, challenges, and future ideas for ML in SCM. There have been 13 articles published between 2016 and 2022 that have been reviewed comprehensively in the paper. Throughout the last few years, there have been numerous challenges in applying and adapting technologies to SCM, the need for a balanced approach to their use, and ultimately, their potential to drive sustainability. Studies can also be conducted in the future to address more complex risks that SCM systems deal with.

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