A Survey on Machine Learning Techniques for Supply Chain Management

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Abstract

Machine learning arose from the increasing ability of machines to handle large amounts of data over the last two decades, and some machines could also identify hidden patterns and complicated associations that humans couldn't, allowing them to make rational and precise decisions, especially for disruptive and discontinuous data. In several areas of decision-making, machines could produce more reliable outcomes than humans, and have already begun to replace them. Machine learning, which is widely recognized as a breakthrough technology, has recently made significant progress in improving supply chain management processes and efficiency. From planning to delivery, machine learning may be applied at different stages of the supply chain management process. Machine learning types are supervised, unsupervised, reinforcement. Each type has many tools which are discussed below in details .This paper presents a detailed survey on machine learning techniques for supply chain management including supply chain and supply chain management interpretation, machine learning definition, its types, and some algorithms belongs to it.

Keywords: Machine learning; Supply chain management; Supervised learning; Unsupervised learning; Reinforcement learning

1. Introduction

These days, an increase in the volume of data leads to growth in the field of supply chain management (SCM). Companies must consider the marketplace's main forces and how to adapt to opportunities quickly enough in order to succeed. Sergio Caballero, a research scientist at MIT's Center for Transportation and Logistics (CTL), estimates that half of the 80 companies working on projects with CTL do not use artificial intelligence (AI) at all, while 25% have done AI pilots and 25% are now using AI. ML is one of the AI methods that has grown in popularity in the field of supply chain management.[21]

ML arose from the increasing ability of machines to handle large amounts of data over the last two decades, and Some machines could also identify hidden patterns and complicated associations that humans couldn't, allowing them to make rational and precise decisions, especially for disruptive and discontinuous data. In several areas of decision-making, machines could produce more reliable outcomes than humans, and have already begun to replace

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them, such as cancer detection and prognosis, drug discovery, and genetics and genomics .For Supply Chain Management, Machine Learning is a true asset (SCM).[1]

We live in the data era, in which everything around us is linked to a data source and everything we do is captured digitally. The Internet of Things (IoT) data, safety data, smart city data, company data, mobile data, social networking data, health data, COVID-19 data, and several other types of data are available throughout today's electronic environment. Structured, semi-structured, and unstructured data are all possibilities.[22] There are several benefits of machine learning. The Decision Tree-based approach is highly interpretable and capable of processing samples with missing attributes and unrelated features; logistic regression is simple to apply and does not require a lot of computational or storage resources; SVM can solve nonlinear problems with a small amount of data. As a result, ML applications are mostly used in the construction industry to deal with standardized data, such as safety monitoring early warning indicators. Deep learning is a better solution for processing unstructured data including images and videos.[23]
ML uses a collection of algorithms to evaluate and interpret data, learn from it, and make the best decisions possible based on that learning.[24] In general, the efficacy and efficiency of ML solutions are determined by the design and characteristics of the data as well as the learning algorithms' results. Classification analysis, regression, data clustering, feature engineering and dimensionality reduction, association rule learning, and reinforcement learning techniques are all examples of ML algorithms that can be used to construct data-driven systems. Furthermore, deep learning is derived from an artificial neural network that can be used to intelligently interpret data and is part of a larger family of machine learning approaches. As a result, choosing an appropriate learning algorithm for a specific domain's target application is difficult.[22]
In the supply chain, ML use cases assist retailers, producers, and distributors in driving the transformational changes that are so desperately required today in the face of the pandemic. ML adds unparalleled value to supply chain operations, ranging from cost savings and risk reduction to improved supply chain forecasting, faster deliveries, and better customer service, to name a few**.** The most important benefits of machine learning, according to McKinsey, would be in providing supply chain practitioners with more significant insights into how supply chain efficiency can be improved, as well as predicting anomalies in logistics costs and performance before they occur. ML is also revealing where automation will have the most important scale benefits

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2. Supply Chain Management(SCM)

Supply Chains (SC) are a web of facilities that connect a variety of entities.These parties should work together in order to reduce the supply chain's total cost. This necessitates cooperation, integration, and knowledge sharing among these entities**.** Consumers, as well as manufacturers, dealers, transporters, and vendors, are also part of the supply chain. As a result, understanding true consumers consumption and desires is important, as they are the primary node of every supply chain, pushing multiple companies to produce and deliver goods.[4] Customer, shipment, distribution, order, selling, shop, and product data are all types of data that can be found in supply chains.[17]Traditionally, the supply chain has been described as a system that "includes all parties involved, directly or indirectly, in fulfilling a customer request." Managers have often handled supply chains deterministically, just as an engineer would approach a system they were constructing or regulating. SCM has been dubbed "the new organization's value creation engine".[26]

SC is a collection of three or more entities – consumers, retailers, warehouses, distributors, producers, and suppliers, for example – through which knowledge, funds, and materials flow upstream and downstream with the ultimate goal of meeting the customer's needs. The transformation of raw materials into semi-finished/finished goods, logistic operations, customer service, and distribution are only a few of the activities involved in each supply chain entity.[5]

The following factors have made supply chain data analysis a difficult task:

- **i.** An increase in the number of SC entities,
- **ii.** An increase in the variety of SC configurations based on product homogeneity or heterogeneity, and
- **iii.** Interdependencies between these entities
- **iv.** Uncertainties in the dynamical actions of these elements,
- **v.** A lack of knowledge in relation to SC entities,
- **vi.** Networked manufacturing/production entities as a result of their increased collaboration and cooperation to achieve a high degree of customization and adaption to varying customer needs, and finally
- **vii.** The implementation of supply chain digitization practices (including the use of Blockchain technologies) to monitor activities across supply chains is growing.[17]

Supply chain management (SCM) is described by the Council of Supply Chain Management Professionals (CSCMP) as a set of main activities that must be performed in an effective and timely manner in order to make desired goods or services available to customers. In most cases, several companies are active in SC-related operations.Suppliers, retailers, logistic- or other service providers, to name a few, all play important roles. The collaboration between those businesses must be coordinated and controlled. This is where SCM comes into play, with the ultimate aim of meeting consumer demand in a timely manner by organizing efficient product flows from point of manufacture to point of use.[2]

The wide range of activities needed to prepare, control, and execute a product's flow from materials to production to distribution in the most cost-effective manner is known as supply chain management (SCM). SCM refers to the coordinated planning and execution of processes that maximize the flow of goods, information, and capital in functions such as demand planning, procurement, manufacturing, inventory management, and logistics, as well as storage and transportation. SCM is concerned with the movement of products, services, and information from points of origin to consumers through a network of interconnected entities and activities[17] as shown in figure 1.

Figure 1: Supply Chain Management

2.1. Processes of SCM

SCM is a process used by businesses to ensure that their supply chain is reliable and cost-effective. A supply chain is the set of steps that a business takes to turn raw materials into a finished product. Below are the five fundamental components of supply chain management. SCM's main goal is to keep track of and link the manufacturing, distribution, and shipping of goods and services.Companies with a strong and tight grip on internal inventories, manufacturing, distribution, internal productions, and sales will accomplish this.

- **i.** The Planning Process: This phase seeks to integrate SC-strategies and involves network architecture as well as market details such as demand forecasts and special customer requirements.
- **ii.** Procurement is the process of locating and purchasing goods or raw materials. During this process, supplier management plays a critical role.
- **iii.** The production process is characterized as the act of producing products with a monetary value for the consumer.
- **iv.** Distribution: The logistical flow of production through the entire SC is referred to as distribution. Third-party transportation firms are critical during this process to ensure that the product is delivered quickly

and safely. Customers care a lot about the so-called "last-mile" of a commodity, and it's always a complicated part of SCM.

v. The Customer Interface: Which involves all forms of customer experiences with the ultimate goal of satisfying him at any point of the customer life cycle. The selection of the appropriate communication medium can have a significant impact on consumer perception[2] as shown in figure 2.

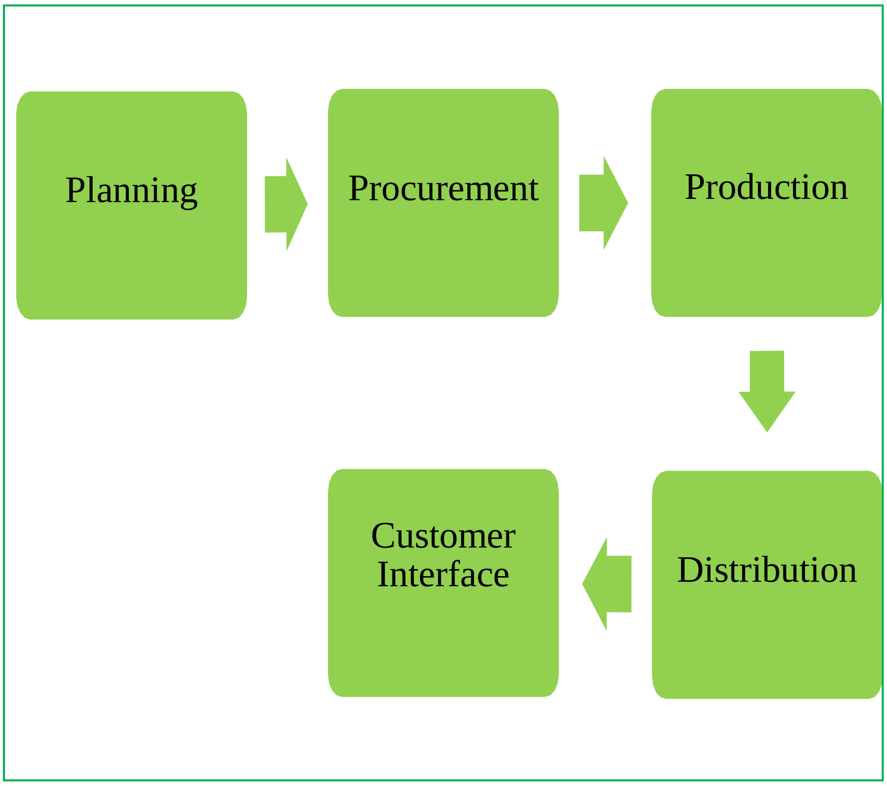

Figure 2: Supply Chain Management Processes

3. Machine learning

ML is a computer science subfield as well as an application that allows IT systems to recognize patterns in existing data and create solutions using algorithms. As a result, it is a generalized term for the mechanism in which an algorithm learns from examples and is able to generalize this knowledge into rules that will develop the method in each cycle. In addition, a simple algorithm may only obey a systematic, logical rule or protocol that has been predefined by humans. Finally, machine learning is an algorithm that allows computer systems to gain and extend information on their own through a learning process in order to solve a problem.[2]
ML is a sub-discipline of artificial intelligence that reflects a different approach to programming. Example data takes the place of a program's rigid calculation law. Learning methods or algorithms extract statistical regularities from given example data and represent them as models. The models will respond to new, unknown data by categorizing it or making predictions.[3] ML is a sub-discipline of artificial intelligence that reflects a different approach to programming. Example data takes the place of a program's rigid calculation law. Learning methods or algorithms extract statistical regularities from given example data and represent them as models. The models will respond to new, unknown data by categorising it or making predictions. ML is a form of artificial intelligence that is based on data and can adapt to new system requirements. In order to automate the analytical model building process, ML learns the latent patterns of historical data in order to model the actions of a system and react accordingly.[19]
The goal of ML is to give computer programs the ability to learn from their mistakes and enhance their results.[4] ML was coined in the late 1950s. “A computer program that can learn to generate a behavior that is not directly programmed by the creator of the program,” writes Joshi (2020, p. 4). ML is a mix of math, economics, and computer science (Li et al. 2018). ML can solve problems using a variety of algorithms, or it can find patterns in data to aid in prediction. Since ML is intelligent and can read, it is considered part of AI. models that are descriptive or predictive can be created using ML.[21]
ML is beneficial to SCM because it helps to minimize uncertainty, resulting in higher revenues and lower losses. In general, ML is similar to how animals and humans learn from their experiences. ML algorithms operate by

learning directly from data rather than relying on a predetermined model or equation. As the amount of data available for learning grows, the algorithm's efficiency improves.These ML algorithms aid in the generation of valuable insights from data by identifying trends in the data, allowing for better predictions and decisions. These algorithms are commonly used to make important decisions in areas such as energy load forecasting, stock trading, and medical diagnosis.[5]

AI includes ML as a subclass. It's algorithm-based self-learning, which means the machine learns from its own mistakes. The type of data that is fed into the machine, for example, learns the pattern and responds to it at the output. In this situation, without human intervention, the machine gets smarter, smarter, and smartest over time. It employs a mathematical learning algorithm that learns and improves on its own, without the need for human intervention. A deep learning system, on the other hand, learns from its experience but also from a large database or a large amount of data given as input. Deep neural networks have several layers between their input and output, while shallow neural networks only have two layers between their input and output. Artificial intelligence (AI) is a broad field that deals with creating intelligent machines. Machine learning is commonly used in artificial intelligence projects because intelligent behavior necessitates a large amount of data or knowledge.[24] There are many different forms of ML. The supervised, unsupervised, and reinforcement learning methods are well-known.[3]

3.1. Supervised Learning: is a technique in which a pattern is identified based on previous results, These patterns are then used to aid in future predictions. Data from the past is input and output in pairs, and it forecasts future meaning. The concept is to forecast the future by learning from the past pattern given by a human operator. These methods are commonly used in automated manufacturing, such as automobiles, vehicles, chatbots, and facial recognition. Different methods, including the Naive Bayes Classifier Algorithm, Support Vector Machine Algorithm, regression, Logistic Regression, Decision Trees, and Random Forests are used in supervised learning.[4]

Models for prediction are developed in Supervised Learning using two techniques, which are as follows:

- *Classification techniques* predicts categorical data like whether a cancer is malignant or benign, and whether an email is spam or real, among other things. This technique is used to create models that work with discrete responses and categorize data. Credit scoring, speech recognition, medical imaging, and other applications are examples.
- *Regression techniques* Work with data that is updated on a regular basis, such as house price increases in a specific region, temperature fluctuations, or changes in power demand. Algorithmic trading, energy load forecasting, and other applications of this technique are examples.[5]

3.2. Reinforcement Learning: focuses on structured learning processes in which a machine learning algorithm is given a set of behaviors, parameters, and end values to work with. The ML algorithm attempts todiscover various options and possibilities after specifying the rules, monitoring and analyzing each outcome to decide which is the best. Reinforcement learning is a form of machine learning that teaches the machine through trial and error. It learns from previous mistakes and adjusts its strategy in response to the situation in order to achievethe best possible outcome.[4]

***3.3. Unsupervised Learning*: There is no human operator available to provide orders. Patterns are recognized and grouped by the learning algorithm itself. Perform the study after segmenting the data into categories.[4] Clustering is the most popular unsupervised learning strategy. It's a tool for analyzing data and categorizing it into parts based on its inherent structure. Object recognition, market research, and gene sequence analysis are examples of unsupervised learning applications[5] as shown in figure 3.

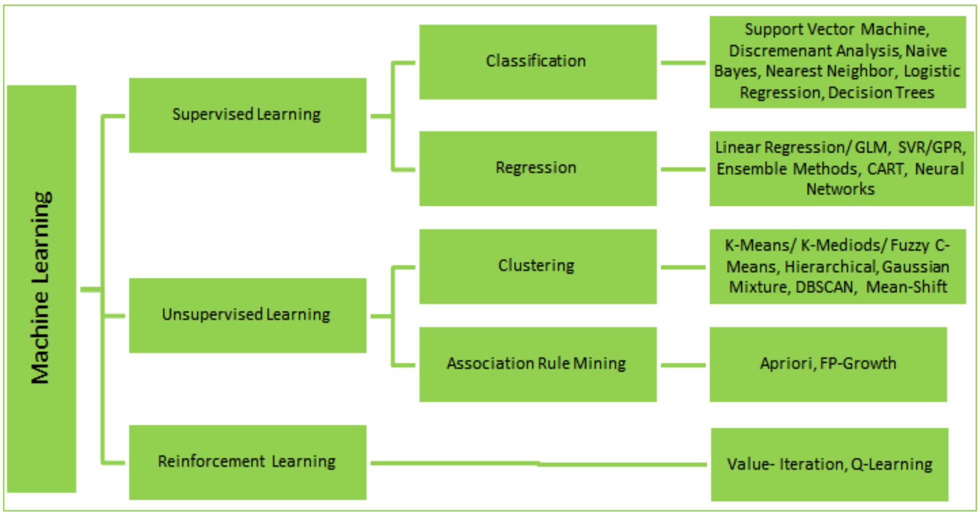

Figure 3. Machine learning Methods

Some algorithms of ML are discussed in details below:

3.4. Support Vector Machine (SVM)**:** SVMs can compensate for NNs' disadvantage because they have a clear structure and replace the experience optimum with the global optimum. SVMs have a high degree of generalization and mathematical interpretability. SVMs are also ideal for multi-dimensional problems, giving SCM opportunities for cross-selling and up-selling. SVMs, on the other hand, depend heavily on their kernels, which require prior knowledge of the data sets in question.[1]

3.5. Decision Tree (DT)**:** Different graphs are used by DTs to show potential outcomes. Each graph node contributes to one distinct function. Discriminant models and multiple regression are often used for DTs. DTs are easy to observe and have a low bias, but they are prone to over-fitting.[1]

3.6 .K-means**:** K-means clustering is an unsupervised process. This approach divides the data into k clusters, which reduces the square errors of each group. Because of its low computational complexity, K-means saves time and money, but the K must be set in advance, which necessitates advanced knowledge of the data sets. Worse, K-means is susceptible to being influenced by outliers and noise.[1]

3.7. Extreme Learning Machine (ELM): ELMs are feed forward NNs, which reduce calculation time by half as compared to traditional NNs. Its preparation is performed in milliseconds, seconds, and minutes for the most part. Furthermore, ELM tunes all network parameters iteratively, eliminating the need for manual tuning. ELM can analyze large data sets for SCM in a short amount of time. Despite the fact that ELM can produce better results with simple calculations, some researchers disagree about its methodological approaches and even its meaning.[1]

3.8. Neural Networks (NN)**:** NN first appeared in the 1980s and was first used in 1988.[1] It was designed to mimic the human brain's ability to learn new skills.[29] SCM may use NN to alert about possible rivals since it is a strong algorithm for defining complex nonlinear input/output relationships. Back propagation (BP) NN, Radial Basis Function (RBF), and convolutional neural networks are all examples of neural networks (CNN). Many of these distinctions apply to SCM. As an example, consider CNN. CNN is a key component of deep learning and is often used to examine imagery. It is used in SCM to evaluate the audio and video communication of customer salespeople, as well as to schedule lead times and customize products. However, since the computational results are obtained from repeated training in a "black box," NNs have an inherent drawback in that they are unable to articulate their reasoning method.[1]

3.9. Random Forest (RF): selects random subsets of features to make predictions using the mean values of all the individual prediction outcomes, using different DTs trained with different data sets. DT and RF are two decision methods that have the potential to be used in SCM by listing the advantages of each decision as well as the likelihood of it being fulfilled. These two decision approaches then provide an aggregate presentation for SC managers to assign resources using lead-scoring.[28]

3.10. Ensemble algorithms (ESM)*:* Researchers are also developing some integrated algorithms, such as Ensemble algorithms, to fully explore the advantages of these algorithms listed above (ESM). ESM incorporates the benefits of each basic classifier and makes more accurate predictions than either of the basic classifiers alone. People can get a credit record more quickly without enough credit evaluation in a fast changing world, so ESM can be especially useful for SCM in the credit risk assessment of stakeholders.[27]

3.11. Logistic Regression (LR): It's a variant of the well-known Linear Regression Model. As compared to the Linear Regression Model, LR can use a non-linear model to replace the linear fitting model to match both dependent and independent variable, but it still relies heavily on the fitting model selection and has low fitness. LR is used in sales forecasting of SCM because it is excellent at predicting continuous data.[1]

3.12.K-Nearest Neighbor (KNN): KNN is a clustering approach that divides data into K clusters, similar to K-means. KNN, on the other hand, is a supervised learning system that is noise-resistant, unlike K-means. KNN, on the other hand, cannot handle massive data sets, and the data sets evaluated by KNN must be normal and free of missing values. In either case, K-means and KNN can also be used in SCM to categorize customers into regular buyers and their purchase amounts. These two machine learning algorithms choose people more critically and quickly than the human brain.[1]

3.13.Naive Bayes Classifier (NBC): The Bayesian Theorem underpins NBC, which works well for small data sets. In SCM, NBC has the power to recognize a stakeholder's credit, predict whether he or she will violate contract laws, and therefore provide an alert to other stakeholders ahead of time[1] as shown in table 1.

Table 1. ML algorithms summary

Algorithm name	Algorithm Usage	Advantages	Disadvantages
Support Vector Machine (SVM)	- Regression/classification	1) It can be used for both classification and regression. 2) There will be less generalization errors. 3) It's easy to explain. 4) Nonlinear classification is possible.	1)Kernel functions and parameters are sensitive.
Decision Tree (DT)	- Regularized Maximum Likelihood Estimate , - Discriminant models - Mutliregression and classification	1) Able to evaluate an object based on its various characteristics. 2) Simple estimate, suitable for samples with missing attribute values. 3) Excellent interpretability.	1)It's easy to be over-fitting.
K-means	- Classifications - Clustering	1) Low level of complexity. 2) It's simple and fast.	1) Noise and outliers are sensitive. 2) Only used when mean values for clusters have been identified. 3) Cluster K's actual line is sensitive to the initial values.
Extreme learning machine (ELM)	- Classification - Regression	1) It's easy to use. 2) Fast learning. 3) Good generalization performance.	1)Arguments about its definition, methodology, and other aspects.
Neural Networks (NN)	-Classification - Regression	1) Strong capacity to self- study and back-propagate errors. 2) Good parallelism. 3) Excellent nonlinear fitting ability, simple learning laws, and robustness, as well as memory.	1) Initial values are sensitive. 2)Incapable of explaining the reasoning process and its foundation. 3) Unsuitable for insufficient data set.

Random forest (RF)	-Classification	1) Relative Bagging can lead to a minor generalization error if done correctly. 2) Missing and irregular values are unknown. 3) The training outcomes are extremely accurate.	1) Sensitive to different values of features 2) For large data, over-fitting is a problem.
Ensemble algorithms (ESM)	-Classification - Regression	1)Good at placing the benefits of NNs together.	1)Being based on the primary classifier.
Logistic regression (LR)	-Regression	1) Resources for storage are restricted. 2)It's easy to use. 3) Calculation is simple.	1)Insufficient fitness and precision.
K-Nearest neighbor (KNN)	-Classification - Mutliregression - Discriminant models	1) Classification and regression are simple, particularly for nonlinear classification. 2) small level of complexity. 3) Unaffected by outliers.	1) Wide unbalanced data sets are impossible to solve. 2) K must be preset.

Naive Bayes classifier (NBC)	-Generative model	1) Can be used for multi-classification. 2) Excellent for limited data sets.	1)Poor classification performance. 2)Requiring conditional independence assumption, which reduces accuracy.

4. Machine learning and Supply chain management:

According to Ni, Xiao, and Lim (2019), there are four reasons to use machine learning in SCM decision-making situations:

- ML techniques can help with visual pattern recognition in physical maintenance,
- ML can find non-linear relationships,
- ML can use unstructured data in modeling,
- ML techniques can find key factors that affect SCM efficiency, and
- ML can help with visual pattern recognition in physical maintenance.

To be successful with ML , the business must implement features that help it succeed. It is critical to recognize that AI was not created to solve all problems (Forger 2020). "Agile, sensitive, customer oriented, technologically savvy, data driven, collaborative, comfortable with experimentation, continuously questioning the status quo, adaptable to change, and ambidextrous" are ten characteristics of successful businesses (Forger 2020).[21]

ML offered financial benefits as well as numerous tangible changes to the business. The results were impressive, as many of the models improved by tens of percent. Customer satisfaction is improved with ML solutions because better service is delivered with higher quality goods and sales at the right time and place. As compared to descriptive analytics, ML has a significant impact on decision making because it can provide new knowledge. Simulation models, in particular, can have a significant effect on decision-making.[21]

4.1. Applications of Machine Learning in different fields of Supply Chain Management

ML is becoming increasingly common in various application areas in the current Fourth Industrial Revolution (4IR) era, thanks to its ability to learn from the past and make intelligent decisions[22]. The potential of ML as a means of solving complex problems and retrieving information in SCM has not been thoroughly explored in the past, based on the development patterns of ML applications in SCM and the study of commonly used ML algorithms in SCM. Six SCM activities will be implemented in this section to illustrate the direct connection between ML algorithms and SCM activities, and then how such commonly used ML algorithms were distributed in the 6 SCM activities will be outlined.[1]

4.1.1 Procurement and supply management

It is critical for any organization's procurement and supply management performance to produce products with high level of quality at low cost and deliver it to customer in time without any delay . The assessment and selection of suppliers is the primary role of ML applications in SCM. Suppliers have traditionally been considered suitable when they can tell the retailer the right quantity of the right product at the right time and in the right place. Potential suppliers, on the other hand, are rarely so obviously superior to their competitors. Thus, Many businesses will implement some kind of supplier „scoring' or appraisal process, which would necessitate information on prospective suppliers' performance history, credit history, and other personal information. This type of information is often unavailable to the general public, and data availability often leads to issues such as limited data sets, inconsistent values, and errors, etc. The ability to deal with missing values is a key benefit of certain machine learning algorithms.
Because of the complexities and uncertainty of the above situations, systematic decision-aid ML algorithms like SVMs are extensively used in the make-or-buy decision.
ML algorithms can accommodate a large amount of data from suppliers and provide an effective analytical decision[1].Some articles belongs to procurement and supply management are shown below in table 2.

Table 2. Articles belongs to procurement and supply management

Paper Title	Author/ Year	Used Algorithm	Contribution
Identification of public procurement contracts with a high risk of non-performance based on neural networks.	Ovsyannikova, Alexandra, and Jenny Domashova ,2020	ML methods , NN in particular.	Improving the accuracy of government contracts at risk of non-performance classification.[11]
Research on supply chain partner selection method based on BP neural network.	Liu, Li, and Wenxue Ran ,2020	Backpropagation NN (BP NN).	Improving the reliability of evaluation and addressing the issue of partner selection and evaluation in the supply chain.[12]
Weighting the Key Features Affecting Supplier Selection using Machine Learning Techniques	Abdulla, Ahmad & Baryannis, George & Badi, Ibrahim, 2019	machine learning classification combined with the Analytic Hierarchy Process (AHP) , DT	Based on historical data, the proposed approach uses a decision tree classifier to identify suppliers as good or bad and to decide which features are the most relevant in the supplier selection process. These findings are then used to keep only the best suppliers and the most relevant criteria, which are then fed into an AHP case, which is much simpler.[13]

4.1.2. Storage and Inventory

The costs of SC inventory management (SCIM) and storage are important. SCIM's objectives are to maximize product/service choice, improve customer service, and minimize costs. However, conventional decision rules make it difficult to accurately estimate, forecast, and obtain information on any of these targets because they are primarily depend on the sound judgment and the inventory managers expertise. As a result, warehouses are often met with unknown inventory input, necessitating the creation of a method to assist humans in overcoming this uncertainty. With warehouse data sets, machine learning algorithms can find fast input comparable patterns. The ML algorithms can recognize invisible inventory patterns that have never been exposed in order to save money.[1] Some articles related to storage and inventory are shown below in table 3.

Table 3. Articles related to storage and inventory

Paper Title	Author/ Year	Used Algorithm	Contribution
Reinforcement learning approaches for specifying ordering policies of perishable inventory systems.	Kara, Ahmet et al, 2018	Q Learning and Sarsa Algorithm	In this paper, two separate ordering policies are investigated for inventory management of perishable items under random demand and deterministic lead-time in order to reduce a retailer's overall expense.[5]
Machine learning for multi-criteria inventory classification applied to intermittent demand.	Lolli, Francesco & Balugani, Elia & Ishizaka, Alessio & Gamberini, Rita & Rimini, Bianca & Regattieri, Alberto , 2019	SVM with a Gaussian kernel and deep NN.	The inventory system chosen is good for intermittent demands, but it could also be used for non-intermittent demands, bringing a lot of mobility. The accuracy of machine learning classifiers was demonstrated in the experimental study of two

			large datasets, implying that they could be used in advanced inventory classification systems.[9]
Inventory management and cost reduction of supply chain processes using AI based time-series forecasting and ANN modeling	Praveen, Umamaheswaran, Ganjeizadeh Farnaz, and Ghasib Hatim ,2019	ANN modeling	This model enhances forecasting research and provides a more accurate estimate of future revenues. The increased overall efficiency of supply chain networks has a number of important benefits. It lowers total operating costs, such as storage and transportation costs. This improves the supply chain surplus in the eventually.[10]
Inventory Management using Machine Learning**.**	Javaregowda, Madhuri & B, praveen & Kumar, Pradyumna & J, Prateek & G, Pragathi **,** 2020	XGBoost, a machine learning algorithm which uses decision trees**.**	With the forecasting technique which was applied , as supplies are purchased based on demand, overstock and stock-outs of products are minimized.[8]

4.1.3. Production

ML algorithms can increase factory scheduling accuracy and production planning by taking into account various conditions. Manufacturers that use build-to-order and make-to-stock production workflows would benefit from ML algorithms because they will be able to manage conditions more efficiently than they have in the past. ML can be used by manufacturers to minimize the level of SC latency for components and parts used in their most heavily customized products. The ML algorithms can predict lead times in production with a faster response time.[1]

4.1.4. Planning

In SCM, demand/sales estimate drives planning. Demand/sales prediction, on the other hand, can be challenging at times since a successful demand forecast serves as an estimate for all sales potential estimation, which is a complicated estimation method. In this case, a highly nonlinear relationship between the parameters associated with multiple explanatory variables and their dependent variables is needed. ML algorithms can increase the accuracy of predicting and forecasting in revenue, demand, and the degree to which inventory is needed by integrating non-linear analyses. Since ML algorithms do not heavily depend on the accuracy of historical data, unlike conventional methods such as moving average, exponential smoothing, time-series methods, and Box-Jenkins methods, they have been confirmed as alternatives for demanding and preparing in SCM . ML algorithms, as opposed to conventional approaches, are able to eliminate data set defects and provide non-linear models that better fit the demand/sales curve.[1]Some articles related to planning are shown below in table 4.

Table 4. Articles related to planning

Paper Name	Author/ Year	Used Algorithm	Contribution
Interpretable machine learning for demand modeling with high-dimensional data using Gradient Boosting Machines and Shapley values**.**	Antipov, Evgeny A., and Elena B. Pokryshevskaya ,2020	RF, Gradient Boosting Machines(GBM), Elastic Net models.	The paper compares three classes of models, Gradient Boosting Machines outperformed Random Forests and Elastic nets. It provided actionable insights into the significance of different

			classes of predictors from the conceptual model by using interpretable machine learning approaches, as well as illustrated how useful it can be for marketing managers to decompose predictions into the effects of individual regressors by using an approximation of Shapley values for feature attribution.[15]
Machine-Learning Models for Sales Time Series Forecasting	Pavlyshenko, Bohdan M,2019	Different machine-learning approaches such as RF or NN.	In this paper, a stacking approach for building regression ensemble of single models has been studied. The results show that the performance of predictive models for sales time series forecasting can be improved by using stacking techniques .[16]

4.1.5. Customer Relationship Management

Customer feedback is critical for SC development, which is essentially about changing the SC to focus strongly in consumer. Traditionally, approaches such as market analysis, surveys, and interviews have been used to allow customers to provide input in a retailer's shop. The truth is that in the course of conducting surveys and interviews, ordinary retailers do not draw a wide audience because customers frequently resist offering their opinions face to face. Thus, their sample size is small. Those SC improvement decisions based on a small sample are vulnerable to being incorrect. However, social media provides a significant amount of consumer information that may represent consumers' true opinions. Customers' feedback can be best channeled via social media data, but it's often erratic and lacking in consistency, as well as large in variety, volume, and velocity. Handling them manually is therefore difficult.[6]

In this case, ML algorithms are used in conjunction with IoT (Internet of Things) sensors, advanced analytics, and real-time monitoring to provide end-to-end insight through SC activities. For instance, once extracted 1338,638 customer views from Twitter data, conducted a sentiment analysis of the data using text mining and SVM, and precisely directed customers' complaints of problems such as extra fat, presence of foreign particles, discoloration, and hard texture to the root causes in the upstream activities of the SC of beef products. Darren Law et al., with the help of LR, NN, and DT, conducted a previous defect-discovery from 11,024 Amazon reviews of various dishwasher brands, and discovered that possible defects were strongly associated with the domain-specific words "smoke" and "sparkle." The results showed that their method could predict dishwasher defects with a 94 percent precision, greatly improving quality assurance on both the supply and demand sides. As a result, ML algorithms can track SC synchronously with the aid of sensor data, while transportation can rule out SC disturbances in advance.[7] Some articles belongs to customer relationship management are shown below in table 5.

Table 5. Articles belongs to customer relationship management

Paper Name	Author/ Year	Used Algorithm	Contribution
Machine-Learning Techniques for Customer Retention: A Comparative Study.	Sabbeh, Sahar F,2018.	Discriminant Analysis, Decision Trees (CART), instance-based learning (k-nearest neighbors), SVM, Logistic	Compare and contrast the results of various machine-learning techniques for the churn prediction problem.[18]

		Regression, ensemble–based learning techniques (RF, Ada Boosting trees and Stochastic Gradient Boosting), Naïve Bayesian, and Multi-layer perceptron.	

4.1.6. Distribution and Transportation

Vehicle routing problems are one of the most popular ML applications in SCM. The best routes for a transporting vehicle to travel out of several options are critical for SC to deliver a commodity to the appropriate customers, and choosing the routes is usually beyond the capacity of a human brain. Applications and ML algorithms jogging ML algorithms excel at analyzing massive, complex data sets and producing accurate demand forecasting results quickly.
By critically and timely exploring the patterns of consumers' actions, cars, transportation, and infrastructures, machine learning algorithms will generate better delivery routes.[1] Some articles related to distribution and transportation are shown below in table 6.

Table 6. Articles related to distribution and transportation

Paper Title	Author /Year	Used Algorithm	Contribution
Inventory management and cost reduction of supply chain processes using AI based time-series forecasting and ANN modeling.	Praveen, Umamaheswaran, Ganjeizadeh Farnaz, and Ghasib Hatim ,2019	ANN modeling	This model enhances forecasting research and provides a more accurate estimate of future sales. The increased overall reliability of supply chain networks has a number of other advantages. It lowers total operating costs, such as storage and transportation costs. This improves the supply chain surplus in the long run.[10]
Machine learning approaches for predicting household transportation energy use.	Amiri, Shideh Shams, et al.,2020	LR model, Elastic net regularization, RF, DT.	This paper examines decision trees, random forests, and neural networks, as well as elastic net regularization analyses, to present four modeling techniques for forecasting household transportation energy usage. It also evaluates how effectively these advanced statistical models can be applied to the Integrated Urban Metabolism Analysis Tool's Transportation Module (TM) (IUMAT).[20]

5. Conclusion and Future Work

In the construction industry, ML is rapidly gaining traction and playing a vital role in the growth of automated technologies**.** ML is a technique for teaching machines to mimic human thought processes. It allows for faster generation of accurate solutions, even when dealing with large volumes of data. Training Data and Test Data are the starting points for machine learning. Supply chains can increase their accuracy in various areas of their market, such as logistics, operations, planning, and workforce, by leveraging machine learning technology. A detailed survey on ML and its applications related to SCM is introduced in this paper. Also, the interpretation of SC, SCM and ML is discussed. Various types of ML and some algorithms belongs to it are explained in details. The following are some possible directions for machine learning applications in supply chain management: There is a need for more "variety". Aside from NN and SVM, only a few algorithms have been investigated in SCM. As a result, there is a sizable area where various machine learning algorithms should be applied to SCM research. Another potential pattern to deal with the latest ML algorithms on the horizon is to reinvent the SC structure. More "robustness" is needed. It is incredibly difficult for a single department or organization to deploy a new system on their own, let alone ML, which operates as a "black box," producing reliable results without explanation. This makes it more difficult for a department or an organization to consider ML in SCM. Furthermore, certain machine learning methods are not capable of performing well in a single event, and their robustness would not be sufficient to withstand real-time applications. How can common end-users such as suppliers and retailers be persuaded to choose a proper ML method in SCM solely based on comparisons between different ML algorithms? In order to test the interpretability of ML algorithms in dynamic settings in the future, further research is needed

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