Machine Learning Techniques in Vehicle Routing Problem

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Abstract

Globalization of trade, urbanization, and the international division of labor are the main factors, that have led to an increasing need for transportation—the opening of different economic markets and the interdependence between countries through the supply and demand of goods. Companies worldwide increasingly facing globalization. Specifically, they must satisfy their customers and improve their performance by optimizing each sub-process in the supply chain process Vehicle routing problem is one of the important combinatorial problems for goods distribution as well as for passengers' transportation. Over time, many variants of this problem have been studied and several approaches have been proposed to obtain optimal solutions with exact methods or near-optimal ones using approximate algorithms (heuristic and metaheuristic). Recently, Machine learning techniques have been explored to determine the best solutions to VRP problems with high performance. In this review, we present the classical formulation of the vehicle routing problem as well as its most prominent variants. We provide an overview of the most significant machine learning concepts and techniques used in the literature for solving VRPs. To classify the papers, we followed the research methodology proposed by Mayring and we finally discussed the findings, analyzed the results, and compared each machine learning technique applied to this problem with other techniques.

Keywords
Vehicle routing problem, Unsupervised learning, Reinforcement learning, Classification, Clustering.

1. Introduction
With the globalization of trade, the development of industrialization, and the boom in trade, companies are facing fundamental challenges, namely technological changes, increased competition, and the demands of market demand. As these customer demands have become increasingly unpredictable, the challenge of competitiveness for businesses is becoming ever greater: In this case, companies seek to stabilize and increase market share while minimizing costs and maximizing profits. To do this, companies must be able to thrive in this environment and meet demand to satisfy their customers, since the objective of all companies is to deliver products to their customers, of the requested quality, in the requested location, on the requested date, and at the lowest cost. A company's smooth functioning relies heavily on its logistics management. As a result, to stay ahead in the market, logistics is becoming increasingly vital. The efficiency of logistics is the determining factor in a company's effectiveness. Due to this evolution of logistics, we found that logistics is the most important part of logistics costs. Distribution logistics can be defined as a structure formed by the partners involved in the competitive exchange process to make goods and services available to consumers, users, intermediaries, or buyers. The objectives of a downstream or distribution.

There are multiple logistics objectives, including satisfying the final customers, achieving profitability, and maximizing product and service quality. Downstream logistics involves determining the distribution system structure, inventory management systems, warehouse work procedures, order processing, handling, packaging, warehousing, shipping, and transportation.

Logistics is the source of many costs, commonly referred to as logistics costs. Carrying very large quantities of products over long and medium distances entails transport costs that can represent a significant percentage of the cost price of the product. Any downward or upward movement in transportation costs immediately improves or decreases the margin, hence the importance of reducing these costs. As a result, optimizing transportation costs has become a key factor in the success of any business.

The Vehicle Routing Problem, introduced by G. Dantzig and J. Ramzer in 1959, is a crucial combinatorial problem for the distribution of goods and transportation of passengers. The problem has several variants, depending on the addition or removal of constraints, and there have been various exact and approximate methods developed to obtain high-quality solutions within reasonable calculation times. Recently, machine learning techniques have been explored to improve performance and find the best solutions to the VRP problem.

Section 1 defines the vehicle routing problem by specifying the different types of this problem, then gives a presentation of the concept of automatic learning while defining the three types of this learning, and goes on to define the different techniques of machine learning into types of learning.
Section 2 studies the research methodology adopted in our work, which is based on four stages :
Step 1: Material collection, including an organized process of delimitation of articles and search.
Step 2: Descriptive analysis, offers the primary traits of the studied literature.
Step 3: Category selection, which means developing a classification framework dependent on a bunch of analytic categories and structural dimensions: variants of vehicle routing problem algorithms types of machine learning, approach types of machine learning, type of hybridization between ML technique and method of resolution (Exact or approximate methods), Type of mathematical model (mono objectif multi-objective, robust, fuzzy), Type of technique (Fuzzy or robust).

Step 4: Material evaluation, investigate publications based on the given classification framework, and give an interpretation of the results.
section 3 discusses the findings, and section 4 analyses the results and compares the different machine learning techniques so that we can achieve the best results in terms of quality and performance, section 5 concludes the review, and research limitations it give the roads to future research.

Vehicle Routing Problem Variants and Machine Learning Techniques

Vehicle Routing Problem Variants

Vehicle Routing Problem (VRP) is used to plan an optimal route for a fleet of vehicles to serve a group of customers under certain conditions. Vehicle routing problems are used in supply chain management, service, and physical delivery of goods. Different vehicle routing problem variants are developed according to the type of goods being transported, the quality of services required, and the characteristics of customers and vehicles.
There are different variations of VRP , and the four common and applicable variants of them are Capacitated Vehicle Routing Problem (CVRP)**:** In a common CVRP, a vehicle is permitted to serve and visit every client on a bunch of courses precisely once. The vehicle starts and finishes its visit to the central depot in such a way that the total cost of the trip (distance or time) is minimal and does not exceed the total capacity of the vehicle.

Vehicle routing problem with time windows (VRPTW)**:** In this type of VRPTW, the old style Vehicle routing problem put into thought the normal time a specific client is to be served. The goal is to discover, for a set of vehicles at a central depot, sets of paths that begin and finish at the station at least expense for serving the solicitations of known clients inside a predefined time stretch. Periodic vehicle routing problem (PVRP): In this type of variant, a set of capacitated vehicles traveling tour routes that begin and end at a single depot, at some stage in every time over the complete length of course construction, The objective of a periodic vehicle routing problem is to set up a set of routes for every vehicle that minimizes the complete tour cost (e.g. distance) such that simple stipulations of client's needs and vehicle capacities are satisfied.

Dynamic vehicle routing problem (DVRP) : with this type of variant, rather than various varieties of vehicle steering issues, a few elements or noticeably sizable data for organizing vehicle courses are only found after the start of the

execution of the primary course plan. In this way, the static idea of constructing a route becomes dynamic. Typically in a dynamic vehicle routing problem, a vehicle serves two unmistakable sorts of requests: static (known) requests and dynamic (dark/progressing) requests. In the dynamic vehicle routing problem, there are two wide classes specifically the stochastic and the deterministic vehicle routing problem. In the deterministic form, a few of the whole demands is obscure and are just gotten during the construction of the route plan. The second wide stochastic form, then again, abuses the stochastic highlights of the recently gotten data during course execution (Pillac V, Gendreau M 2011).
(Aderemi O, Olawale A, 2016) give some classes of these variants:

Table 1. Vehicle routing problem variants

Vehicle Routing Problem Variants	Class associated
Capacitated vehicle routing problem(CVRP)	The classical version of CVRP Cumulative Cvrp (Ribeiro GM, Laporte G, 2012) Stochastic demand and time windows (Lei H, Laporte G, 2011) Fuzzy demand (Kuo RJ, Zulvia FE, 2012) Multi-depot and full truckloads Multi compartment vehicle routing problem Capacited location routing problem Open capacitated routing problem Capacitated vehicle routing problem with simultaneous pick-up and drop in shared Transportation
Dynamic vehicle routing problem (DVRP)	Dynamic vehicle routing problem with time windows , split delivery and heterogeneous fleet Dynamic vehicle routing problem with soft time windows Dynamic vehicle routing problem with hard time windows Dynamic vehicle routing problem with stochastic demand Dynamic vehicle routing problem with pick-up and delivery Dynamic multi period vehicle routing problem
Periodic vehicle routing problem (PVRP)	Periodic vehicle routing problem with service choice Periodic vehicle routing problem with time windows Multi depot Periodic vehicle routing problem Multi-period vehicle routing problem with due date Multi-period vehicle routing problem with profit
Vehicle routing problem with time windows (VRPTW)	Single depot Vehicle routing problem with time windows Vehicle routing problem with time windows with a central depot Vehicle routing problem with time windows with a single vehicle and multiple routes

	Vehicle routing problem with time windows with soft time windows Vehicle routing problem with time windows with heterogenous fleet

Machine Learning techniques

In general, Machine learning is such learning from experiences that humans and animals take for granted, The work of machine learning algorithms does not rely on fixed models or conditions but learns directly from information. As the amount of data available for training increases, the performance of the algorithm will also improve.
Machine learning algorithms can help formulate better expectations and make decisions by creating valuable experiences from information and discovering patterns in the information. These algorithms are usually used to make key decisions in areas such as energy load forecasting, transportation, and medical diagnosis (Anshul A, Arvind J, 2019).

There are three types of Machine Learning:

Supervised Learning:

In this type of training, sample output is provided to the structure, and performance (output) is considered in the plan. In this type of training, each model is a pair consisting of an input object (essentially a vector) and an ideal output value. (Management feature) This type of algorithm checks and analyzes the learning data, and creates an induction function, this function can be used to plan new examples. In the best case, the algorithm can correctly define class labels for invisible instances. A learning algorithm used to "intelligently" extend training data to invisible situations.

Unsupervised Learning:

In this type of training, the system will obtain multiple samples of input data, but no output data. Since there is no ideal performance, classification is performed here to calculate and accurately separate the information-intensive collection. This is the task of defining the function to be described, which is a hidden structure of unlabeled data. Since the test or preparation tools provided to the learner are not marked, there is no error in compensating for the possible location assessment marks. Therefore, helpless assimilation is different from guided learning and supportive learning. This is closely related to density estimation and statistical issues (Vikramaditya, 2013).

Reinforcement Learning:

Reinforcement learning is a subset of machine learning based on behavioral brain research, which studies the idea of how software agents should behave in the environment to maximize cumulative rewards**.**

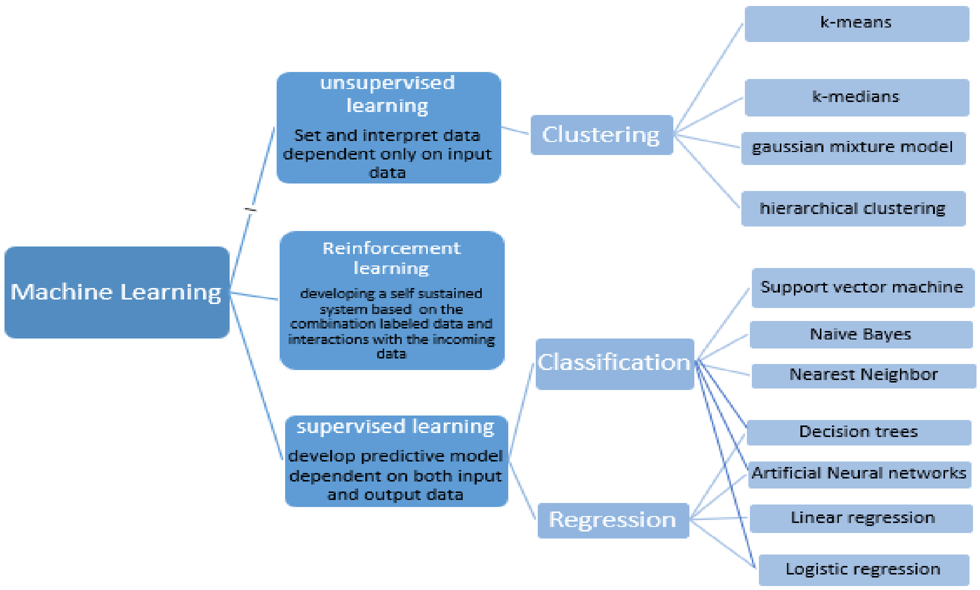

Figure 1. Machine learning types and algorithms

Various machine learning algorithms are used to optimize different processes of supply chain management, especially in vehicle routing problems. Each algorithm has its advantage in predicting the outcome of the process or optimizing the process in which that particular algorithm is applied.
A summary description of prominent machine learning algorithms is presented in Table 2:

Table 2. Machine learning algorithms

Machine learning algorithm	Description
Artificial Neural Networks (ANN)	it is a mathematical and computational model inspired by the biological nervous system. The error between the true value and the predicted value is reduced through the learning of the weight in the network (Schmidhuber, 2015), ANNs are further subdivided into backpropagation networks, perceptron networks and Hopfield networks.
Decision Trees	Decision-making is a selection tool that uses a tree-based selection model and its potential results, including random results, asset costs, and profits. This is a way to display calculations that contain only restrictive control statements. (Anshul Agral, Arvind Jayant, 2019)
Linear Regression	this method is a linear technique that gives the relationship between (or dependent variable) and one or more independent variables (or independent variables). Use simple linear regression when there is only one independent variable. and Use multiple linear regression when there are multiple variables. This term is distinct from multidimensional.
Logistic Regression	Logistic regression (LR) is a statistical technique similar to linear regression, which finds an equation based on one or more X responses to predict the outcome of a binary variable Y. In contrast to linear regression, because the model does not require continuous data. the response variable in categorical regression can be categorical or continuous. Logistic regression uses log odds ratios instead of odds ratios to predict group membership (A Elizabeth, Dighanji, 2013).

K-Means	K-means clustering is considered to be one of the most effective unsupervised segmentation techniques. Group objects/pixels/data points into K groups, with a small distance between data points in the same group . The K-means method is an iterative loop that calculates the normal score for each group and processes the separation of each point from the coordinate group corresponding to the next group. This iterative loop is repeated until the number of square errors in each group can be further reduced (Hawas, Ahmed Refaat, 2019).
Hierarchical Clustering	Hierarchical clustering is a simple and effective method for analyzing gene expression data by grouping genes with similar expression patterns. This is achieved by iteratively grouping highly related genes in their expression matrix. As a result, a tree diagram is created. In the dendrogram, they represent gene similarity: the shorter the branch, the more similar the genes, and the more similar the way the genes are expressed. Hierarchical groupings are also popular because they illustrate general similarities in expression profiles. Biologists can quickly evaluate patterns in data sets (Howard, 2013).
Naive Bayes	A naive Bayes classifier is considered as a probabilistic classifier based on Bayes' theorem, it indicate that each feature independently and equally affects the target class. In Naive Bayes, it classifies any features and does not interact with each other. and is independent, so each feature independently and equally affects the probability of a sample that belongs to a specific category. The NB classifier processes the training data set to calculate conditional probabilities and category probabilities P(yi) that determine The frequency of each feature value of a certain category value divided by the frequency of instances with that category value (Misra, Siddharth, 2020).
Support Vector Machine	SVM is the most widely used matrix method in machine learning today. It depends on actual teaching assumptions and was developed by Vapnik in 1995. An important part of this process is to use different types of components to propagate distinguishable non-linear examples into another higher-dimensional space. In recent years, great attention has been paid to sub-methods. Part of the reason is the increasing importance of SVM. The slicing function has a key function in SVM-the transition from linear to non-linear. Least squares SVM is also an important SVM strategy, which can be applied to clustering problems. Our powerful learning machine, fuzzy SVM and inherited, calculus-adjusted master model can also be used for the final goal of characterization. Diagnostic work, evaluated three unique bit possibilities, namely straight line, polynomial and RBF details (k. Sandeep, Satapathy, 2019).

Methodology

In order to collect and select articles to be included in this review, we applied a method based on content analysis methods. Many frequently cited reviews in the SCM literature have adopted this approach, such as (Govindan, Soleimani, 2015)and (Nguyen, Truong, 2018) . The review is conducted systematically according to a four-stage iterative process:

Step 1: Material collection, use an organized collection of materials to search and delimit articles.

Step 2: Descriptive analysis, the general quality of research writing is given in this step.

Step 3: Category selection, select a category to construct a classification structure based on multiple structural dimensions and analysis categories.

Step 4: Material evaluation, it Submit an evaluation, analyze the article according to the given classification system and interpret the results.

Material collection

On the first step, it is important to determine a set of effective keywords able to cover the synthesis on the subject of our research of existing literature. We divide the keywords into two groups:
Group 1: Words related to machine learning : unsupervised learning, supervised learning ,reinforcement learning, classification, regression clustering, k-means, neural networks, support vector machine, decision tree, linear regression, logistic regression, hierarchical clustering, naïve bayes.
Group 2 : Words related to vehicle routing problem : capacitated vehicle routing problem (CVRP) , vehicle routing problem with time windows (VRPTW), periodic vehicle Routing problem (PVRP), dynamic vehicle routing problem (DVRP) .

In the timeline from 2000 to the first half of 2019, searches are performed based on all possible pairs between these two types of keywords, in a well-known academic databases., i.e, web of science ,sciences direct, google scholar, researchgate, and scopus.
We only focus on magazine and conference articles. The resulting articles are examined to identify various machine learning techniques, which are then combined with a series of key words related to the field of the vehicle route problem.

Descriptive analysis

These figures shows that the number of articles published in this area has increased steadily over the past four years. they show also the change in the number of publications so there is not a stable rhythm for each year, there are years when there are no publications and on the other hand there are years when the publications reach a very high number of publications.

Neural Networks

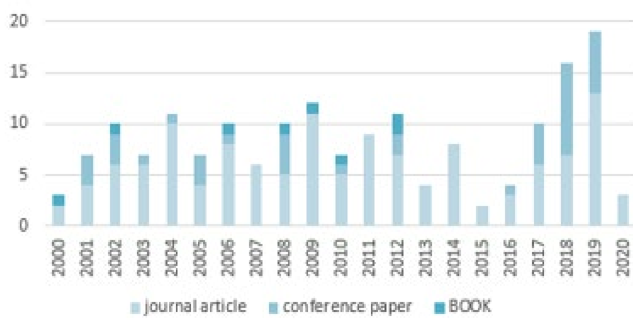

Figure 2. Number of publications per year in Neural networks

Figure 2 shows that the number of articles published in this area increased steadily between 2000 and 2020. some years know some decrease in the number of publications, then gradually the number of publications increases , because this type of techniques has the capacity to deal with various and varied problems. The result can be prediction, classification, or data analysis. They make it possible to deal with unstructured problems, that is to say problems on which no information is available beforehand.

Decision Trees

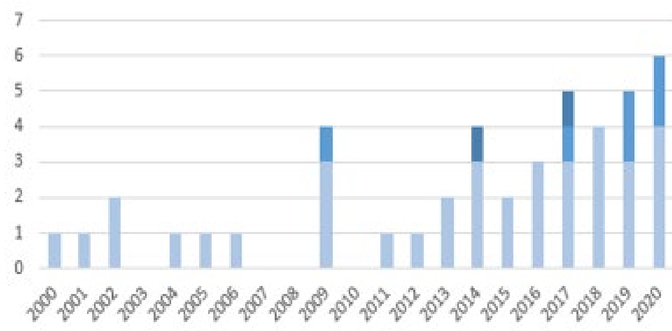

Figure 3, Number of publication per year in Decision trees

Following on from Figure 3, there has been increasing interest in using decision tree for vehicle routing problem especially in the over seven year, because this algorithm is characterized by its simplicity of understanding and interpretation and it is efficient on large datasets.

Linear Regression

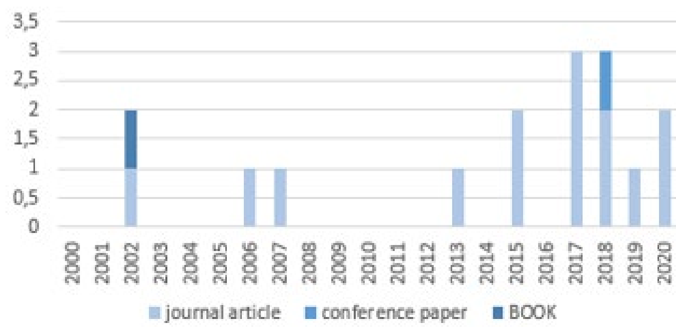

Figure 4. Number of publication per year in Linear regression

Figure 4 indicates that the number of publications for this technique is very low especially between (2000-2012) because of their Prone to noise and overfitting, Prone to outliers and their Prone to multicollinearity , this number increased over last years in starting by 2017 because this linear regression algorithm is known for its simplicity of interpretation and ease of calculation.

Logistic Regression

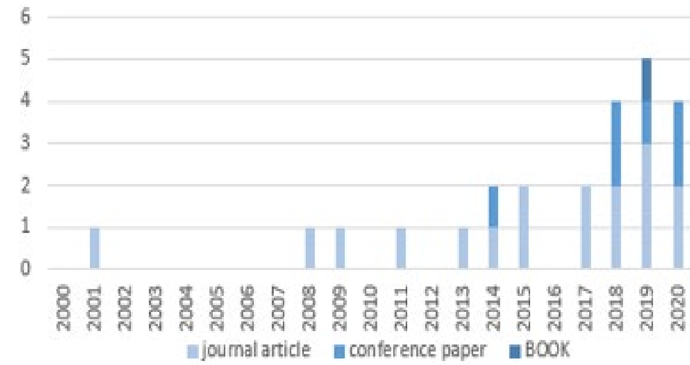

Figure 5. Number of publication per year in Logistic regression

Figure 5 shows the stability in number of publications during some years and their absence during some others years , since 2017 the number of publications has increased significantly ,because this technique allows to have good estimated probabilities and guarantees linear inter-class separations.

K-means

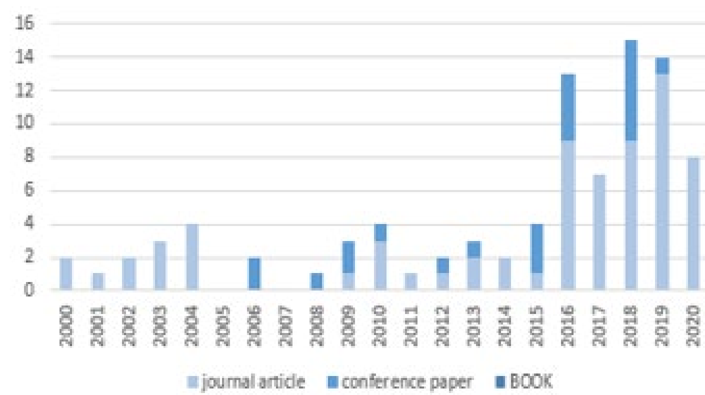

Figure 6. Number of publication per year in k-means

Figure 6 Shows the importance of using this technique in this field, especially in recent years, starting from 2015 , due to their simplicity, speed and its ease to understand and adapt with several problems and also due to their variants that is improving continuously.

Hierarchical Clustering

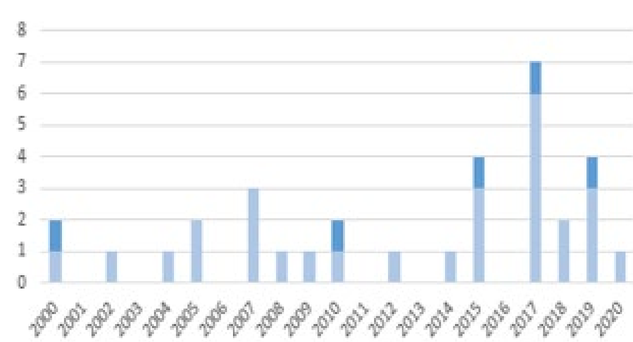

Figure 7. Number of publications per year in hierarchical clustering

Figure 7 shows the number of publications published in this field, which is considered weak, especially before the year 2015, this is due to the fact that this technique its algorithmic complexity is very heavy, because At each iteration, to decide which clusters to join, we will need the two by two distances between all the pairs of points in the dataset.

Naïve Bayes

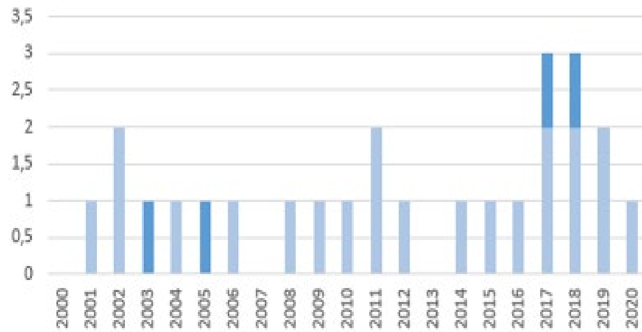

Figure 7. Number of publications per year in Naïve Bayes

Following on from Figure 8, there has been increasing interest in using Naïve Bayes for vehicle routing problems in contract to the past years, which did not know a large number of publications in this field, this is due to the fact that this technique is very fast for classification: indeed the probability calculations are not very expensive. and even Classification is possible even with a small dataset.

Support vector machine

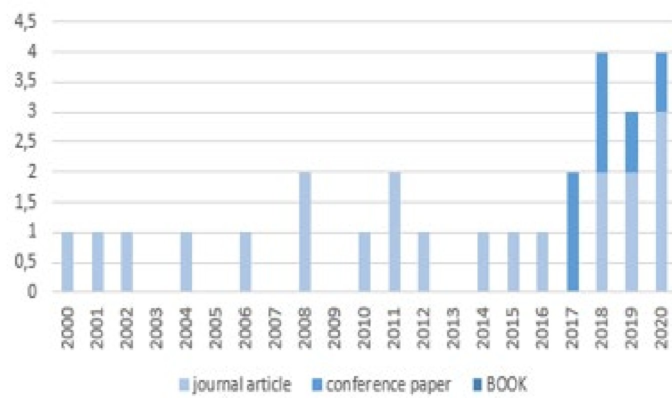

Figure 8. Number of publication per year in Support vector machine

Figure 9 illustrates the consistent publication numbers from 2000 to 2002 and from 2014 to 2017, punctuated by interruptions in 2003, 2005, and 2007, followed by a resurgence in publications thereafter, notably increasing from 2017 onward. This resurgence aligns with the evolving suitability and expanding applicability of this technique across various domains, reflecting the growing interest in utilizing it to address diverse problem sets.

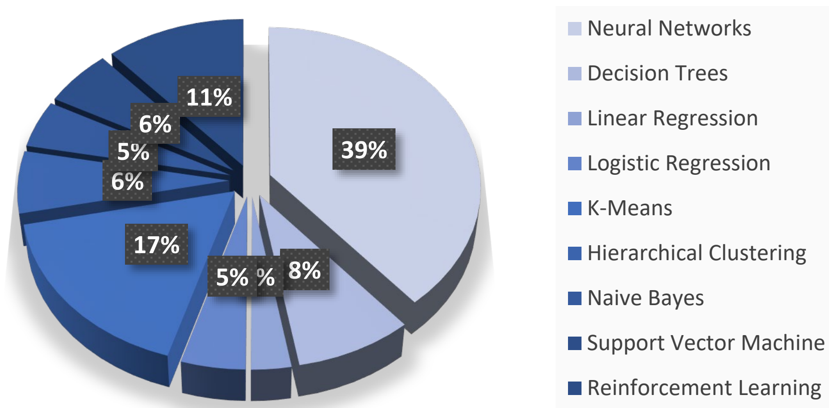

Figure 9. Distribution of Publications For Each Machine Learning Algorithm

Figure 10 depicts the percentage of machine learning technique adoption in addressing the Vehicle Routing Problem (VRP) within the literature.it illustrates that neural networks are the most widely used algorithm in this subject because of their efficiency in finding the best solution and due to their performance.it indicate also the important number of papers published for the use of support vector machine and k-means in this field.

Category selection

The category selection step includes the design of our classification system, which consists of structural dimensions and analysis categories.
In order to answer the research questions raised, we have selected four structural dimensions, and the classification structure is superimposed on them :

- variants of vehicle routing problem
- algorithms types of machine learning
- sapproach types of machine learning
- type of hybridization between ML technique and method of resolution (Exact or approximate methods)
- Type of mathematical model (mono objectif multi objectif ,robust,fuzzy)
- Type of technique (Fuzzy or robust)

The analysis categories, that is, the key issues in each dimension, are derived from the previous literature according to various classification structures. Table 3 shows these analysis categories.

Table 3. Analytic Categories of Structure dimension

Structure dimension	Analytic Categories
VRP variants	Capacited vehicle routing problem (CVRP) , periodic vehicle routing problem (PVRP), vehicle routing problem with time windows (VRPTW), dynamic vehicle routing problem (DVRP) .
Algorithms Types of Machine Learning	Supervised learning , unsupervised learning and reinforcement learning (Sang, Zhou, 2018).

Approach type of Machine Learning	Classification, clustering and regression.
Type of mathematical model	Mono objectif ,multi objectif ,fuzzy model ,robust model, and stochastic model (Sun Bingrong, Park, 2017).
Machine learning algorithm	Artificial neural networks, linear regression, decision trees, logistic regression, k-means, hierarcical clustering, naïve bayes, support vector machine (Gomez, Andres, 2015)

MATERIAL EVLUATION

Vehicles Routing Problem Variants

Table 4. Summary of literature by Vehicle routing variants

Machine learning Algorithm	Vehicles Routing Problem variants)	Research studies	Contribution
Neural Networks	**Capacitated Location routing problem**	(Fadoua Oudouani, Mohamed Lazaar, 2020)	It uses self-organizing map (SOM) to identify depots and affect customers to depots and uses trained self-organizing map (CSOM) to improve location depots
	vehicle routing problem with time windows	(Jean YvesPotvin, Robillard, 1995)	Neural network identifies source clients that are evenly distributed in a geographic area.
	Urbain Vehicles routing Problem	(Seongjin Choi, Jiwon kim, 2019)	A recurrent neural network model based on urban vehicle trajectory prediction is proposed
	Open Vehicle Routing Problem	(Raras Tyasnurita, Ender Ozcan, 2017)	In order to extract hidden patterns in the collected data,Time Delayed Neural Network (TDNN) is used in the form of a classifier (ie, "learner" hypereuristic), and then use to solve "invisible" instances of the problem.
k-means	**Cumulative Vehicle Routing Problem with limited Duration**	(Cinar, Didem, 2016)	In order to improve the computing power of CumVRP-LD's improved C&W algorithm, a two-stage construction heuristic method including K-means clustering algorithm is used. Load distribution and load shedding take into account the extraordinary characteristics of the problem, and a fast and easy operating value calculation method has been developed for CumVRP-LD.
	Multi depot vehicle routing problem with time window	(Mirabi Mohammed,	Clusternig GA method aims to minimize transportation costs, including travel distance. Two other clustering methods (fuzzy C-means (FCM)

		Shokri Nasibeh, 2016)	and K-means algorithm) were used to compare the earliest arrival time and the last arrival time. The experimental results show the reliability and effectiveness of the algorithm.
	Multiple vehicle routing problem	(R. Nallusamy, Parthiban, 2020)	It utilized a system of clustering the given urban communities relying on the quantity of vehicles and each bunch is dispensed to a vehicle. k-Means bunching algorithm has been utilized for simple clustering of the urban areas
	Multi compartment vehicle routing problem	(M. Reed, A.Yiannakou, 2014)	K-means improve the exhibition by first bunching the hubs, and afterward applying the ACS to each cluster thusly
Naive Bayes	Capacitated Vehicle Routing Problem with Simultaneous Pick-up and Drop in Shared Transportation	(P. Gupta, 2020)	Execution of chose drivers is utilized to refresh driver evaluations for the ensuing run, and the cycle is rehashed on multiple time

Algorithms type of machine learning

there are a number of articles which aim to solve the problem of vehicle tours and all its variants through the different Algorithms types of machine learning which are classified into 3 types :
Supervised learning : With a growing range of dedicated answer approaches for vehicle routing problem , based supervised learning approach (Mayer 2018) investigate a simulation- to see the quality of a specific algorithmic rule from a group of algorithms for a given dynamic problem instance supported a spread of its characteristics. (Federico Perrota, Tonny Parry, 2017) also proposed a supervised learning method that can simulate tractor fuel economy in big data sets., and (Wu, H. Lee 2004) used supervised learning to predict travel time.

Unsupervised Learning : (Andrés Gómez, Ricardo Mariño, Raha Akhavan 2015) Use unsupervised learning methods to simulate random driving and service times along the vehicle's route, A new and efficient supervised learning algorithm with supervised k-means is introduced by (H.Ruhan, X. Weibin, 2009) which can subdivide the area into large-scale vehicle routing problems, A supervised clustering method is also proposed by (Kim, Byung 2006) to improve performance to solve the actual problem of garbage truck routing with time windows (VRPTW) considering multiple recovery trips and driver lunch breaks.

Reinforcement Learning: In the form of a route-based Markov decision process, a formulation of the problem of dynamic routing of vehicles with known and random time windows and customers is proposed by (W. Joe, H. Chuin, 2020) that Provides a method that combines deep learning and enhancement for value function approximation and routing heuristic algorithm based on simulated annealing, (Cao, 2020) also uses a Reinforcement learning approach to optimize in distribution the probability of delay occurrence. Aiming at the online vehicle routing problem, a neural combinatorial optimization strategy based on deep reinforcement learning is proposed by (J. James, Q. Yu, 2019) In particular, it converts online route selection tasks into vehicle route selection tasks, and provides pointer networks embedded in structured graphics for iterative design of these routes. To explore a reinforcement learning application as a model-free non-parametric method to solve the adaptive routing problem in stochastic and time-dependent (STD) networks (Chao, Shen, 2018) it focuses on developing parameter models that reflect network dynamics and develop effective algorithms to resolve these models. A new method of traffic flow optimization based on reinforcement learning is proposed by (E. Walraven, and T. Matthijs 2016).

Type of hybridization between Machine Learning technique and method of resolution

Table 5. Summary of literature by type of hybridization

Title	Method of resolution	Machine learning technique	The link between them
A 2 phase constructive algorithm for cumulative vehicle routing problems with limited duration (Cinar D , Konstantinos G, 2016)	Approximate method(Clarke and wright ,heuristic)	k-means	A two-stage construction heuristic method combined with k-means clustering algorithm is used to improve the computing power of the improved CumVRP-LD Clark and Wright algorithm.
A hybrid clustering technique combining a novel genetic algorithm with k-means (Anisur R ,Islam Z, 2014)	Approximate method(genetic algorithm ,meta-heuristic)	k-means	it proposed a new GA-based clustering technology that can find the correct number of clusters and identify the correct genes through a new method of initial population selection.
A hybrid K-means Metaheuristic Algorithm to solve a class of Vehicle Routing Problem (L. Korayem, M. Khorsid, 2015)	Approximate method(Bio inspired grey wolf ,meta-heuristic)	k-means	A new hybrid k-means meta-heuristic algorithm is developed based on the newly created bionic gray wolf optimizer, which is used to group customers in the grouping stage.
Research-based on k -means clustering and artificial fish swarm algorithm for Vehicle Routing Problem (Ji, 2012)	Approximate method(artificial fish swarm, meta-heuristic)	k-means	This paper proposes a vehicle route optimization combined algorithm (KMAFA) based on artificial fish swarm algorithm and K-Means clustering .
An ant colony algorithm for the multi compartment vehicle routing problem (M. Reed, A. Yiannakou, 2014)	Aproximate method(An ant colony algorithm, meta-heuristic)	k-means	Demonstrated the application of the ant colony system (ACS) to find the solution for the capacitated vehicle routing problem linked to the collection of domestic waste, which is considered a node in the spatial network. Using k to represent clusters in a network where nodes are concentrated in a single group can considerably increase the solution's efficiency.
A hybrid approach to vehicle Routing Problem using neural networks and genetic algorithm	Aproximate method(genetic algorithm ,meta-heuristic)	Neural networks	To improve the initializition and development period of an equal inclusion heuristic for the vehicle routing problem with time windows A competitive neural network model and a genetic algorithm are deployed.

Green logistic vehicle routing problem : Routing light delivery vehicles in urban areas using a neuro fuzzy model (Goran C, Dragan P, 2014)	Aproximate method(simulated annealing ,meta-heuristic)	Neural networks	An adaptive neural network was utilised which was prepared by a simulated annealing algorithm

Type of Mathematical Model

Table 6. Summary of Literature by Type of Mathematical Model

Title	Machine learning technique	Type of mathematical model	Contribution
Green logistic vehicle routing problem: Routing light delivery vehicles in urban areas using a neuro-fuzzy model	**Neural** networks	Fuzzy-mono objectif model	The adaptive neural network is contributed to train the simulated annealing algorithm. In the objective to solve the routing problem in the model, an adaptive neural network is used to evaluate the performance of the network branches. The environment (exhaust gas and noise) of a specific vehicle route is input into the neural network.
Fuzzy Vehicle Routing Problem with Uncertainty in Service Time	k-means	Fuzzy multi objective problem	Further attributes are included to minimize the number of vehicles, thereby extending the fuzzy multi-criteria optimization problem.
Sentiment Analysis for Driver Selection in Fuzzy Capacitated Vehicle Routing Problem with Simultaneous Pick-up and Drop in Shared Transportation	k-means	Fuzzy Mono objective problem	Use fuzzy modeling to estimate labor costs in a reliable environment. The selected drivers contribute to update the driver evaluations for the resulting run, and the loop is repeated several times. The given results confirm the reason for passing the exam in the future. Research will be conducted to confirm the function of the model. Another case of triangular fuzzy estimation and its influence on the model in question is also shown. It also provides driver classification suggestions for human resource management.
A novel approach based on heuristics and a neural network to solve a capacitated location routing problem	Neural Networks	Mono objective Model	A method to determine the solution for the location routing problem (CLRP) to optimize the transportation distance of the proposed vehicle. CLRP is used to determine the location of the warehouse, assign the warehouse to each customer, and define the route. The goal is to optimize the cost (distance). In the location issue, we use self-organizing cards (SOM) to identify deposits and allocate deposits to customers

Critical Analysis

The results presented indicate that better cluster first/second path routing requires special attention to the grouping angle. Angular distance is not so important to the buyer closest to the warehouse. When many meta-heuristic codes are not available, it has been updated with Business Solvers. Combined with open-source meta-heuristics, the SL-RTR (Slender Record-to-Record) strategy has shown amazing results in very large new vehicle routing problem cases where they use RTR based on spherical k-means and k-median. Despite setting parameters, the clustering algorithm can still outperform larger practical problems. A possible direction for future research is to combine an economical clustering method to match the customer clustering trend of each test instance, and to provide a critical analysis of evaluation methods to manage routing needs. To this end, the method provides an improved version of the least squares method, in which the minimum distance and the minimum distance are realistic methods to find the solution of this problem. The results demonstrate that compared with the comparison method, the use of fuzzy logic provides a closer solution to the real situation. The results also show that the strategy used here leads to a preferred solution to the current problem, which can be proposed based on the on-demand information in the company's documents. It has also been found that in some cases, when the three main parts are input, output and parameters, something is ambiguous and random. Fuzzy linear regression is a more powerful analysis tool, so it is.

more popular than other models. The conclusion is that it is more appropriate to use fuzzy trapezoidal numbers as the analysis basis for industrial case studies. another option is the use of a new algorithm, based on a special program using Thyssen polygons to create such clusters. It covers various criteria for balancing clusters, such as, the number of customers in each cluster, the service revenue in each cluster, or the delivery/receipt volume in each cluster. Compared with other clustering algorithms, the calculation results show the efficiency of this algorithm in comparison with the other algorithms of clustering.

Conclusion and Future Directions

Considering the content analysis method proposed by Mayring, a large number of articles in this literature review were reviewed to fully understand where and how machine learning is applied to vehicle routing problems. In especially, we built up a characterization system dependent on six classes: variants of vehicle routing problem algorithms types of machine learning, approach types of machine learning, type of hybridization between ML technique and method of resolution (Exact or approximate methods), Type of mathematical model (mono objectif multi-objective, robust, fuzzy) and Type of technique (Fuzzy or robust). Tending to these classes, the conversation has featured various exploration holes and future research for machine learning techniques to catalyze the examination advancement of this topic.

We can see the great use of neural network technique to solve this problem because this technique has a lot of features, it Allows optimization in real-time, Avoids manual forecasting for every data change, Saves time when setting up the network, it is intuitive and easy to use (known interface), and it extends the range of problems that can be analyzed such as our problem. There is also a great use of the k-Means clustering technique because it is ease to interpret, simple, flexible, and efficient, and their clusters are closed, and it has a Low computational cost.

There are several future research About this topic that are: How we can hybridize other heuristics and metaheuristics with machine learning techniques to improve the solution and its performance? Which big data architecture can be proposed using machine learning techniques to improve large-scale solutions? can we combine object internet with machine learning techniques to obtain better solutions?

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