

# **Fleet management through Vehicle Routing Problem and Multi Depot Vehicle Scheduling Problem: A Literature Review**

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## **Abstract**

Nowadays, one of the objectives of fleet management is to reduce fleet size and costs and to improve efficiency at the level of assignment, scheduling, and routing. In this paper, we present a literature review focusing on solution methods by analyzing 245 journal papers dealing with exact methods as well as heuristics and metaheuristics to solve large instances of two main problems in this area, namely the Vehicle Routing Problem (VRP) and the Multi Depot Vehicle Scheduling Problem (MDVSP).

## **Keywords**

Fleet management, VRP, MDVSP, heuristics, metaheuristics.

## **1. INTRODUCTION**

Fleet management often includes apart from the management of vehicles, the management of drivers as well. Its optimization allows improving the productivity of a company. Transportation professionals have to reduce their costs while, satisfying all kinds of constraints such as scheduling, capacity, time windows, maintenance, regulation, service level, quality constraints. In this review, we are interested in vehicle scheduling and routing problems, with the objective of optimizing the assignment of resources to routes and to control fleet size, according to several criteria.

A wide volume of research work in this area focus on the vehicle scheduling and routing problems at the same time. This article is a review of the literature published between 2010 and 2018 on VRP, and the literature published between 2015 and 2018 on MDVSP. It is presented in such a way that it specifies the variant of the problem that is studied as well as the solution method that is used.

## 2. RESEARCH METHODOLOGY

We conducted this research in relation with a fleet management problem in an interurban transportation company where VRP and MDVSP came naturally. In order to select the papers related to these two problems that our review cover, we used web search facilities such as Science Direct, Google Scholar and kept only references of interest for our problem. More precisely, we did the following:

- (1) We defined keywords and used web search of academic search. We used Science Direct as the major web search.
- (2) We selected journal articles.
- (3) We selected the articles having a directly relation with our fields.
- (4) We classified the papers into two sections one for the VRP and the other for the MDVSP, and in each section according to the variant of the problem that is studied and the solution method that is used.

Table 1: Major themes discussed

Section / Topic	Issues
Section 1 : VRP	which we analyze two of the main variants of the VRP “ CVRP, VRPTW” by focusing on the resolution methods that are generally exact, heuristic, metaheuristic
Section 2 : MDVSP	which we analyze the MDVSP by focusing on the resolution methods that are generally exact, heuristic, metaheuristic

## 3. VEHICLE ROUTING PROBLEM “VRP”

The Vehicle Routing Problem (VRP) is an extension of the travelling salesman problem Danzig et al. (1954). The VRP can be described as the problem of designing optimal delivery or collection routes from one or several depots to a number of geographically scattered cities or customers, subject to side constraints. There are many variants of this problem among which we will focus on two of them: the Capacitated VRP (CVRP) and the VRP with Time Windows (VRPTW).

Figure 1 and 2 show the number of the papers published between 2010 and 2018 that we have selected according to our methodology.

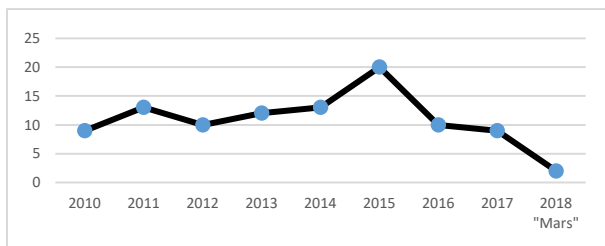


Figure 1: Number of Research articles VRPTW published (2010- 2018)

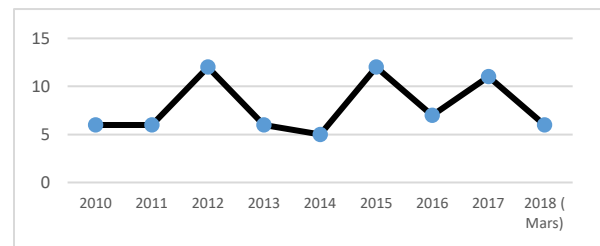


Figure 2: Number of Research articles CVRP published (2010- 2018)

### 3.1 Capacitated Vehicle Routing Problem “CVRP”

In its most basic version called Capacitated VRP or VRP with capacity constraints. CVRP is a VRP in which a fixed fleet of delivery vehicles of uniform capacity must serve a known customer demand for a single commodity from a common depot while respecting constraints of capacity of vehicles at a minimum transit cost. There are several variants of "CVRP" such as the Pyramidal Capacitated Vehicle Routing Problem (PCVRP). A PCVRP is the CVRP with the additional restriction that each route must be pyramidal. A pyramidal route is defined as a route on which the vehicle first visits customers in increasing order of customer index, and on the remaining part of the route visits customers in decreasing order of customer index; this problem has been studied by J.Lygaard. (2010), He developed a Branch-and-Cut-and-Price (BCP) algorithm; therefore the results showed that the BCP algorithm performs

consistently better than other algorithms. S.Ulrich Nogueira et al. (2010) were interested in the Cumulative Capacitated Vehicle Routing Problem (CCVRP) which occurs especially in humanitarian aid programs when the objective is to minimize the sum (or the maximum) of arrival times to customers, instead of the classical route length, subject to vehicle capacity constraints, and they presented the first upper and lower bounding procedures for this problem. G.Mattos Ribeiro et al. (2012) have also been interested in CCVRP, and they presented an adaptive large neighbourhood search heuristic. L.Muyldermans et al. (2010) were interested in the Capacitated Arc Routing Problem (CARP) in which, a fleet of identical vehicles with limited capacity must service all edges with positive demand, and the objective is to search for a set of minimum cost tours that begin and return to a distinguished node, called depot. They presented a local search algorithm that exploits well-known moves (2-opt, re-insert, relocate, exchange and cross), and they also combined it with a guided local search metaheuristic in order to reach higher quality solutions. F. Luiz Usberti et al. (2011) treated a variant related to the CARP but differs from it since it does not consider a depot, and tours are not constrained to form cycles, that we call the Open Capacitated Arc Routing Problem (OCARP).

### 3.2 Vehicle routing problem with time windows “VRPTW

When a customer specifies a time window during which he wants to be delivered in a VRP, we speak about the VRPTW and the objective then is to minimize the vehicle fleet size and the sum of travel, waiting and service times. There are several variants of the VRPTW. Shu-Chu Liu et al. (2011) were interested in one of them called the Inventory Routing Problem with Time Windows (IRPTW), in which inventory and routing decisions are considered at the same time. Obviously, several factors may affect the travels’ timing and make it vary in time, such as traffic congestion, weather conditions and vehicle breakdowns. S.R.Balseiro et al. (2011) were interested in the VRPTW taking into consideration these factors, and thus considered the problem known as the Time-Dependent Vehicle Routing Problem with Time Windows (TDVRPTW). A.Âgrâ et al. (2013) have processed a robust optimization problem called the robust VRPTW, in which travel times are stochastic, e.g. in the case of maritime transportation where delays are frequent and should be taken into account. They proposed two new formulations and developed a new cutting plane solution technique. Several constraints can be considered during the modelling of the VRPTW that generate different variants, J. d’Armas et al. (2015) were interested in a dynamic rich VRPTW in which customer requests can be revealed dynamically during the day or known at the beginning of the planning horizon. They also considered several constraints, such as a heterogeneous fleet, multiple, adaptable time windows, and customer priorities.

### 3.3 VRP Solution methods

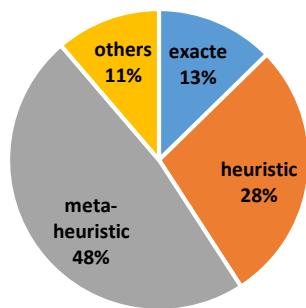


Figure 3: Repartition of the solution methods for CVRP encountered in our review published (2010- 2018)

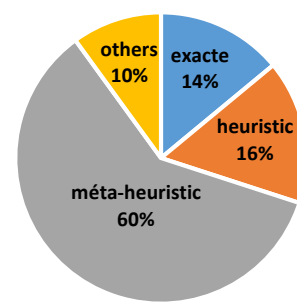


Figure 4: Repartition of the solution methods for VRPTW encountered in our review published (2010- 2018)

In our study we classified the solution methods used in 70 CVRP and 98 VRPTW papers in three types, namely exact methods, heuristics, and metaheuristics. The pie charts in figures 3 and 4 show the use frequency for these different types of methods. We note that metaheuristics are more used than simple heuristics and exact methods, due to the difficulty to find a “good quality” feasible solution for difficult optimization problems which is the case for VRP, CVRP, VRPTW... Metaheuristics that are currently used are simulated annealing, tabu search, and genetic algorithms; table 2 shown the solution methods are most widely used for solving the differs variants of CVRP and VRPTW.

Table 2: Solution methods and the variants of CVRP and VRPTW treated.

	<b>Resolution methods</b>	<b>The variants of CVRP and VRPTW treated</b>
<b>Capacitated Vehicle Routing Problem “CVRP”</b>	Branch-and-cut-and-price; Branch-and-Cut	The pyramidal CVRP; the Capacitated Location-Routing Problem; the two-echelon capacitated location-routing problem; the capacitated -ring-star problem; the cumulative CVRP; the mixed CVRP; the mixed CVRP with Time Windows
	Memetic algorithm	The cumulative CVRP; The mixed CVRP with turn penalties; periodic capacitated arc routing problem
	Guided local search; treated local search	The multi-compartment capacitated arc routing problem; large scale capacitated arc routing problem;
	Greedy randomized adaptive search procedure	The two-dimensional loading CVRP; the capacitated arc routing problem
	Genetic Algorithm	The CVRP with fuzzy demand; Periodic CVRP
	Particle swarm optimization	The Distance-constrained CVRP; he capacitated location routing problem
	Tabu search algorithm	The CVRP with three-dimensional loading constraints; 3L-CVRP
	Adaptive large; variable neighborhood search	The two-echelon capacitated location-routing problem; the Distance-constrained CVRP; the CVRP with two-dimensional loading constraints
<b>Vehicle routing problem with time windows “VRPTW”</b>	Column generation	VRPTW and multiple use of vehicles; VRP with semi soft time windows; the VRP with discrete split deliveries and time windows; Dynamic VRP with Soft Time Windows; the vehicle routing problem with hard time windows and stochastic service times; the multi-trip VRPTW.
	Branch-and-cut algorithm	the VRP under capacity and time window constraints; the Time Window Assignment Vehicle Routing Problem
	Genetic algorithm	The Multi-objective VRPTW; large-scale VRPTW; VRPTW considering overtime and outsourcing vehicles; the simultaneous delivery and pickup problems with time window
	Memetic algorithm	handling time windows in vehicle routing problems; multi-objective VRPTW; the VRPTW and stochastic travel and service times
	Tabu search	VRPTW and stochastic travel and service times; VRPTW Based on Spatiotemporal Distance; Vehicle routing with multiple deliverymen; Time-dependent Multi-zone Multi-trip VRPTW; A Vehicle Routing Problem with Flexible Time Windows; the vehicle routing problem with backhauls and time windows; VRPTW and driver-specific times
	Simulated annealing	Competitive VRPTW; the truck and trailer VRPTW; the VRP with simultaneous pickup-delivery and time windows
	Ant colony	The period VRPTW; the Time Dependent VRPTW; close-open VRPTW and fuzzy constraints; VRPTW with split deliveries
	Variable neighborhood search	The time-dependent VRP with soft time windows and stochastic travel times, a Dynamic Rich VRPTW; real-world Rich VRPTW; VRPTW and Vehicle Preventive Maintenance Constraints

## **4. MULTI-DEPOT VEHICLE SCHEDULING PROBLEM “MDVSP”**

In this section, we are interested in the scheduling and assignment problems; our literature review is based on 77 articles between 2013 and 2018. We reported the different solution methods used and their percentage of use (Figure 5). Table 3 classifies the different contributions according to the solution method used.

### **4.1 Introduction**

One of the objectives in fleet management is to reduce costs while assuring the same service quality level, and respecting deadlines. For large-sized and mainly heterogeneous fleets, the resulting problem becomes more and more complex to deal with. Several authors were interested in the optimization of the Vehicle Scheduling Problem by taking into account various constraints, starting from environmental, to financial and human aspects. M.Wei et al. (2013) were interested in the urban traffic, especially regional traffic bus scheduling, subject to several constraints such as depot capacities, fuelling, and emissions of polluting gases. They applied a bi-level programming model to address the relationship between bus scheduling and procurement scheme from an overall perspective, and they obtained solutions by using Genetic Algorithm (GA). Generally, in transportation we try to keep the same level of service and at the same time to minimize operating costs. For that purpose, Ibarra-Rojas (2014) proposed two linear programming models, one for maximizing the number of passengers benefiting from transfers, and the other for minimizing operating costs; they also combined the two objectives in a bi-objective integrated model that he solves by implementing a  $\epsilon$ -constraint method.

### **4.2 The MDVSP application in the different modes of transportation**

#### **4.2.1 Public and interurban transportation**

The MDVSP consists of assigning a fleet of vehicles stationed at several depots to a given set of planned trips and scheduling the routing of these vehicles. Bertossi et al. (1987) proved that the MDVSP is an NP-hard problem. In the public and interurban transportation sectors, the process of this problem is an essential stage in operation planning. S. Hassold et al. (2014) were interested in the Multiple Vehicle Types Vehicle Scheduling Problem (MVT-VSP) in public transport; they proposed a methodology based on a minimum-cost network flow model utilizing sets of Pareto-optimal calendar for individual bus lines. S.Salhi et al. (2014) gave a mathematical formulation of the multi-depot routing vehicle with heterogeneous fleet. They implemented a variable neighborhood search solution algorithm, and a lower and upper bound are produced. There are several variants of MDVSP like the Dial-A-Ride Problem (DARP) which is a problem in which a set of deliveries must be made along a set of available routes between fixed sources and destinations, within limited time periods, and with the possibility of changing vehicles during a trip. These services, are provided for people with reduced mobility. K.Braekers et al. (2014) handled the Multi-Depot Heterogeneous Dial-A-Ride Problem (MD-H-DARP), and they adapted a branch-and-cut algorithm to solve it.

#### **4.2.2 Intermodal transport**

We talk about the intermodal or combined transport mode, when we use successively several transportation modes. The idea behind intermodal transportation is to exploit economies of scales. Generally truck transportation companies treat transportation requests by managing homogeneous or heterogeneous fleet which are localized in one or several depots. The objective of these companies is to minimize the total truck use duration to increase truck availability in order to maximize requests satisfaction rate, and to improve the productivity and thus maximize the benefits, but the conditions imposed by customers make this optimization difficult. J.Nossack et al. (2013) were interested in truck scheduling problem in intermodal transportation containers. They formulated it as a Pickup and Delivery Problem with Time Windows (FTPDPTW) in which customers may both receive and send goods under capacity, time windows and precedence constraints. They solved it by a two-stage heuristic solution. S.Sterzik et al. (2013) have treated the Container transportation problem that describes the movement of full and empty containers among a number of terminals, depots and customers, but without intermodal transport, and they solved it with a tabu Search heuristic.

#### **4.2.3 Rail transportation**

Rail transportation is the most ecological way of transportation. It is characterized by its high capacity, high flexibility, and its competitive costs compared with other transportation modes, especially when electricity cost is not very high. Rail transportation management encompasses train composition, train maintenance, train-railway assignment and scheduling (due to the fact that a railway cannot be used by two trains at the same time and at the same place); thus,

trains scheduling optimization is very important. First before establishing assignments, railway transportation professionals have to manage effectively the maintenance and rolling stock. Yung-Cheng Lai et al. (2015) proposed a model for optimizing the rolling stock use, considering all the necessary regulations and practical constraints. They developed an exact solution method and a hybrid heuristic process to make solution quality better. Recently, in many industrial countries, a new concept of railway transportation has appeared, which aims at assuring by rail goods delivery from suppliers to plants. But, this new concept created a problem that the same railroad is used by both passengers and freight trains. O.Ozturk et al. (2017) presented a decision support framework for the problem of urban freight movement which consider a single rail line on which some stations can be used as loading/unloading platforms for goods. They developed a heuristic solution method, two mixed integer models and a  $\epsilon$ -constraint method.

#### 4.2.4 The maritime transportation

The maritime transport is another way of delivering goods and products. It is characterized by its high capacity (much higher than train transportation) and its competitive cost. It is an intercontinental transportation that can transport very heavy and voluminous parcels for long distances. It has become very successful since the introduction of container use. It is however unable to transport goods door-to-door. Many scientific contributions have dealt with problems encountered in this context. For instance, C.Min Joo et al. (2014) handled a block transportation scheduling problem under a delivery restriction to limit the number of transporters by determining when and who would deliver the blocks from the source to the destination. They have proposed two metaheuristics solution algorithms based on a Genetic Algorithm (GA) and Self-Evolution Algorithm (SEA). Another scheduling optimization problem concerns ships movements so as to govern port connectivity, avoid bottlenecks and congestions in the corridors and to reduce the polluting emissions caused by ships. E.Lalla-Ruiz et al. (2016) were interested in minimizing the waiting times for entering and outgoing ships and proposed a mathematical model and heuristic solution algorithms.

#### 4.2.5 Air transportation

As the other ways of transportation, air transport is facing fierce competition. Airline companies search to decrease operational costs such as staff, fuel, navigation, landing, and maintenance costs and at the same time to improve quality service. The optimization of plane maintenance is thus necessary, by making optimal schedules according to periods, duration, and type of maintenance. J.Díaz-Ramírez et al. (2014) have treated the Aircraft Maintenance Routing Problem (AMRP) and the Crew-Scheduling Problem (CSP) in sequential and integrated fashions for airlines having a fleet with a single maintenance base; they have adapted a labeling and the Column-Generation (CG) solution algorithms. Recently, several airlines ticket sale agencies have proposed new services as door-to-door service of Pickup and Delivery of Customers to the Airport (D2PDCA), which offers a higher quality service alternative to usual airport shuttle. J.Tang et al. (2015) proposed exact algorithms based on the Trip-Chain-Oriented Set-Partitioning (TCO-SP) model for the resolution of this problem.

### 4.3 Vehicle scheduling problem solutions methods

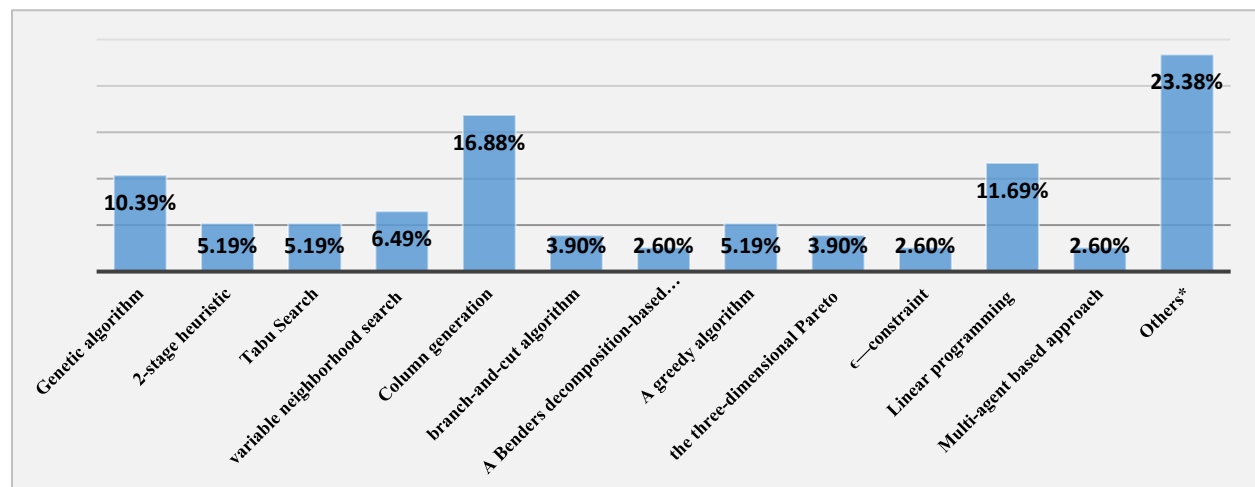


Figure 5: The main resolution methods used in 77 scheduling problem articles.

Others\* contains other solutions methods not often used, such as a Customized heuristic algorithm; Simulation-based evaluation method; a Multi-cut L-shaped based algorithm; a Clonal selection algorithm; exact algorithm based on the trip-chain-oriented set-partitioning; a Partition algorithm; Differential evolution algorithms ; and others metaheuristic algorithm.

We notice that the column generation method is the most used for solving scheduling problems, which is normal because this method solves effectively large linear optimization problems like most variants of the MDVSP; but generates the phenomenon of degeneracy, which must be combated with other methods.

Table 3: Solution methods and the scheduling problems treated.

<b>Solution methods</b>	<b>The scheduling problems treated</b>
<b>Genetic algorithm</b>	Uncertain Regional Bus Scheduling Problems; Scheduling and Delivery Problems; Block Transportation Scheduling; Emergency Logistics Scheduling; Location-Scheduling Programming; Maintenance Scheduling of Geographically Distributed Assets; Scheduling Trucks; Multistage Assignment Optimization
<b>2-stage heuristic</b>	A truck Scheduling Problem; Scheduling in Intermodal Transport; Inland-Empty-Container Depot Locations. Transit Stop Inspection and Maintenance Scheduling
<b>Tabu Search</b>	Inland Container Transportation Problem; Scheduling Operations based on Readiness Criteria; Schedules for Sequential Agricultural Operations; A Dial-a-Ride Problem
<b>Variable neighborhood search</b>	Multi-Depot Vehicle Routing Problem; Scheduled Penalty; the Electric Vehicle Scheduling Problem; Bi-objective Orienteering for Personal Activity Scheduling; Bi-objective Orienteering for Personal Activity Scheduling
<b>Column generation</b>	Ship Routing and Scheduling Problems ; Routing and Crew Scheduling Planning; Planning towing processes at airports ; the Multiple-Depot Vehicle Type Scheduling problem; Freight Railway Operator Timetabling and Engine Scheduling; Delay Management in Public Transportation; the Train unit Scheduling Problem; The Multi-Vehicle Traveling Purchaser Problem ; Integrated Operational Transportation Planning Problem ; the Multi-Depot Vehicle Scheduling Problem; the Multi-Period Technician Routing and Scheduling Problem; Optimization of Periodic Crew Schedules; High School Timetabling.

## 5. CONCLUSION

In the present time, transportation management has become increasingly important, especially when we take into consideration the increase in demography and human development, which generate high demands. Therefore, plants implantations have become exponential to meet these demands, making logistics management difficult in terms of supply, shipping, and transportation of personnel; as there are several modes of transportation, this management becomes much more complicated to manage. In our paper, we are interested in the VRP and MDVSP, because they have a common objective which is to reduce the fleet size and then to reduce the costs. The objective of this literature review is to give an idea about the solution methods that have been used to tackle such problems in recent papers in this area.

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