A SURVEY ON THE VEHICLE ROUTING PROBLEM AND ITS VARIANTS

V.Bugcy Mettilda[1], D. Saravanan[2]
[1] Research Scholar,[2] Professors, Department of Mathematics,
JJ College of Arts and Science (Autonomous), Pudukkottai, Tamilnadu, India.

Abstract:Vehicle Routing Problem (VRP) plays an important role in logistics management and has been broadly used as a partof Transportation Framework, Logistics Distribution Frameworkand Faster Delivery System. In this paper, we have conducted a literature review on the recent developments and publications involving the Vehicle Routing Problem and its variants, namely Vehicle Routing Problem with Time Windows (VRPTW) and the Capacitated Vehicle Routing Problem (CVRP) and also their variants. The VRP is classified as an NP-hard problem. Hence, the use of exact optimization methods may be difficult to solve these problems in acceptable CPU times, when the problem involves real-world data sets that are very large. The vehicle routing problem comes under combinatorial problem. Hence, to get solutions in determining routes which are realistic and very close to the optimal solution, we use heuristics and meta-heuristics. We discuss the characteristics and classification of VRP, the constraints in VRP Solutions and future of VRP solutions in coming years.We also discuss the various VRP Solutions using Bio-inspired algorithms like Ant Colony Optimization(ACO), Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO) and Genetic Algorithm (GA). VRP is viewed as a smart vehicle routing problem and the intelligent heuristic algorithm will be a critical field of futureresearch.

Keywords: Vehicle Routing Problem, Exact Methods, Heuristics, Meta-Heuristics, VRPTW,Bio-inspired algorithms, Ant Colony Optimization, Genetic Algorithms

1. Introduction

Vehicle Routing Problem was first proposed by Dantzig and Ramsarin 1959[1],and is mainly used to design an optimal route for a fleet of vehicles to service a set of customers, given a set of constraints. The subject quickly attracted the attention of experts and scholars, such as operations researchmanagement, computer graph theory, and proved to be widely used in transportation system, logistics distribution system and express delivery system. After several decades of development, the vehicle routing problem has become an important part of logistics management research, and is classified as the general term for such type of problem: by a number of vehicles from one or more warehouses to multiple geographically distributed customers, how to arrange the vehicle and itsroutes tominimize the total distribution costs. The vehicle routing problem (VRP) has been very extensively studied in the optimization literature.Now VRP offers a wealth of heuristic and meta- heuristic approaches. The VRP is so widely studied because of its wide applicability and its importance in determining efficient strategies for reducing operational costs in distribution networks.

The VRP was first statedby[1] that was about the routing of a fleet of gasoline delivery trucks between a bulk terminal and a number of service stations supplied by the terminal. The distance between any two locations is given and a demand for a given product is specified for the service stations. The VRP can be defined as the problem of designing least cost delivery routes from a depot to a set of geographically dispersed locations (customers) subject to a set of constraints. Today, exact VRP methods have a size limit of 50-100 orders depending on the VRP variant and the timeresponse requirements. Consequently, current research concentrates on approximate algorithms that are capable of finding high quality solutions in limited time, in order to be applicable to real life problem instances that are characterized by large vehicle fleets and affect significantly logistics and distribution strategies.

2. Classification of Vehicle Routing Problem.

At present, the enthusiasm of experts and scholars of the VRP research is high, and according to different perspectives, the classification of VRP:

1. According to the number of distribution centers: single distribution center and multi-distribution center problem;
2. According to the type of vehicle:single –vehicle type and multi-vehicle type problem;
3. According to the characteristics of the task: pure send (take) cargo problem and loading and unloading mixing problem;
4. According to whether the time constraints: no time window problem and time window problem;
5. By vehicle loading: And the problem of non-full load;
6. According to the optimization of the number of goals: a single objective and multi-objective problem;
7. Vehicle and vehicle by the ownership of the points: the vehicle open problem and vehicle closure problems;
8. By mastering the information of certainty: Sexual VRP and non-deterministic VRP problems;

As can be seen from these classifications, solutions to the VRP problem are varied, each category will be mapped a corresponding models and algorithms for solving the natural process is varied. But back to the original point of view to build the model of VRP,VRP problem can be seen as a variant or in combination with integer programming model of graph theory model or other models among which we can find some rules, to achieve the purpose of solving.

3. Constraints of vehicle routing problem

As mentioned earlier, VRP problems have a variety of classification methods, for different classification methods also have different corresponding models and algorithms. However, no matter how complex the model of the algorithm, common constraints in the discussion of VRP problem is the same capacity constraints [2].

1. Capacity constraints: regardless of which vehicle, it should be less than the total path of the vehicle load capacity. The vehicle routing problem with capacity constraints is brought forward.
2. Priority constraints: leads to the priority of the vehicle to constrain the path problem.
3. Vehicle constraints: leads to multi-vehiclevehicle routing problem.
4. Time window constraints: including hard time window, soft time window constraints. The vehicle routing problem with time window (including hard time window and soft time window) is brought forward.
5. Compatibility constraints: leads to compatibility constraints of the vehicle routing problem.
6. Radom demand: leads to a random demand for the vehicle routing problem.
7. Open: leads to open the path of the vehicle problem.
8. Multi- transport center: leads to a multi-transport vehicle routing problem.
9. Return transport: leads to a return route with the vehicle routing problem.
10. The last time period: leads to the vehicle with the last time period issue.
11. Vehicle speed changes with time: with time leads to the vehicle speed with time changes in vehicle routing problem.

4. Variants of VRP

In this section vehicle routing variants are explained.

4.1 VRP with Time Windows

In VRP Time Windows, for every consumer,goods must be distributed in certain time window with known demands along with least cost and distance. The vehicles cannot arrive earlier or later than the time [3,4,5] . In case if the vehicle arrives earlier then the earliest arrival time and waiting time will occur. Each customer should also consider the service period for loading or unloading the goods for each route. VRP using Time Windows aims to reduce the vehicle fleet, overall travel period and waiting time [5] .

4.2 Capacitated VRP

In CVRP, the vehicle has capacity limitation where the goods must be distributed to the customer from a common depot at lowest travel cost and every vehicle must have equal capacity for a single product. CVRP aim is to reduce the vehicle fleet, sum of travel period and the overall demand of commodities for each route that may not exceed the capacity of the vehicle, which serves that route [6,7,8]. The solution is achievable if the overall quantity assigned to each route should not go beyond the vehicle capacity.

4.3 Multiple Depot VRP

In Multi-Depots Vehicle routing problem, first it entails the assignment of customers to the depots. Customers are serviced by several depots, each depot having their own fleet of vehicles. Each vehicle departs from a depot and finally turns back to the original depot with respective constraints (capacity distance travelled along with time window). The routes of all vehicles are intended before they depart from the original depots [9,10] . MDVRP goal is to reduce the vehicle fleet, travel period, and overall demand of commodities that must be distributed from various depots. The solution is achievable if each route fulfils the standard VRP conditions.

4.4 Periodic VRP

In periodic vehicle routing problem variant customers must be served many times for a given designed period and the set of dates in which a vehicle serves a customer is not fixed earlier, but instead a list of possible set of dates is related through every customer. Whenever the customer is served and its duty period or vehicle capacity is over the vehiclescan turn backs to the original depots [11,12]. The objective is to reduce the vehicle fleet and the overall travel period needed to supply all customers while satisfying operational constraints.

4.5 Split Delivery VRP

In the Split Delivery Vehicle Routing Problem, visiting each customer only once rule is removed, instead deliveries can be split and served many times and the demands can be larger than the vehicle capacity and number of vehicle constraints is also excluded. The main intention of SDVRP is to distributing the customers goods and in each tour, it does not exceed the capacity of the vehicles and the overall distance travelled is reduced. A solution is possible by satisfying the VRP rules including that the customers may be delivered by using a greater number of vehicles [13,14].

4.6 Stochastic VRP

In stochastic vehicle routing problem where some information is random, it is not necessary to satisfy all the rules.The goal of this variant is to reduce the vehicle fleet and stochastic or service period along with the customer demands. A feasible policy for the vehicle is any strategy of visiting locations such that all demands are satisfied[15].

4.7 VRP with Backhauls

The vehicle Routing Problem with Backhauls incorporates customers to whom the goods are to be distributed and a set of sellers whose goods need to be shift back to the depots. In VRPB, distributions for each path must be accomplished earlier any pickups are made, this is to avoid the rescheduling the loads on the vehicles. The goal of VRPB is to minimize the overall distance toured. In VRPB routes which have only pickup is not acceptable and deliveries should be made before pickups without omitting the constraints [15].

4.8 VRP with Pick-Up and Delivery

In VRPPD customers can resend some goods and it must fit into the vehicle and this constraint faces challenging problems like planning, bad consumption of the vehicle volumes, enlarge travel distances and number of vehicles also increases. Due to this issues cost is increases to face the consumer needs. The solution is achievable if each route fulfils overall quantity allotted without violating capacity rule and also vehicle should have sufficient capacity for picking – up the products at the customers [16].

4.9 VRP with Satellite Facilities

In satellite Facilities there are no restrictions for the vehicle to return back to the depot, it can continuously deliver the goods to the customer until the duty period of the deliver is over. Distribution of fuels and certain retail items are the main application for this variant. Satellite facility is an intermediary facility with unlimited supply used for the replenishment by a vehicle. Extra cost arises to optimize the routes when the customer needs is random and this variant helps to safeguard against unpredicted demands [17].

4.10 Open Vehicle Routing problem.

In OVRP variant, vehicles not necessary to return back to the distribution center if it requires, similar route in the reverse order is used [18,19]. The OVRP describes well-organized paths with least overall distance and cost for the vehicles that distribute the goods to the consumers.Each consumer must visit once by unique vehicle,along with capacity and time constraints. The foremost variance among Open Vehicle Routing Problem and Vehicle Routing Problem is that the paths in the Open Vehicle Routing

Problem contains Hamiltonian paths starts at the depot and ends with customer, while the paths in the Vehicle Routing Problem remains Hamiltonian cycles. OVRP aims to reduce the total vehicles used and minimize the overall distance covered and the issue faced by this variant is cost for the extra vehicle but it reduces the distance with extra paths.

5. Bio-inspired algorithms

Swarm Intelligence (SI)-based algorithms belong to a wider class of algorithms, called Bio-Inspired Algorithms (BIA). In fact, bio-inspired algorithms form a majority of all nature–inspired algorithms. From a theory point of view, SI-based algorithms are a subset of bio-inspired algorithms, while bio-inspired algorithms are a subset of nature –inspired algorithms. Vehicle routing problem is one of the Nondeterministic Polynomial-Hard combinatorial optimization problems which focuses on optimizing the routes and reduces the overall cost of the routes with minimum distance. Bio-inspired algorithms solve optimization problems which have the capability to define and decide difficulty dealings from nature by using simple rules.

5.1 Ant Colony Optimization (ACO)

ACO is a technique useful in problems that deal with finding better paths through graphs. In (G.Dantzig and J.Ramser,1959) a mathematical model and an algorithm based on ant colony optimization to solve a long distance routing problems are considered. Small Freight size with several time constraints is solved using Last In First Out "LIFO" policy. The objective here is about reducing costs by optimizing the loading of the passenger in vehicles, grouping orders and minimizing a number of routes. The performance of the algorithm is said to be verified by using experimental data based on historical data from a large Spanish transport company.

5.2 Artificial Bee colony (ABC)

Artificial Bee Colony is a predominant algorithm simulating the intelligent foraging behavior of a honeybee swarm, proposed by Karaboga and Basturk[20].In ABC algorithm, the colony of artificial bees contains three groups of bees: employed bees, onlookers and scouts.A bee waiting on the dance area for deciding to choose a food source is called onlooker and one going to the food source visited by it before is named employed bee. The other kind of bee is scout bee that carries out random search for discovering new sources. The position of a food source represents a possible solution to the optimization problem and the nectar amount of a food source corresponds to the quality(fitness) of the associated solution. A swarm of virtual bees is generated and started to move randomly in two-dimensional search space. Bees interact when they find some target nectar and the solution of the problem is obtained from the intensity of these bee's interactions.

5.3 Partial Swarm Optimization (PSO)

PSO is an evolutionary computation technique firstly introduced by Kennedy Eberhart (John Jairo Santa Chavez, 2015).It is inspired by the behavior of birds when looking for their food. This algorithm is based on population. In PSO terms swarm is used for a group of particles say a population which moves in search space to find the shortest distance between source and destination (IvonaBrajevic,2011). The fitness of particles is evaluated on the basis of a search function. Particles move through search space by dynamically updating their velocities leading to the new position of the particle. This method achieves local best and global best if and only if the new values are better than previous values. After maximum iteration, this algorithm generates global best having best fitness.

5.4 Genetic Algorithm (GA)

Genetic algorithm [21, 22]was derived from Darwin's theory of evolution. A genetic algorithm-basedhybrid approach is to solve clustered VRP. In this type of VRP passengers are grouped together to form clusters and these clusters are served by the same depot. To find optimum clustered route for the above genetic algorithm is used in combination with local – global approach. This approach is used to distinguish between local and global connections of clusters. Hence genetic algorithm presence a search technique which can be used to generate true or approximate solutions to optimization and search problems in a better manner. The objective for a VRP function is to minimizethe number of routes or the number of vehicles utilized; the optimal number of routes is unknown. A secondary objective is to minimize the total time or distance travelled [Sheng-HuaXu,2015].

Many of the most successful meta-heuristics for the large VRPTW instances are based on some form of parallel computation. In [22], they were the first to apply a genetic algorithm to VRPTW.They hybridized a genetic algorithm with a greedy heuristic. Under this scheme, the genetic algorithm searches for a good ordering of customers,while the construction of the feasible solution is handled by the greedy heuristic. During the past few years, numerous papers have been written on generating good solutions for VRPTW with GAS. Almost all these papers present hybridizations of a GA with different construction heuristics [22, 23] a, local searches [24] and other meta-heuristics such as tabu search [25] and ant colony system [26].

The authors [27] have considered a variant of VRPTW constrained by a limited vehicle fleet, which is a more realistic problem in logistics. A limited number of vehicles is given (m- VRPTW)). Under this scenario,a feasible solution is one that may contain either un-served customers and /or relaxed time windows. They present an analytical upper bound for that formulation, and show that their tabu search approach came fairly close to the upper bound. This algorithm is also good from the stability point of view.They also show that the same algorithm could be used to give reasonably good results for the standard VRPTW problem.

The authors [28] propose a cellular Genetic Algorithm (CGA)which is a kind of decentralized population-based heuristic, which is used for solving CVRP, improving several of the best existing results so far in the literature. Their study shows a high performance in terms of the quality of the solutions found and the number of function evaluations (effort).

5.5 Evolutionary Algorithm

A multi-objective evolutionary algorithm (EA)for solving the VRPTW was suggested by [29], For multi-objective problems, heuristics generally have two aims (1) To minimize the distance of the generated solutions, called the pareto approximation, from the true pareto front, and second to maximize the diversity of them.Evolutionary algorithms (EAs) are optimizers based on Darwin's theory of evolution, where only the fittest individuals survive and produce offspring to populate the next generation.

In this article, [30] proposed a hybrid ACO algorithm for solving vehicle routing problem (VRP) heuristically in combination with an exact algorithm. In the basic VRP, geographically scattered customers of known demand are supplied from a single depot by a fleet of identically capacitated vehicles. The intuition of the proposed algorithm is that nodes which are near to each other will probably belong to the same branch of the minimum spanning tree of the problem graph and thus will probably belong to the same route in VRP. Given a clustering of client nodes, the solution is to find a route in these clusters by using ACO with a modified version of transition rule of the ants. At the end of each iteration, ACO tries to improve the quality of solutions by using a local search algorithm, and update the associated weights of the graph arcs.

6. Conclusion

Vehicle routing problems forms an integral part of supply chain management, which place the significant role for productivity improvement in organizations through efficient and effective delivery of goods/services to customers. In this paper an attempt has been made to survey the resent development in the vehicle routing problems (VRP) and its variants. The literature is classified into exact methods, heuristics approaches, meta-heuristics. Since the VRPTW is a combinatorial problem, development of efficient heuristic is inevitable to find near/ global optimal solution. So, in this paper, in the next section, the contributions of researches in two categories, viz heuristics& meta – heuristics have been presented.

Various vehicle routing problems and its solutions by applying bio-inspired algorithms like Ant Colony Optimization (ACO), Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) are studied in this paper. It is found that the total demand of each passenger is fulfilled. Guarantee that the vehicle capacity will not be exceeded. It is known that the demand of each passenger will only be fulfilled if a determined vehicle goes by the place. A research shows that with the expansion of the scale of logistics distribution, the research of exact algorithm has little significance. In the future for a long time, construct the approximate algorithm, especially the intelligent heuristic algorithm will be the important content of VRP algorithm research. The rapid development of social economy, consumer demand for quality of service is also progress, logistic, as a producer services industry, the importance of this area should be increased.

REFERENCES

[1]Dantzig, G. andRamser,J.1959. The Truck Dispatching Problem,Management Science,6(1):80-91

[2]Dorigo, M. Maniezzo, V. and Colorni, A. 1996. Ant System: Optimization by a colony of cooperating agents, IEEE Transactions on System, Man, and Cybernetics-Part B,26,29-41.

[3] Luo, J. Chen, MR.2014. Multi-Phase modified shuffled frog leaping algorithm with extremal optimization for the MDVRP and the MDVRPTW, Computers and Industrial Engineering. 72:84-97.

[4] EI-Sherbeny, NA. 2010. Vehicle routing with time windows: An overview of exact, heuristic and metaheuristic methods, Journal of King Saud University (Science). 22(3):123-31.

[5] Jindal, P.2011. Towards The Solution of variants of vehicle routing problems, Global Journal of Computer Science and Technology.11(15-1).

[6]Allahyari, S. Salari, M. and Vigo, D.A. 2015. Hybrid metaheuristic algorithm for the multi-depot covering tour vehicle routing problems, European Journal of Operational Research. 242(3):756-68.

[7]Berhan, E. Kromer, P. Kitaw, D. Abraham, A. and Snasel, V.2014. Solving stochastic vehicle routing problem with real simultaneous pickup and delivery using differential evolution, Innovation in Bio–inspired Computing and Applications Advances in Intelligent Systems and Computing. 237:187-200.

[8] Pan, F. Ye, C. Wang, K. and Cao, J. 2013. Research on vehicle routing problems with time windows using firefly algorithm, Journal of Computers. 8(9):2256-61.

[9] EI-Sherbeny, NA.2010. Vehicle routing with time windows: An overview of exact, heuristic and metaheuristicmethods, Journal of king Saud University (Science). 22(3): 12331.

[10]Marinakis, Y. Marinaki, M. and Spanou, P.2015. A memetic differential evolution algorithm for the vehicle routing problem with stochastic demands, Adaptation and Hybridization in Computational Intelligence Adaptation, Learning, and Optimization. 18:185-204.

[11]Kurdel, P.andSebestyenova, J. 2013. Routing optimization for ATM cash replenishment, International Journal Of Computers. 7(4):135-44.

[12]Gaur,V.2004. A periodic inventory routing problem at a super market chain, Operations Research. 52(6):813-22.

[13]Archetti, C. and Speranza, MG. 2012. Vehicle routing problems with split deliveries, International Transaction Operational Research.

[14]Campos, V. Corberan, A. and Mota, E.2008. A scatter search algorithm for the split delivery vehicle routing problem.Advances in Computational Intelligence in Transport, Logistics and Supply Chain Management Studies in Computational Intelligence. 144:137-52.

[15]Bard, JF. Hung, L. Dror, M. and Jaillet, P.1998. A branch and cut algorithm for the VRP with satellite facilitie 30:821-34.

[16]Cueve, R. and Tupia, M. 2013. A continuous genetic algorithm for pickup and delivery problem in a VRP environment, Advances in information Sciences and Service Sciences (AISS). 5(10):1110-9.

[17]Escudero, A. Munuzuri, J. Arango, C. and Onieva, L.2011 .A satellite navigation system to improve the management of intermodal drayage, Advanced Engineering Informatics. 25(3):427-34.

[18] Available from: http://www.bdigital.unal.edu.co/47414/1/80190790.2015.pdf

[19]Ropke, S.andPisinger, D.2004. A unified Heuristic for a large classof vehicle routing problems with backhauls.

[20]Karaboga,D. and Basturk,B. 2007. A Powerful and Efficient Algorithm for Numerical Function Optimization, Artificial Bee Colony (ABC) Algorithm, Journal Global Optimization, 39

[21]Liu, Yun-Zhong, XUAN Hui-Yu.2005. Review of Models and Algorithms for Vehicle Routing Problem, Chinese Journal of Management, (1):124-130.

[22]Blanton,J.l. and Wainwright,R.L.1993. Multiple Vehicle Routing with and Capacity Constraints using Gengtic Algorithm, Proceeding of the 5th International Conference on Genetic Algorithms, 452-459.

[23]Berger,J. Salois,M. and Begin,R.A.1998. Hybrid Genetic Algorithm for the Vehicle Routing Problem with Time Windows, Lecture Notes in Artificial Intelligence 1418,Springer, Berlin,114-127.

[24]Potpin,J-Y. andBengio,S.1996. The Vehicle Routing Problems with Time Windows Part II: Genetic Search, INFORMS Journal on Computing, 8(2):165 – 172.

[25]Thangiah,S.R. Osman,I.H. and Sun,T. 1995. Hybrid Genetic Algorithms, Simulated Annealing and Tabu Search methods for Vehicle Routing Problems with Time windows, Technical Report UKC/OR94/4,Institute of Mathematics and Statistics, University of Kent, Canterbury,

[26] Berger,J. Barkaoui, M. and Braysy,O.A.2003. Route-Directed Hybrid Genetic Approach for the Vehicle Routing Problem with Time Windows, INFOR, 41(2):179-194.

[27]Hoong,C.L. Sim,M. and Teo,K.M. 2003. Vehicle Routing Problem with Time –Windows and a Limited Number of vehicle, European Journal Operational Research, 148(3):559-569.

[28]Alba,E. and Dorronsoro,B.2005. The Exploration / Exploitation Tradeoff in Dynamic Cellular Genetic Algorithms,IEEE Transactions on Evolutionary Computation, 9(2):126-142.

[29]Abel,G-N.and Bullinaria John, A.2011. An Improved Multi – Objective Evolutionary Algorithm for the Vehicle Routing Problem with Time Windows" Computers & Operations Research, 38(1):287-300.

[30]Aziz, E. 2010. An Algorithm for the Vehicle Problem, International Journal of Advanced Robotic Systems, 7(2):125-132.