International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2017 IJSRCSEIT | Volume 2 | Issue 5 | ISSN : 2456-3307

A Survey on Proficient Solution for Automobile Routing Problem

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ABSTRACT

A solution is designed for the vehicles to minimize the cost of distribution by which it can supply the goods to the customers with its known capacity can be named as a vehicle routing problem. In Clarke and Wrights saving method and Chopra and Meindl savings matrix method mainly an efficient vehicle routing can be achieved by calculating the distance matrix and savings matrix values based on the customers location or the path where the customer's resides. The main objectives of this paper are to reduce the total distance and the total number of vehicles which is used to deliver the goods to the customers. There are few new algorithms which are mainly based on the min-min, max-min and k-means clustering algorithm techniques which are used in cloud computing and data mining scenario effectively. The proposed algorithm decreases the total distance and the number of vehicles assigning to each route. The important thing we need to consider here is that, this new algorithm can enhance the Chopra & Meindl saving matrix method and Clarke and Wright saving matrix method.

Keywords: K-Means, Min-Min, Max-Min, Saving Matrix, Vehicle Routing Problem

I. INTRODUCTION

In general, there are many practical applications which can provide efficient distribution of goods to the customers. Goods in the sense it can be any home appliance products which are used daily.

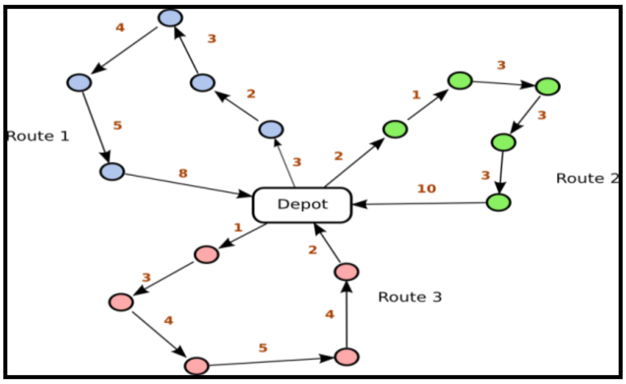

Figure 1. Example for Vehicle Routing Problem

The vehicle scheduling problem was first formulated in the year 1959 [8] and in that set of customers with each of its known locations and known demand for any commodity, and that required goods can be delivered to the customer from a single depot by some calculated amount of delivery vehicles with some basic conditions and constraints are specified [2]:

(i) The demands of all customers are met
(ii) Each customer is served by exactly one vehicle
(iii) For each route the total demands must not exceed the capacity of the vehicle which is already defined.

From a depot different products must be distributed to several retailers. An efficient collection (or) distribution of goods keeps transport inventories low, it saves resources and energy. Therefore vehicle routing is one of the important topics for this kind of problems.

The vehicle routing problem is a common name given to a whole class of problems involving the visiting of customers by using vehicles. These problems derive their name from the basic practical problem of supplying geographically dispersed customers with goods using a number of vehicles operating from a common goods depot (or) warehouse.

An example for a single depot based vehicle routing problem is shown in the Figure 1. For a classical vehicle routing problem, the best solution is to serve the goods to the customers exactly once by starting from and ending to the depot.

The main objective is to reduce the overall transportation cost of satisfying all the constraints. The cost for transporting the goods can be reduced by minimizing the total distance travelled and as well as the total number of vehicles. While comparable to the classical vehicle routing problem, the majority of the real world problems is much more complex to solve. In general the classical vehicle routing problem is based on some constraints like the total vehicle capacity or some time interval to reach the customers.

A single depot vehicle routing problem uses a single depot (or) warehouse for delivering the goods to the customers, several algorithms and saving methods are proposed for solving the single depot based real time problems. In general, the VRP is a Combinatorial Optimization Problem and it consists of two main things are depot and destinations. A formal example for this kind of problem is Soft Drink Company. In that they are travelling from the company to all the retail stores to distribute the products and again came back to the company. The main constraint followed here is to visit the customers exactly once.

Vehicle routing problem is also known as vehicle scheduling or delivery problem. For example, Garbage must be collected from households and industries to a distracting place, so for transportation that we need an efficient route to travel from one place to another. It is very much useful for the daily transportation because it reduces the cost of forming the routes based on the capacity of the vehicle.

The rest of the paper is organized as follows. Section II presents the literature review about the existing methodologies. Section III presents a numerical example, using Clark and Wright saving method. Section IV describes the proposed methodology based on Min-Min, Max-Min and k-means clustering methods. The final conclusion is presented in Section V.

II. LITERATURE SURVEY

The first article for the 'Truck dispatching problem' was published by Dantzig and Ramser (1959)[8] who presented a larger truck dispatching problem, that is referred to as D&R problem and many more publications has been made which is completely relevant to this article after it was published.

The Clark and Wright algorithm (1964) [9] is one of the most popular heuristic algorithms in the vehicle routing problem. Laporte (1992) [11] describes the Clark and Wright algorithm with the following steps:

Step 1. Select the warehouse as the central city and a distance matrix calculated.
Step 2. Calculate the savings $S_{ij}=c_{i0}+c_{0j}-c_{ij}$ sigh for all pairs of cities (customers) i,j (i=1,2,…n; j=1,2,…n; ij).
Step 3. Order the savings, S_{ij} from largest to smallest.
Step 4. Starting with the largest savings, do the following:

(a) If linking cities I and j results in a feasible route, and then add this link to the route;
(b) Try the next savings on the list and repeat (a).

Do not break any links which are formed earlier. Start new routes when necessary and stop when all the cities are on a route.

Cordeau et al. (2002)[6] present that parallel version is much better because merge yielding the largest saving is always implemented, but the sequential version keeps expanding the same route until there is no longer feasible route.

Chopra and Meindl (2004)[3] provide a solution for transport planning, in that they present a routing and scheduling, transportation problem for a company in which they solve with a method called savings matrix method. It can be classified into four steps which are: (1) Identify the distance matrix for the given location, (2) calculating the saving matrix using the distance matrix values, (3) assigns, customers to vehicles or routes, and (4) sequence the customers within the routes. The first two steps are explained clearly. The third step is that assign the customers to vehicles and routes by, initially each customer are assigned to a separate route. If the two routes can provide a feasible solution by which it doesn't cross the limited capacity means it can be combined. The procedure is continued until no more feasible combinations are possible.

For a transportation problem, Lumsden (2006) and Jonsson (2008) present a similar explanation but it is not clear. Rand (2009) made an analysis and presents an article about the different saving methods for the vehicle routing problems. In that he argues about the parallel version, because it is not always better than the sequential version. Parallel version is a heuristic and there is no assurance from the obtained results that it produces the optimal solution or near optimal solution.

Mainly Chopra and Meindl savings matrix method [10] decreases the total length of the trip about 7% and even a better solution is obtained against this method by decreasing the total distance of about 3%. Chopra and Meindl description present a clearer idea about saving methods than the original Clarke and Wright (1964) algorithm, even though so many wonder that how a vehicle routing is done effectively. The method presented here is widely used in the teaching section since 2008, because it provides an excellent result and easy to implement when compared to the Clarke and Wright method. An important advantage for saving methods in vehicle routing problem is its simplicity and robustness. So it's a best suited one for vehicle routing problem.

Anders et.al (2013) [1] provides an enhanced solution for Clarke and Wright's saving method by introducing the search procedure method. It is same as that of Clarke and Wright algorithm, but in addition to that, the final routes are arranged in different order to reduce the total distance. This method only produces an enhanced solution for truck dispatching problem which was already solved by Dantzig and Ramser in the year 1959.

III. NUMERIC EXAMPLE

The ultimate base for the vehicle routing problem is travelling salesman problem because the constraint "visit all the customers exactly once" used in the vehicle routing problem is as same as that of travelling salesman problem. Imagine that a delivery boy must visit some 'n' number of customers and returned to the starting point after visiting all the customers exactly once and the total cost for visiting all the customers is the major problem.

The solution is to obtain a minimum cost route to visit all the customers exactly once. Suppose when the cost for travel from city x to city y is equals to the cost of city y to city x, then the problem is symmetric. If $C_{xy} \neq C_{yx}$ means then the problem is asymmetric. Starting from the central depot (or warehouse), goods or items delivered to the customers: 0-8. Initially the distance for each customer is presented in the Table I as locations and the demands for each customer are also given. This problem is solved using the Clarke and Wright's saving method.

According to the existing scenario both the Clarke & Wright savings method and Chopra & Meindl savings method uses the symmetric cost for returning to the depot, i.e. the distance from 1 to 5 is the same as the distance from 5 to 1 etc.

TABLE I. Distance and Demands for Customers

Customer	Location	Demand
1	(22,22)	18
2	(36,26)	26
3	(21,45)	11
4	(45,35)	30
5	(55,20)	21
6	(55,45)	16
7	(26,59)	29
8	(55,65)	37

Here the location for the depot (or warehouse) is (40, 40) (x-axis and y-axis values) and obviously the demand is zero. Based on the customer location, initially distance matrix [13] is calculated using the Equation 1 and its cost are symmetric.

Equation 1, Distance matrix formula

$$D(c_i, k) = \sqrt{(x_{c_i} - x_k)^2 + (y_{c_i} - y_k)^2} \quad (1)$$

TABLE II. Distance Matrix Calculation

C_{ij}	0	1	2	3	4	5	6	7
0	-	26	15	20	7	25	16	24
1		-	15	23	26	33	40	38
2			-	24	13	20	27	35
3				-	26	42	34	15
4					-	18	14	31
5						-	25	49
6							-	32
7								-

Equation 2, Savings matrix formula,
Which represents the distance between the customer c_i and the depot k. The calculated distance matrix values are shown in the Table II. Based on the calculated distance matrix values, the cost savings is calculated using the Equation 2 and here also the values are symmetric which are shown in the Table III.

$$S(c_i, c_j) = D(k, c_i) + D(k, c_j) - D(c_i, c_j) \quad (2)$$

TABLE III. Savings Matrix Calculation

S_{ij}	1	2	3	4	5	6	7	8
1	-	26	23	7	18	2	12	1
2		-	11	9	20	4	4	1
3			-	1	3	2	29	10
4				-	14	9	0	4
5					-	16	0	9
6						-	8	25
7							-	23
8								-

Once the values are found, it is arranged in a non-increasing order (from largest to smallest), and then the routes are combined one by one up to the total capacity is reached.

TABLE IV
Solution for the Problem with Four Routes

	Trip	Total Distance	Total Demands
Route1	0-1-2-5-0	86	65
Route2	0-3-7-0	59	40
Route3	0-4-0	14	30
Route4	0-6-8-0	65	53

If the newly added route exceeds the total capacity, then the new link is discarded and the previously formed links are undisturbed. Based on the total capacity defined earlier, the number of vehicles may found along with the feasible route for each vehicle.

The maximum vehicle capacity defined in this example is 70. Table IV shows that the result with the total distance of 224 and four vehicles is needed for that transportation. Finally the search procedure applies to the final routes, it reduces the total distance of 1% compared to the Clarke and Wright saving method but the total number of vehicles is increased by one.

The search procedure method doesn't produce a better solution, but Chopra and Meindl savings matrix method produces a result of about 3% decrease in the total cost of the trip. This decrease is not enough when the vehicle is used daily for delivering the goods to the customers, so for these new methods are proposed to solve the same kind of vehicle routing problems.

IV. PROPOSED METHODS

The first parameter is the total distance travelled to deliver the goods or some products to different distribution points. Because of routing problems, the main thing that all need to focus is on the total distance. If the total distance is reduced at some amount of range means definitely the total cost is reduced gradually in parallel. The second parameter is the total number of vehicles. This type of parameter will help for a large instance set of problems which are mainly related to real world applications. When the total distance is reduced to a somewhat minimum then the time consumption is reduced because the time consumption is calculated based on the total distance travelled to distribute the goods to the customers.

The first two proposed methodologies are mainly based on min-min and max-min methods [10] which are effectively used to solve the task scheduling problems with cloud computing. Using these two methods, the proposed methodology will reduce the total cost when compared to the Chopra and Meindl savings matrix method. Initially the locations (x-axis and y-axis) are marked and based on the capacity (or limit) of the vehicle defined, the total number of vehicles needed to travel can be found.

In existing methods, initially the distance matrix values are calculated using the equation(1) and using that value savings matrix values are calculated to find the most efficient route for the vehicles which are going to deliver the goods to the customers and simultaneously the total load doesn't exceed the maximum vehicle capacity. In Min-Min based proposed method [12], the distance matrix values are found as like the Clark & Wright savings matrix and Chopra & Meindl savings matrix method.

The distance from depot to all customers are found in the distance matrix calculation and from those set of values, the highest minimum values are selected and routed to that customer. After reaching those highest minimum distance customers, again the distance is calculated from that point to all the customers who are all unvisited. The process is carried out by all the customers are reached by the vehicle. The return path for reaching the depot is same because it follows symmetric method.

The second proposed method is based on the max-min method. It is an exact opposite to the min-min method. Initially the first three largest maximum values are selected and that three customers are routed. Once the routing is finished from the depot, again the distance matrix is calculated from the present customer to all the customers who are all unvisited. This process is carried out again and again until all the vehicles reached the depot.

These two methods can produce the result of having the same number of vehicles and total distance when compared to Clarke and Wright's savings method. But one thing mainly need to focus is that Clarke and Wright's saving method doesn't work well for large set of problems. The two proposed methods can work well for large set of problems with ease but the results are same. In order to yield a better result compared to all these methods, a new methodology is proposed.

The third proposed methodology is k-means clustering based method for solving the vehicle routing problem with multiple depots. When the clustering is performed for a set of values, there may be two or more depots can be formed. Based on the algorithm of k-means clustering, two centroid values are found with two sets of customers.

Each set of customers belongs to one centroid value, otherwise called as depot. After that the distance between the customers to particular depot is calculated and finally the total distance and the total number of vehicles needed to perform efficient transportation is found. This method definitely provides a good solution compared to the previous proposals by different authors.

V. CONCLUSION

While calculating the savings matrix approach for the Clark and Wright savings matrix method can provide a good solution for the small instance set, but for a large instance set it doesn't yield a better result. The proposed methods show even a better solution against the previously proposed methods by introducing the min-min, max-min scheduling methods and k-means clustering methods which are mainly used in the cloud computing and data mining concepts. Among the three proposed methods, k-means clustering based method can reduce the total number of vehicles of about 60% (small set of problems) while using multi depots for delivering the products to customers.

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