International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 21 (2018) pp. 15247-15254

Solution to a Capacitated Vehicle Routing Problem Using Heuristics and Firefly Algorithm

Rajulapudi Bala Sai Shankar[1]
M.Tech Scholar, Department of Mechanical Engineering,
Sri Venkateswara University,
Tirupati, Andhra Pradesh, India.

Dr. K. Dharma Reddy[2]
Assistant Professor, Department of Mechanical Engineering,
Sri Venkateswara University,
Tirupati, Andhra Pradesh, India.

Dr. P. Venkataramaiah[3]
Professor, Department of Mechanical Engineering,
Sri Venkateswara University,
Tirupati, Andhra Pradesh, India.

Abstract
In the present day scenario most of the requirements of our day to day life are made by service providers to our footsteps. These services are door delivery off Pizza (Domino's Pizza) within a stipulated time limit, transportation service like office picking of employees or School Children, Milk man delivering milk door-to door, postal and logistic services like Ekart logistics, Blue Dart etc. In such services, service delivery and timely service are very important. These issues mainly require scheduling and routing of service vehicles. The Vehicle Routing problem (VRP) is a combinatorial optimization and integer programming problem seeking to service a number of customers with a fleet of vehicles. Objective of this problem is to minimize the time and distance travelled. Among the various types of VRP'S, Capacitated Vehicle Routing Problem is the most important operational decision related to transport in Supply Chain Management. C-VRP is a Vehicle Routing problem which has an additional constraints like capacity constraint for a vehicle and variable demand at different nodes. Service Providers must plan in such a way that service is delivered to customers at right location to a right person at right time to draw the attention of Customer's satisfaction. In this present work a real time data from a logistic company is collected and evaluated using Heuristic Algorithms like Clarke and Wright Savings Algorithm, Sweep Algorithm and Holmes and Parker Algorithm and results are compared with state-of-art techniques, which shows that performance of Firefly Algorithm (F.A) is feasible for solving this Capacitated Vehicle Routing Problem.
Keywords Capacitated Vehicle Routing Problem, Firefly Algorithm, Heuristic Algorithm, Routing and Scheduling.

INTRODUCTION

Physical distribution is one of the key functions in Logistic industries. Distribution companies face great challenges to organize their fleet efficiently and effectively. It is a very costly function in Logistic & in Supply Chain

Management. Dantzig and Ramser proposed Vehicle routing Problem in the year 1959 as a generalized problem of travelling salesman problem and from then many hundreds of research works have been published on several variants of VRP.VRP's found to be useful in many of the real world applications like newspaper distribution, goods distribution, mail delivery, school bus routing, garbage collection, private travels operation, courier service applications and many more. Even though VRP is classified into many variants the most important and basic variants of VRP are Capacitated Vehicle Routing Problem (CVRP), VRP with time windows (VRPTW), Open VRP (OVRP), Multi Depot Vehicle Routing Problem (MDVRP) and VRP with pickup and delivery (VRPPD).The present variant on which the work is focused is Capacitated Vehicle Routing Problem (CVRP). In this problem, a complete study was done on a Private Courier service provider, who has a warehouse at particular location, homogeneous vehicles for delivery with a capacity constraints and customers at different places with a particular demand are organized to form nodes. Based on the data collected we will formulate the Forecasted demand at every node point. The distance matrix is formulated from the warehouse to all the nodes available. After this the main objective of our work is to minimize the distance travelled by providing the courier service ,the optimal routes by using Heuristic algorithms like Clarke and Wright Savings method, Holmes and Parker and Sweep algorithm and the results obtained from these algorithms are Analyzed and compared with a Meta-Heuristic algorithm i.e. Firefly Algorithm(F.A). The next phase of the paper is structured as follows; Literature review in section 2, methodology and methods in section 3, data collection in section 4, result analysis in section 5, discussion and conclusion in section 6 and finally references in section 7 at the end of the paper.

LITERATURE REVIEW

Amberg et al (2000) in his paper mainly focused on Capacitated arc routing problem which has Multiple number of centres the main aim is to find out the optimum route starting from the initial depot or centre by satisfying various constraints involved and thereby reducing the travelling cost.Here he used a heuristic algorithm called Capacitated Minimum Spanning tree.Additionally in this paper he also mentioned the possibilities to introduce additional and side constraints into the objective function.After evaluating the results with the real world problems he compared them with Tabu Search , Simulated Annealing and various other Meta Heuristic algorithms.

Caricl et al (2007) in his paper basically proposed and proposed a framework model for solving large and complex vehicle routing problems. He used a Script based modelling language. The performance measures and algorithm is very clearly explained and also a detailed description of how this framework helps in solving vehicle routing problems with time windows. This is a programming language which is very much similar to other languages which consists of syntax, data types, Boolean and various characteristics like loops. Here the list of customers to be served at different nodes and list of vehicles available and their capacity are stored in the database and attributes are assigned to them. But in this paper he was not able to solve the VRP with time windows because in practical and real time view it would become much complex in calculations and due to his time and other constraints he applied on capacitated vehicle routing problem and evaluated the results. The major objective of the paper is finding the best routes by limiting the usage of vehicles and allocating the nodes to the vehicle very effectively there by reducing the cost of the transportation and various other costs.

Mohibul Islam, Sajal Ghosh (2015) in his paper also dealt with the case of capacitated vehicle routing problem. In this basically a real time data of a Coca-Cola distribution company in Bangladesh are taken at various nodes and analyzed and evaluated using various heuristic algorithms like Clarke and wright algorithm, Holmes and Parker algorithm and Fisher and Jaikukumar algorithm and compared the results among them and concluded that Clarke and wright algorithm proved to be more effective for his work and also mentioned that these heuristic algorithms might provide better results for small instances and might be ineffective when the problem becomes complex.

Watanabe and Sakakibara (2007) in the present paper mainly focused on the ways of translating single objective optimization problem into multi objective optimization problem and by using various evolutionary algorithms he stated that the results of multi objective optimization are far better than single objective optimization. Further he also described the differences of dividing the problem into subways and compared them with the traditional methods of solving the problems.

METHODOLOGIES AND METHODS

For solving the capacitated vehicle routing problem (CVRP) three heuristics named Clarke and Wright Algorithm, Holmes and Parker Algorithm and Sweep Algorithm methods are applied and are compared with a Meta Heuristic Algorithm - Firefly Algorithm(F.A). This study finds out the optimum routes by comparing these three algorithms that minimizes the travelling distance of service delivery of the Logistic Company. Here in this project demand data of the past 10 days are collected and Simple Moving Average method is applied to it and an allowance of +5 units is given to every node. The Approximated and the forecasted demands at each node are tabulated.

Clarke and Wright Algorithm

In 1964 Clarke & Wright published an algorithm for the solution of vehicle routing problem, which is often called the classical vehicle routing problem. This algorithm is based on a so-called savings concept. The distance matrix identifies the distance between every pair of locations to be visited. If the transportation costs between every pair of locations are known, the cost can be used in place of distance.
The distance d_{ij} on a grid between a point i with a coordinates (x_i,y_i) and a point j with a coordinates (x_j, y_j) is evaluated as:

$$D_{ij} = \sqrt{}\ ((x_i-x_j\ ))^2 + (y_i-y_j)^2$$

1. Starting solution: each of the n vehicles serves one customer.
2. For all pairs of nodes i,j, i…j, calculate the savings for joining the cycles using edge [i,j]:
   $\mathbf{S_{ij} = C_{0i} + C_{0j} - C_{ij}}$.
3. Sort the savings in decreasing order
4. Take edge [i,j] from the top of the savings list. Join two separate cycles with edge [i,j], if

(a) The nodes belong to separate cycles
(b) The maximum capacity of the vehicle is not exceeded.
(c) i and j are first or last customer on their cycles and Repeat 4 until the savings list is handled or the capacities don't allow more.

Holmes and Parker Algorithm

Clarke and Wright algorithm has its own limitations sometimes. It may not give us a very good solution sometimes. People try to work better, get better solutions compared to the Clarke and Wright. It is possible to get better solution by Holmes and Parker algorithm which is better than the Clarke and Wright solution.

1. This is an extension of Savings Algorithm, the first step in this is we will eliminate the first highest saving considered in the optimum Iteration of Savings Algorithm.
2. Now after the elimination we will initiate the iteration from the next highest saving.
3. Follow the same procedure of Clarke & Wright method.
4. Follow Step 3 & 4 until you get an optimum solution.

5. Terminate the iterations if you are left with an optimum solution.

Sweep Algorithm

This heuristic is of the type "clustering first, route later". Assume the customers are points in a Plane with Euclidean distances as costs. The distance between (x_i, y_i) and (x_j, y_j) is calculated.

1. Compute the polar coordinates of each customer with respect to the depot. Sort the customer by increasing polar angle.
2. Add loads to the first vehicle from the top of the list as long as the capacity allows. Continue with the next vehicle until all customers are included. Now the customers have been clustered by vehicles.
3. The value of Angle (θ_i) is given by $\theta_i = \tan^{-1}(Y_i/X_i)$.

Firefly Algorithm

Firefly Algorithm is a novel nature inspired meta-heuristic algorithm based on rhythmic flashing behavior of Fireflies introduced by Xin-She-Yang in the year 2008. Fireflies are small winged beetles capable of producing a light flashes in order to attract mates. They are believed to have a capacitor like mechanism that slowly charges until certain threshold is reached at which they release the energy in the form of light after which cycle repeats. The Firefly Algorithm (FA) is a nature - inspired algorithm which is based on the social flashing behavior of fireflies. A significant advantage of the algorithm is the fact that it uses mainly real random numbers, and it is based on the global communication among the swarming particles i.e., the fireflies, and as a result, it seems more effective multi objective optimization. In this algorithm, the flashing light helps fireflies for finding mates, attracting their potential prey and protecting themselves from their predators. The swarm of fireflies will move to brighter and more attractive locations by the flashing light intensity that associated with the objective function of problem considered in order to obtain efficient optimal solutions.

The development of firefly-inspired algorithm was based on three idealized rules:

- Artificial fireflies are unisex so that sex is not an issue for attraction.
- Attractiveness is proportional to their flashing brightness which decreases as the distance from the other firefly increases due to the fact that the air absorbs light. Since the most attractive firefly is the brightest one, to which it convinces neighbors moving toward. In case of no brighter one, it freely moves any direction.
- The brightness of the flashing light can be considered as objective function to be optimized.

The main steps of the FA start from initializing a swarm of fireflies, each of which is determined the flashing light intensity. During the loop of pair wise comparison of light intensity, the firefly with lower light intensity will move toward the higher one. The moving distance depends on the attractiveness. After moving, the new firefly is evaluated and updated for the light intensity. During pair wise comparison loop, the best-so-far solution is iteratively updated. The pair wise comparison process is repeated until termination criteria are satisfied. Finally, the best-so-far solution is visualized.

Key Parameters in Firefly Algorithm :-

1. Light Intensity and Attractiveness:

In the firefly algorithm, there are two important issues: the variation of light intensity and formulation of the attractiveness. For simplicity, we can always assume that the attractiveness of a firefly is determined by its brightness which in turn is associated with the encoded objective function. In the simplest case for maximum optimization problems, the brightness I of a firefly at a particular location x can be chosen as $I(x) \propto f(x)$. However, the attractiveness β is relative; it should be seen in the eyes of the beholder or judged by the other fireflies. Thus, it will vary with the distance r_{ij} between firefly i and firefly j. In addition, light intensity decreases with the distance from its source, and light is also absorbed in the media, so we should allow the attractiveness to vary with the degree of absorption. In the simplest form, the light intensity I(r) varies according to the inverse square law $I(r) = I_s / r2$ where I_s is the intensity at the source. For a given medium with a fixed light absorption coefficient γ, the light intensity I vary with the distance r. That is $I=I0\ e^{-\gamma r}$ where I_0 is the original light intensity. In order to avoid the singularity at r = 0 in the expression I_s / r^2, the combined effect of both the inverse square law and absorption can be approximated using the following Gaussian form

$$I_r = I_0\, e^{-\gamma r2}$$

As a firefly's attractiveness is proportional to the light intensity seen by adjacent fireflies, we can now define the attractiveness β of a firefly by

$$\beta_r = \beta_0 e^{-\gamma r2}$$

Where β_0 is the attractiveness at r = 0.

2. Distance and Movement

Distance

Distance between fireflies i and firefly j are defined by their Cartesian distance which is given by the formula:

$$r = \sqrt{(x2 - x1)2 + (y2 - y1)2}$$

Where (x_1, x_2) and (y_1, y_2) are the coordinates of various Demand points.

Movement:

The movement of firefly i which is attracted by a more attractive or a brighter firefly j is given by the following equation

$$x_{ij} = x_j + \beta_0 \times e^{-(\gamma r2)} \times (x_j - x_i) + \alpha\,(rand - 0.5)$$

Where first term is current position of firefly, second is firefly attractiveness and the third represents random movement of firefly.

3. The settings of Firefly Algorithm Parameters:

- Light Absorption Coefficient (γ) = 1.0
- Randomized parameter (α) = 0.3
- Attractiveness value (β_0) = 1.0
- Rand- random number generated in [0, 1] = 0.8

First each firefly generates an initial solution randomly; parameters like Light Intensity I, Initial Attractiveness β_0, and light absorption coefficient γ are defined. Then for each firefly, find the brightest firefly. If there is brighter firefly then less bright firefly will move towards the brighter one. When firefly moves its light intensity decreases and its attractiveness will change. Then best firefly will be chosen based on an objective function for the next iteration. This condition will continue until the max iteration is reached.

Implementation of Firefly Algorithm

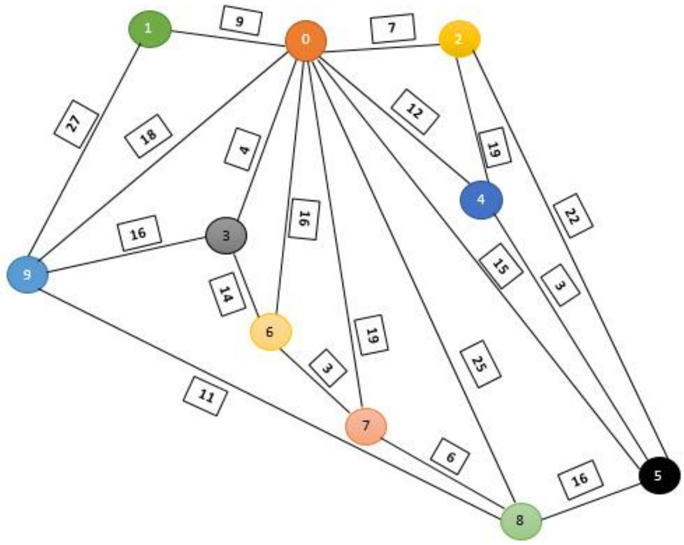
The application of Firefly algorithm technique for the solution is explained below:

1. Step1: Initialization of the firefly algorithm
- The dimension of the problem
- The number of fireflies
- The maximum number of iterations
- The values of α, β, γ and δ are chosen.
- Iteration counter i=0

2. Increment the iteration counter i= i+1
3. Calculate the fitness of the fireflies in very iteration by using the fitness functions and associate light intensity of each firefly to the same.
4. For each iteration, the fireflies are segregated based on intensities to the best one.
5. Vary the light intensity perception of all other fireflies based on the distance between them
6. Move the fireflies based on attraction which depends on light intensities and also control parameters.
7. If the stopping criteria in not reached go back to step2 else go to step 8
8. Display the results with the firefly particle of highest light intensity.

DATA COLLECTION

The data of the demand at each nodal points are taken from the Logistics Service and a Forecasted demand at each node point is calculated and tabulated. There is a capacity constraint of 100 orders per vehicle. The co-ordinates of the nodes are taken from the logistics service and a distance matrix and Coordinate table are prepared.



The above Network is the Layout of a city that is being considered for present work, where “0” represents initial point or the Depot and 1 to 9 are the nodes or the delivery points where the orders are to be delivered. The respective distance between the nodes are mentioned in the network diagram. Note: Distance provided is in Km.

4.1 Clarke & Wright Method:

Capacity of each vehicle/delivery Person: 100

Table 1: Distance matrix (From warehouse at “0”to 9 different nodes) in K.ms

C_{ij}	0	1	2	3	4	5	6	7	8	9
0	-	9	7	4	12	15	16	19	25	18
1	9	-	16	13	21	24	25	28	34	27
2	7	16	-	11	19	22	23	26	32	25
3	4	13	11	-	10	13	14	17	23	16
4	12	21	19	10	-	3	4	7	13	6
5	15	24	22	13	3	-	7	10	16	9
6	16	25	23	14	4	7	-	3	9	2
7	19	28	26	17	7	10	3	-	6	5
8	25	34	32	23	13	16	9	6	-	11
9	18	27	25	16	6	9	2	5	11	-

Table 2: **Demands at different nodes:**

i	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
D_i	50	40	50	40	45	50	45	40	45

1. Using the distance matrix and demand table initially we need to find the list of savings for every node using the formula $S_{ij} = d_{0i} + d_{0j} - d_{ij}$.

2. After calculating all the savings sort out the savings based on decreasing order of savings.

3. Now based on the capacity constraint and the demand at particular nodes assign the vehicles such that it would come up with an optimal route.

Table 4.1.1 Assignment of Vehicles

ALGORITHM	ROUTES AND VEHICLES (V)ASSIGNED	DISTANCE	LOAD	DISTANCE IN KM'S
Clarke & Wright Algorithm	0-7-8-0 (V1)	50	85	156
	0-6-9-0 (V2)	36	95	
	0-4-5-0 (V3)	30	85	
	0-1-2-0 (V4)	32	90	
	0-3-0 (V5)	8	50	

Hence the total distance travelled by all the vehicles using Clarke & Wright Algorithm is 50+36+30+32+8= **156 kms**

Homes & Parker Algorithm:

Clarke and Wright algorithm has its own limitations sometimes. It may not give us a very good solution sometimes. People try to work better, get better solutions compared to the Clarke and Wright. It is possible to get better solution by Holmes and Parker algorithm which is better than the Clarke and Wright solution.

1. This is an extension of Savings Algorithm, the first step in this is we will eliminate the first highest saving considered in the optimum Iteration of Savings Algorithm.
2. Now after the elimination we will initiate the iteration from the next highest saving.
3. Follow the same procedure of Clarke & Wright method.
4. Follow Step 3 & 4 until you get an optimum solution.
5. Terminate the iterations if you are left with an optimum solution.

Here in this algorithm we will initially exclude the first highest saving that we have considered during Clarke & Wright Algorithm and proceed with the next highest saving by satisfying the capacity constraints and also number of iterations can be done further if we are getting better solution than the previous solution. In case after one iteration if the savings in kms is less than the previous solution, then terminate the iterations and don't move further and conclude that it is the better solution obtained using this algorithm.

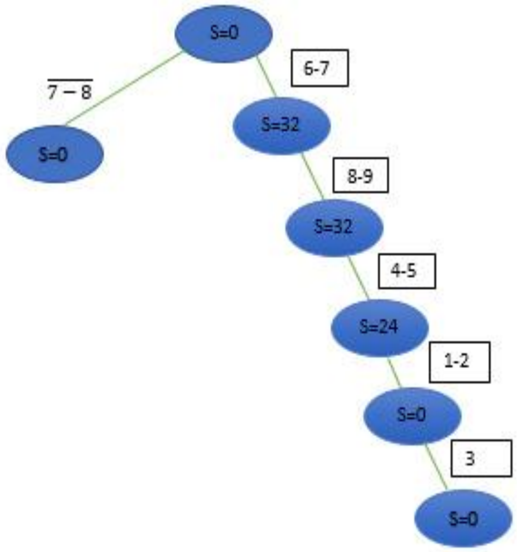


Figure 4.2.1 Homes & Parker Algorithm

Table 4.2.1 Assignment of Vehicles

ALGORITHM	ROUTES AND VEHICLES (V)ASSIGNED	DISTANCE	LOAD	DISTANCE IN KM'S
Homes and Parker Algorithm	0-6-7-0 (V1)	38	95	162
	0-8-9-0 (V2)	54	85	
	0-4-5-0 (V3)	30	95	
	0-1-2-0 (V4)	32	90	
	0-3-0 (V5)	8	50	

Hence the total distance travelled by all the vehicles using Holmes and Parker Algorithm is 38+54+30+32+8= **162 kms**

Sweep Algorithm:

In this algorithm initially we will find the values of all the angles and from the increasing order of the (θ) we will start assigning the nodes to the vehicles based on the demand and the capacity constraints of the vehicles. In this way optimal route is evaluated using Sweep Algorithm. Here now we have the coordinates of various nodes of the city which we have considered. By using these co-ordinates we will now plot a scatter graph in order to project the nodes considered in a city and will be considered as a map for the city from which we can find the rectilinear distances between various nodes in the city.

Table 1. Calculation of (θ) using Sweep Algorithm

i	X	Y	d_i	Angle (θ)	q
1	-4	5	9	141.34°	30
2	6	1	7	10°	40
3	0	-4	4	0°	45
4	3	-9	12	288°	30
5	6	-9	15	301°	20
6	1	-15	16	274°	40
7	4	-15	19	285°	35
8	10	-15	25	304°	30
9	-3	-15	18	259°	35

Figure 1. Coordinate points of various nodes in the city

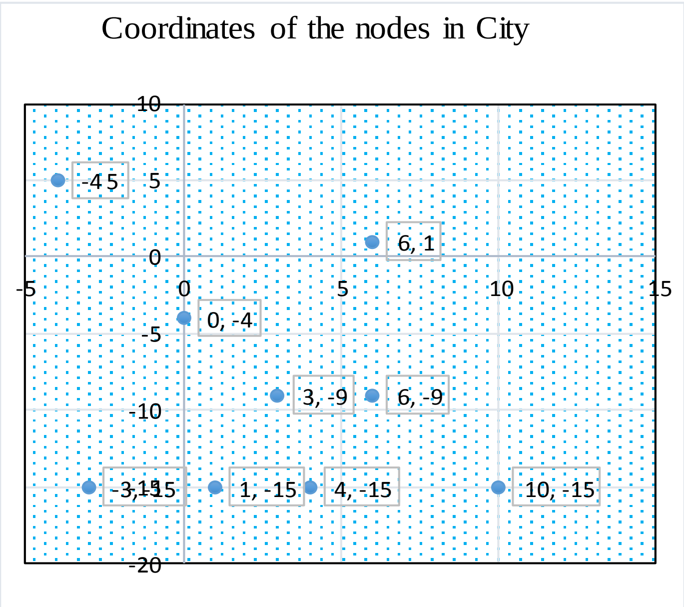


Table 4.3.1 Assignment of Vehicles

ALGORITHM	ROUTES AND VEHICLES (V)ASSIGNED	DISTANCE	LOAD	DISTANCE IN KM'S
Sweep Algorithm	0-3-1-0 (V1) 0-2-9-0 (V2) 0-6-7-0 (V3) 0-4-5-0 (V4) 0-8-0 (V5)	26 50 38 30 50	100 85 95 85 40	194

Hence the total distance travelled by all the vehicles using Sweep Algorithm is 50+26+38+30+25= **194 kms.**

Firefly Algorithm

Based on the formulae we will find out the brightness and movement values for all the nodes and the following allocation is made.

Table 4.4.1 Assignment of Vehicles

ALGORITHM	ROUTES AND VEHICLES (V)ASSIGNED	DISTANCE	LOAD	DISTANCE IN KM'S
Firefly Algorithm	0-3-4-0 (V1) 0-2-1-0 (V2) 0-5-6-0 (V3) 0-7-9-0 (V4) 0-8-0 (V5)	26 32 38 42 50	90 90 95 90 40	188

Hence the total distance travelled by all the vehicles using Firefly Algorithm is 38+26+32+42+50= **188 kms.**

RESULT ANALYSIS

Table 5.1 Results obtained from Various Algorithms

ALGORITHM	ROUTES AND VEHICLES (V)ASSIGNED	DISTANCE	LOAD	DISTANCE IN KM'S
Clarke & Wright Algorithm	0-7-8-0 (V1) 0-6-9-0 (V2) 0-4-5-0 (V3) 0-1-2-0 (V4) 0-3-0 (V5)	50 36 30 32 8	85 95 85 90 50	156
Homes and Parker Algorithm	0-6-7-0 (V1) 0-8-9-0 (V2) 0-4-5-0 (V3) 0-1-2-0 (V4) 0-3-0 (V5)	38 54 30 32 8	95 85 95 90 50	162
Sweep Algorithm	0-3-1-0 (V1) 0-2-9-0 (V2) 0-6-7-0 (V3) 0-4-5-0 (V4) 0-8-0 (V5)	26 50 38 30 50	100 85 95 85 40	194
Firefly Algorithm	0-3-4-0 (V1) 0-2-1-0 (V2) 0-5-6-0 (V3) 0-7-9-0 (V4) 0-8-0 (V5)	26 32 38 42 50	90 90 95 90 40	188

Here in this table, routes, vehicle allotted, demand satisfied by each vehicle and also distance travelled per day by each vehicle in kms are tabulated.

The main purpose of this study is to compare and evaluate the results obtained in order to suggest a best heuristic that helps in solving a Capacitated Vehicle Routing Problem. To compare our results we need some data so that we can justify our work or results. Hence here we considered two cases:

1. In Case 1 we will use 9 vehicles and they travel 250 kms per day.

2. In the second case, by satisfying the demand and capacity constraints we will formulate a random allocation and find out the results without any use of algorithm and after that we will compare these results with the results obtained from various algorithms.

Table 5.2 Random Allocation (Case-2)

ROUTES	ASSIGNED VEHICLE	DEMAND SATISFIED	DISTANCE TRAVELLED
0-1-9-0	V1	95	9+27+18=54
0-2-8-0	V2	80	7+32+25=64
0-3-6-0	V3	100	4+14+16=34
0-4-5-0	V4	85	12+3+15=30
0-7-0	V5	45	19+19=38
TOTAL DISTANCE TRAVELLED WITHOUT USING ANY ALGORITHM			220 KM

Here in Case 2, we allocated vehicles randomly by satisfying both demands and capacity constraints and we can see that there was a reduction in 30 km per day when compared to this random allocation and to Case 1 where 1 vehicle serves one node and comeback to the warehouse.

COMPARISON OF RESULTS

In the first comparison table we compare the results obtained using various algorithms with the results obtained in Case 1 where each vehicle travels to single node and comes back to the warehouse.

Table 5.3 Comparison table -1

ALGORITHM	ESTIMATED VEHICLE USED	ACTUAL VEHICLES USED	ESTIMATED DISTANCE	ACTUAL DISTANCE (KM)	DISTANCE SAVING (KM)	DISTANCE SAVING (%)
Clarke & Wright Algorithm	9	5	250	156	94	37.6%
Homes and Parker Algorithm	9	5	250	162	88	35.2%
Sweep Algorithm	9	5	250	194	56	22.4%
Firefly Algorithm	9	5	250	188	62	24.8%

Here we can see that estimated distance in case 1 is 250 with 9 vehicles, but with the use of algorithms we can cut down the vehicle fleet to 5 vehicles but the distance travelled is different in different algorithms. From the results we can see that with the implementation of Clarke & Wright Algorithm we will save 94 kms and with Sweep Algorithm we got least savings of 56 kms per day.

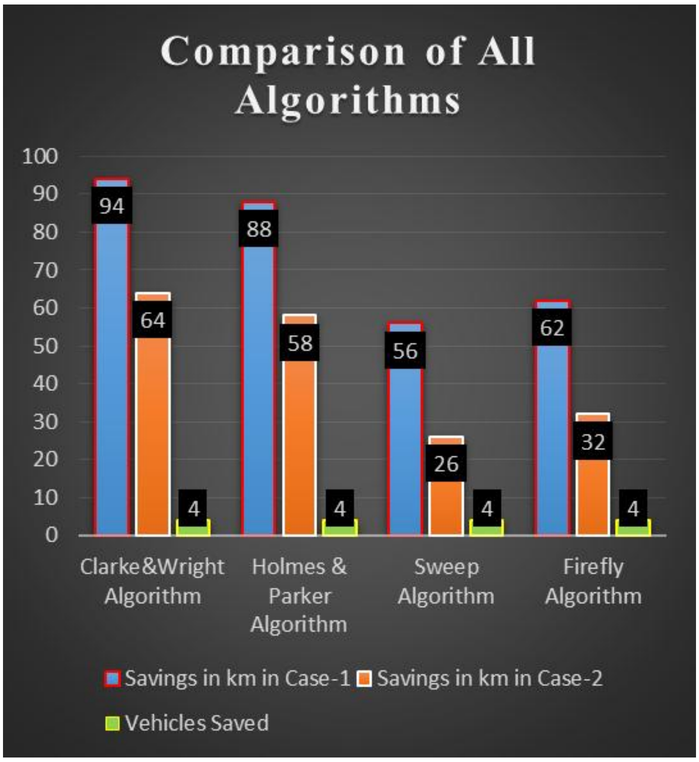
In the second comparison table we compare the results obtained using various algorithms with the results obtained in Case 2 where nodes are randomly assigned to the vehicles without violating the demands and capacity constraints.

Table 5.4 Comparison table -2

ALGORITHM	ESTIMATED VEHICLE USED	ACTUAL VEHICLES USED	ESTIMATED DISTANCE	ACTUAL DISTANCE (KM)	DISTANCE SAVING (KM)	DISTANCE SAVING (%)
Clarke & Wright Algorithm	5	5	220	156	64	29.09 %
Homes and Parker Algorithm	5	5	220	162	58	26.36 %
Sweep Algorithm	5	5	220	194	26	11.18 %
Firefly Algorithm	5	5	220	188	32	14.5%

Here we can see that estimated distance in case 2 is 220 with 5 vehicles, with the use of algorithms we used 5 vehicles but the distance travelled is different in different algorithms. From the results we can see that with the implementation of Clarke & Wright Algorithm we will save 64 kms and with Sweep Algorithm we got least savings of 26 kms per day.

Table 5.5 Comparison Graph



From this graph we can compare the results of all the algorithms used for solving a Capacitated Vehicle Routing Problem. Here we considered two cases in both the cases all the four algorithms utilized same fleet of vehicles but there is a variation in distance travelled by these vehicles in all the four algorithms. From the graph we can see that in both the cases Clarke & Wright Algorithm provided us with more savings in kms when compared to the other 2 heuristic and one Meta – heuristic algorithm. Sweep Algorithm provided us with the least savings in kms in both the cases. Holmes and Parker Algorithm stood second and the Meta-heuristic algorithm gave us the third highest saving in both the cases. Hence in the present study on comparing all the heuristic algorithms used for solving the Capacitated Vehicle Routing Problem we can say that Clarke and Wright Savings Algorithm will be the best heuristic to solve Capacitated Vehicle Routing Problem.

DISCUSSION AND CONCLUSION

A number of Heuristic approaches are available for solving CVRP. In this we used both heuristic and Meta heuristic algorithms. In general it is a known fact that we get optimum solutions from Meta heuristics and Holmes and Parker Algorithm but in this present situation Clarke and Wright algorithm produced better results due to its simplicity, greediness and robustness. The Capacitated Vehicle Routing Problem is a challenging unsolved problem and has attracted the attention of several researchers due to its immense practical importance.

The savings approach used by the Clarke and Wright algorithm can provide good solutions for small size instances. However for large instances calculating the savings may consider large values which affect the solution because the problem solving becomes complex. In addition, classical heuristics are easy to understand and implement compared to meta-heuristics. Meta-heuristics delivers better results in most of the cases. But in this study it is showed that classical algorithms can also provide accurate result which indicates that no single heuristic will always produce better result in a consistent manner. So a wide range of scope is available in this area and also various new Meta heuristic algorithms are also being introduced which might come up with better results.

REFERENCES

[1] AAltinel, K., and Oncan (2005), 'A new enhancement of the Clarke and Wright savings heuristic for the capacitated vehicle routing problem', *Journal of the Operational Research Society*, 56(8), pp. 954-961.

[2] WWatanabe, S., and Sakakibara, K. (2007), 'A multi objectification approach for vehicle routing problems' *4th international conference on Evolutionary multi-criterion optimization*, EMO 2007, Matsushima, Japan, March 5-8, 2007, Springer, pp. 660-672.

[3] AAmberg, A., Domschke, W., and Voss, S. (2000), 'Multiple center capacitated arc routing problems: A tabu search algorithm using capacitated trees', *European Journal of Operational Research,* vol. 44, no. 2, pp. 360-376.

[4] BBraysy, O., and Gendreau, M. (2005), 'Vehicle routing problem with time windows, Part I: Route construction and local search algorithms', *Transportation Science*, 39(1), pp. 104-118.

[5] RRand, G. K. (2009), 'The life and times of the Savings Method for Vehicle Routing Problems', *ORION: The Journal of ORSSA*, vol. 25, no. 2, pp. 25-145.

[6] SSolving Capacitated Vehicle Routing Problem by Using Heuristic Approaches: A Case Study Mohibul Islam, **Sajal Ghosh and***Mahfujur Rahman