# ROUTE OPTIMIZATION OF ELECTRIC VEHICLES IN LOGISTICS OPERATIONS PROJECT


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## PROJECT ABSTRACT


**The aim of the Project is construct route optimization for a VRP problem. The problem contains distributions of goods to a set of customers with electric vehicles which have limited capacities in terms of battery and need refueling in stations.**

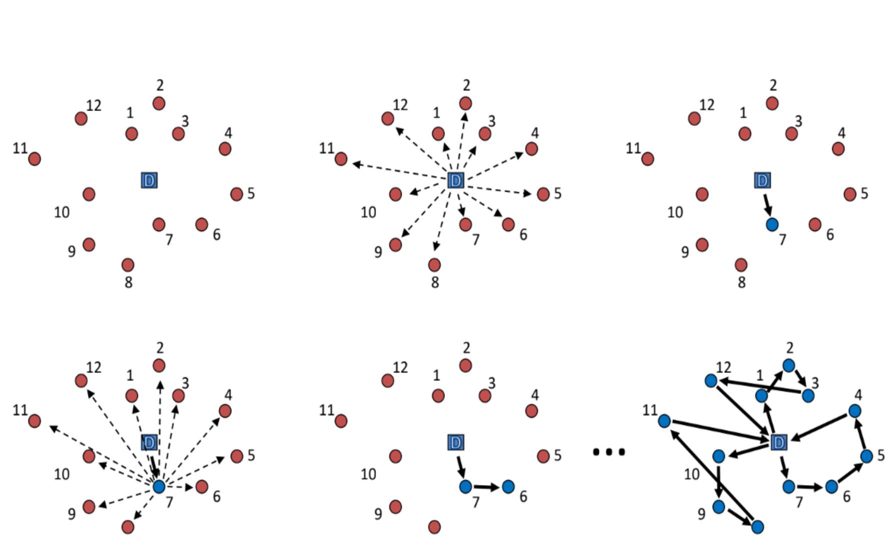

## SOLUTION METHODS

In this Project, a set of real data were studied, nearest neighbor and insertion algorithms were used. The algorithm was coded in python language by using Spyder.

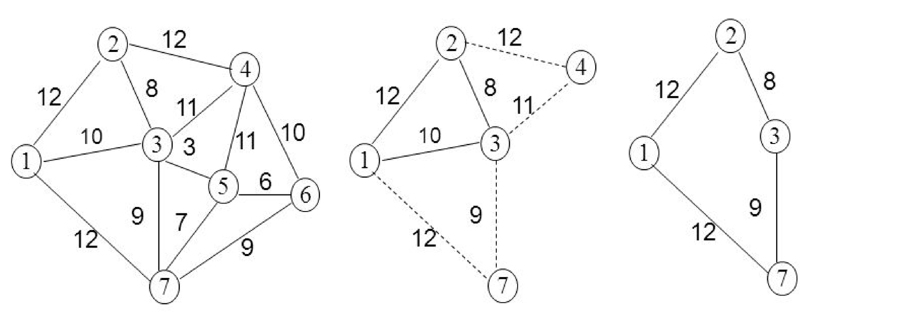
In nearest neighbor algorithm tour starts from the depot and adds nearest customer in each time. When it has not enough battery to go to next nearest customer, it visit the nearest station and refuels its battery and moves on with full battery to the next customer. Ends the tour again at the depot after visiting and distributing all the customer needs.

In insertion algorithm tour starts from the depot and selects a seed node which is furthest in these tours. It creates a tour like depot-seed node-depot. Afterwards, in each step it finds the best customer which gives the least extension when it is added to the tour.

Nearest Neighbor Algorithm



Cheapest Insertion Algorithm



- From loop (1,2,3), nodes 4 and 7 can be inserted
- If node 4 is inserted, the cost increase is 12+11-8=15
- If node 7 is inserted, the cost increase is 12+9-10=11
- So node 7 is to be inserted, which leads to a new loop (1,2,3,7)

## OBJECTIVES

The constraints in the Project are:

- Vehicle load capacity
- Customer demands
- Shift time
- Service time- Charging time
- Vehicle battery capacity
- Time window of customers

The objectives are trying to construct feasible tours and determining the optimal solution in terms of distance and energy with the electric vehicles. Electric vehicles should start to tour from the depot with full capacity and distribute the goods according to customer demands.

Timing is an important constraint. Tours should be constructed considering shift time of the drivers, service time for each customer (unloading time) and charging time in the stations. On the other hand, every customer has a time window which indicate available time for that customer. Vehicle should visit customers within their time slots. If the vehicle arrives earlier than the customers' earliest available time, it must wait. If the vehicle arrives later than the customers' due time, the tour becomes infeasible.

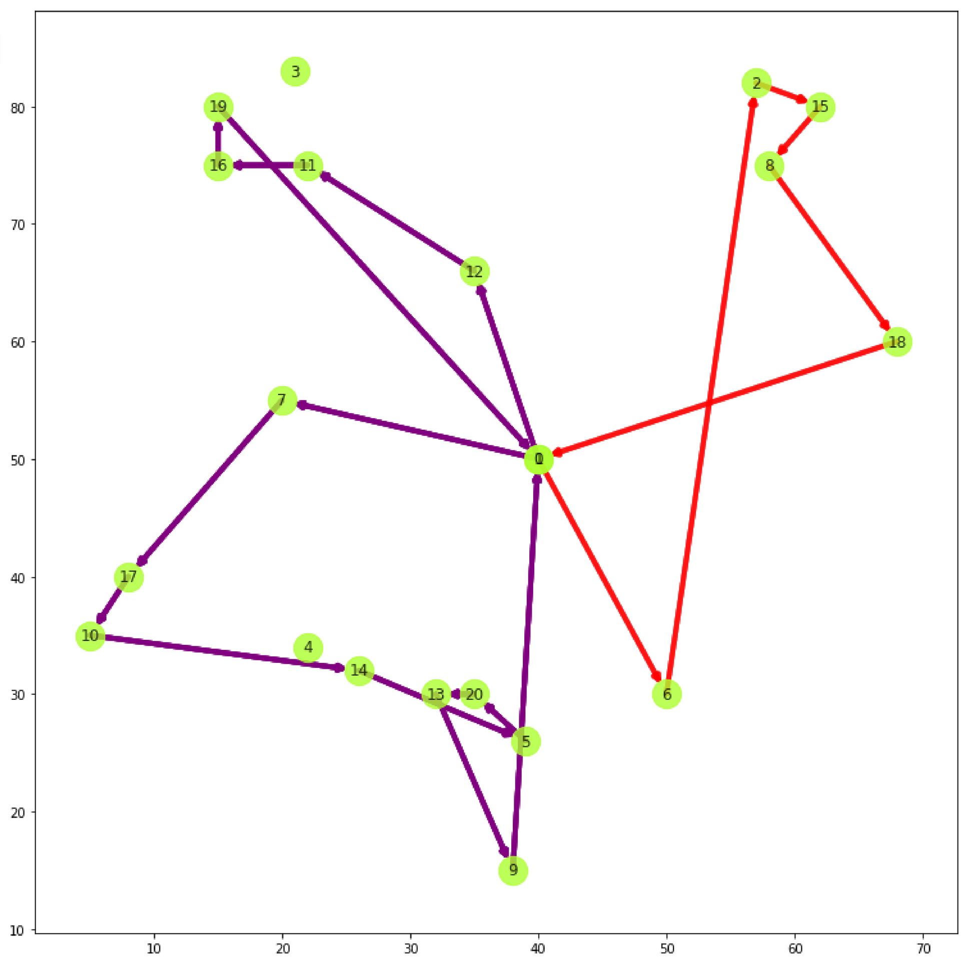
Furthermore, vehicles need to refuel their batteries. Since they are electric vehicles their charging take considerable amount of time compared to petrol fueled vehicles.

Whenever adding any customer violates either the demand or battery capacity constraints, the tour is terminated meaning the vehicle must return to the depot and a new vehicle is used to serve remaining unvisited customers.

## FINDINGS FROM NEAREST NEIGHBOR ALGORTIHM

| NextNode | Electricity | Demand | NewCapacity | Time/CarNumber |
|---|---|---|---|---|
| D0 | 77.75 | 0.0 | 200.0 | CAR 1 |
| C10 | 60.99 | 10.0 | 190.0 | 1129.24 |
| C13 | 45.18 | 30.0 | 160.0 | 1023.43 |
| C18 | 38.18 | 20.0 | 140.0 | 926.43 |
| C19 | 33.18 | 10.0 | 130.0 | 831.43 |
| S0 | 77.75 | 0.0 | 130.0 | 792.03 |
| C30 | 57.13 | 10.0 | 120.0 | 681.41 |
| C33 | 37.92 | 40.0 | 80.0 | 572.2 |
| C35 | 32.09 | 10.0 | 70.0 | 476.37 |
| C50 | 10.88 | 10.0 | 60.0 | 365.16 |
| S15 | 77.75 | 0.0 | 60.0 | 335.5 |
| C40 | 72.09 | 10.0 | 50.0 | 239.84 |
| C44 | 69.09 | 10.0 | 40.0 | 146.84 |
| C59 | 52.93 | 10.0 | 30.0 | 40.68 |
| D0 | 33.72 | 0.0 | 30.0 | 21.47 |
| D0 | 77.75 | 0.0 | 200.0 | CAR 2 |
| C61 | 55.39 | 10.0 | 190.0 | 1123.64 |
| S3 | 77.75 | 0.0 | 190.0 | 1085.51 |
| C95 | 72.36 | 30.0 | 160.0 | 990.12 |
| C98 | 65.96 | 20.0 | 140.0 | 893.72 |
| C85 | 47.93 | 30.0 | 110.0 | 785.69 |
| D0 | 27.31 | 0.0 | 110.0 | |

Route 1:
D0- 12- 11- 16- 19- 1- 7- 17- 10- 14- 5- 20- 13- 9- 0-
Distance: 184.14
Route 2:
D0- 6- 2- 15- 8- 18- D0-
Distance: 97.39
Total distance: 281.53



In this approach, time window of customers have not considered yet. Daily shift time and service times are studied. In each time vehicle visits a station, it fulls battery capacity with fixed refueling time.

## FINDINGS FROM INSERTION ALGORITHM

```
Car Number  1
D0  distance: 0.00  fuel: 77.75 time = 0.00 RT: 0.0 DT: 1236.0  new capacity: 200.0
C30 distance: 20.62 fuel: 57.13 time = 20.62    RT: 0.0 DT: 1125.0  new capacity: 190.0
C18 distance: 41.24 fuel: 36.51 time = 131.24   RT: 0.0 DT: 1110.0  new capacity: 170.0
C19 distance: 46.24 fuel: 31.51 time = 455.00   RT: 455.0   DT: 513.0  ==> came at 226.24 waited 228.76 minutes new capacity: 160.0
S7  distance: 52.95 fuel: 77.75 time = 735.45   RT: 0.0 DT: 1236.0  new capacity: 160.0
C98 distance: 90.80 fuel: 39.90 time = 773.30   RT: 0.0 DT: 1115.0  new capacity: 140.0
D0  distance: 121.61    fuel: 9.09  time = 894.11   RT: 0.0 DT: 1236.0  new capacity: 140.0

total length    121.61  total time  894.11

Car Number  2
D0  distance: 0.00  fuel: 77.75 time = 0.00 RT: 0.0 DT: 1236.0  new capacity: 200.0
C33 distance: 33.53 fuel: 44.22 time = 355.00   RT: 355.0   DT: 437.0  ==> came at 33.53 waited 321.47 minutes  new capacity: 160.0
C35 distance: 39.36 fuel: 38.39 time = 655.00   RT: 655.0   DT: 725.0  ==> came at 450.83 waited 204.17 minutes new capacity: 150.0
C50 distance: 60.57 fuel: 17.18 time = 766.21   RT: 0.0 DT: 1123.0  new capacity: 140.0
S13 distance: 65.04 fuel: 77.75 time = 1086.37  RT: 0.0 DT: 1236.0  new capacity: 140.0
D0  distance: 89.12 fuel: 53.67 time = 1110.45  RT: 0.0 DT: 1236.0  new capacity: 140.0

total length    89.12   total time  1110.45

Car Number  3
D0  distance: 0.00  fuel: 77.75 time = 0.00 RT: 0.0 DT: 1236.0  new capacity: 200.0
C95 distance: 37.20 fuel: 40.55 time = 37.20    RT: 0.0 DT: 1108.0  new capacity: 170.0
S3  distance: 42.59 fuel: 77.75 time = 280.38   RT: 0.0 DT: 1236.0  new capacity: 170.0
C85 distance: 67.19 fuel: 53.15 time = 304.98   RT: 0.0 DT: 1116.0  new capacity: 140.0
S0  distance: 96.92 fuel: 77.75 time = 613.23   RT: 0.0 DT: 1236.0  new capacity: 140.0
C44 distance: 118.46    fuel: 56.21 time = 634.77   RT: 0.0 DT: 1124.0  new capacity: 130.0
D0  distance: 140.00    fuel: 34.67 time = 746.31   RT: 0.0 DT: 1236.0  new capacity: 130.0

total length    140.00  total time  746.31

Car Number  4
D0  distance: 0.00  fuel: 77.75 time = 0.00 RT: 0.0 DT: 1236.0  new capacity: 200.0
C59 distance: 35.06 fuel: 42.69 time = 66.00    RT: 66.0    DT: 124.0  ==> came at 35.06 waited 30.94 minutes   new capacity: 190.0
C40 distance: 50.36 fuel: 27.39 time = 171.30   RT: 143.0   DT: 199.0   new capacity: 180.0
D0  distance: 70.98 fuel: 6.77  time = 281.92   RT: 0.0 DT: 1236.0  new capacity: 180.0

total length    70.98   total time  281.92

Car Number  5
D0  distance: 0.00  fuel: 77.75 time = 0.00 RT: 0.0 DT: 1236.0  new capacity: 200.0
C10 distance: 16.76 fuel: 60.99 time = 779.00   RT: 779.0   DT: 845.0  ==> came at 16.76 waited 762.24 minutes  new capacity: 190.0
C13 distance: 32.57 fuel: 45.18 time = 1042.00  RT: 1042.0  DT: 1106.0  ==> came at 884.81 waited 157.19 minutes    new capacity: 160.0
D0  distance: 63.38 fuel: 14.37 time = 1162.81  RT: 0.0 DT: 1236.0  new capacity: 160.0

total length    63.38   total time  1162.81

Car Number  6
D0  distance: 0.00  fuel: 77.75 time = 0.00 RT: 0.0 DT: 1236.0  new capacity: 200.0
C61 distance: 22.36 fuel: 55.39 time = 980.00   RT: 980.0   DT: 1064.0  ==> came at 22.36 waited 957.64 minutes new capacity: 190.0
D0  distance: 44.72 fuel: 33.03 time = 1092.36  RT: 0.0 DT: 1236.0  new capacity: 190.0

total length    44.72   total time  1092.36
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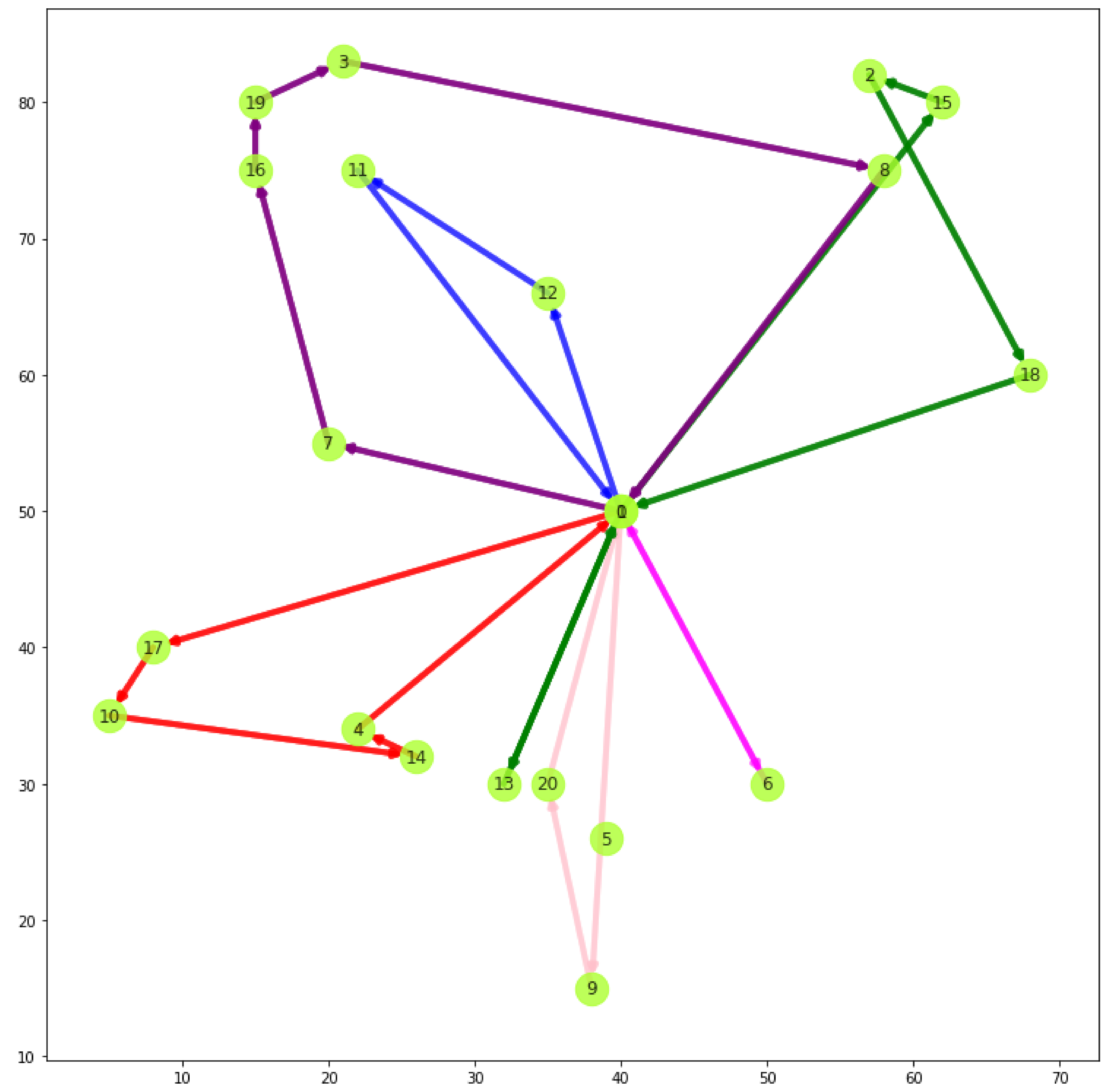

## CONCLUSION

Two construction algorithms were used in the Project. While using nearest neighbor algorithm time windows were not considered, however using insertion time window of customers were also included.

With the latest version of insertion algorithm electric vehicles start from the depot and distribute the goods according to customers' time window and refuel the battery if needed . When a vehicle runs out of good or can not find a feasible customer, a new vehicle starts with a new tour.

To improve the feasible solutions in terms of minimizing the distance, local search algorithms such as 2-opt, relocate and exchange can be used in further steps.

## REFERENCES


Erdoğan, S. Miller-Hooks, E. (2012). A Green Vehicle Routing Problem, Transportation Research Part E 48, 100-114.