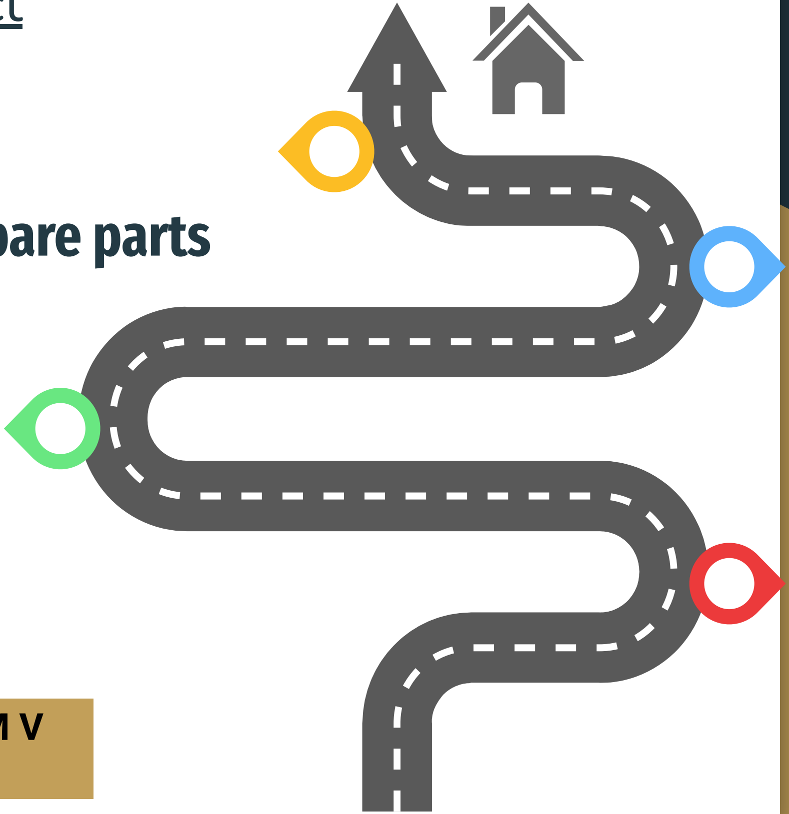
B.Tech Project

Inventory and distribution routing for a multi-product supply chain model for spare parts in Automobile company

Under the supervision of
Prof. Biswajit Mahanty



Mohammed Raafid M V
20MF3IM33

Introduction

- Inventory management and Transportation are vital for supply chain efficiency.
- It ensures seamless movement of products from production to point of sale.
- Our core aim is having the right products available at the right place and time
- Enhancing efficiency, reducing costs, and maximizing operational potential

Problem Statement

- Consider a Manufacturing Plant at **Hosur** with **8** Distribution center from **Tamil Nadu**
- Let us consider the number of parts are **5 parts** and, **4 weeks** period condition
- Focus on 5 parts that are being supplied to the distribution centers via **5** transportation companies
- Truck capacity - **7 Tonne** truck is used by all the vehicles from different transporters

Locations

- Main Manufacturing Plant is at **Hosur**

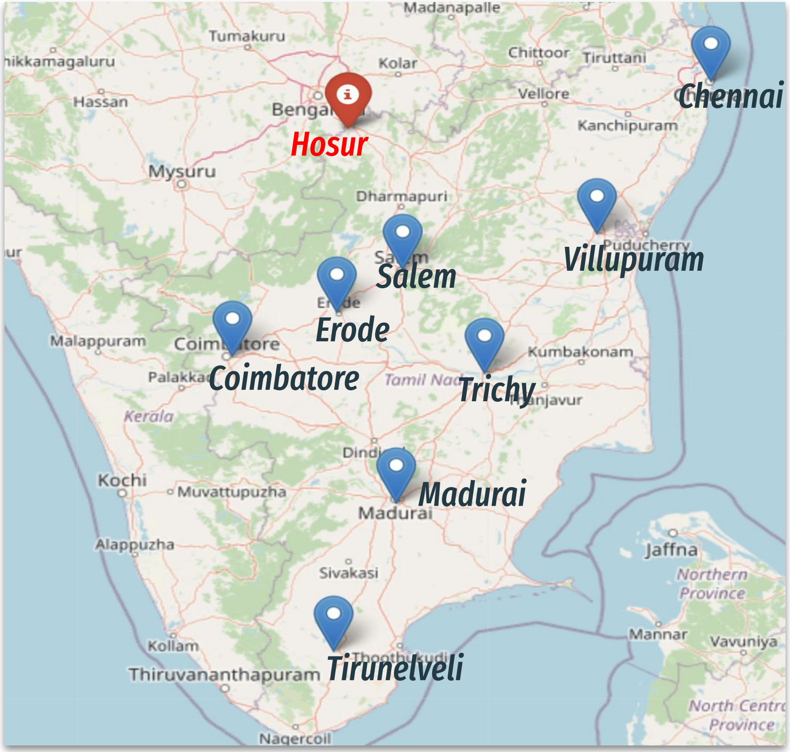
S.NO	NAME	CITY	LATITUDE	LONGITUDE
1	POPULAR PRIVATE LIMITED (*DC1*)	CHENNAI	*13.06486*	*80.26754*
2	TBF AUTO SOLUTIONS (*DC2*)	SALEM	*11.6489*	*78.1591*
3	POPULAR AUTO DISTRIBUTORS (*DC3*)	MADURAI	*9.8784*	*78.1149*
4	RKS AUTO AGENCIES (*DC4*)	ERODE	*11.3323*	*77.7037*
5	MVR AUTO SOLUTIONS (*DC5*)	TRICHY	*10.8606*	*78.7121*
6	XMR ENTERPRISES (*DC6*)	TIRUNELVELI	*8.7555*	*77.6883*
7	SPH ENTERPRISES LLP (*DC7*)	VILLUPURAM	*11.925*	*79.4836*
8	ADR ENTERPRISES (*DC8*)	COIMBATORE	*10.998*	*76.99*

Data

Considering 1 Distribution Center the demand data for DC1 is:

Distributor 1	Week 1	Week 2	Week 3	Week 4	Total
Part 1	16	16	15	15	62
Part 2	249	263	248	300	1060
Part 3	226	246	226	290	988
Part 4	376	418	350	459	1603
Part 5	28	28	23	25	104

Table 1



- **Inventory holding capacity** and **cost** for Distributor center 1 during all time periods in table 2

- **Transportation charges** and **Number of trucks available** for service based on destination to distributor center 1 in table 3

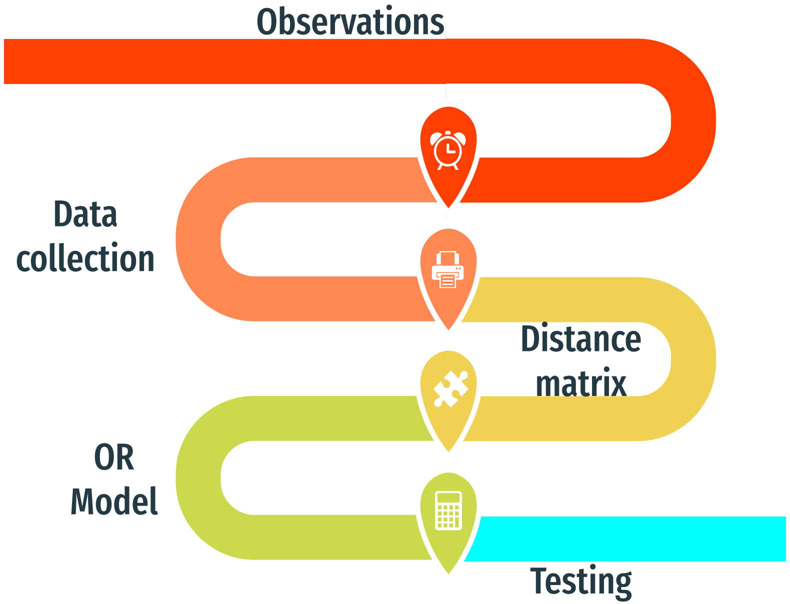
DC1	Inventory Capacity	Invetory Holding Cost	Part Weight (KG)
Part 1	967	91	2.575
Part 2	725	84	0.682
Part 3	258	6	0.287
Part 4	645	41	0.929
Part 5	226	7	0.510

Table 2

	Part 1	Part 2	Part 3	Part 4	Part 5	Number of trucks available
Transporter 1	19.67	18.2	2.19	7.1	2.06	2
Transporter 2	17.18	15.89	1.91	6.2	1.8	5
Transporter 3	19.13	17.7	2.13	6.9	2.01	4
Transporter 4	9.89	9.15	1.1	3.57	1.04	3
Transporter 5	38.63	35.73	4.31	13.94	4.05	3

Table 3

Methodology



Observation
Understanding the current model, its objectives, and its relevance to recent industrial practices and trends is essential

Preliminary data collection
Gathering preliminary data is crucial. This data will be used for calculations and fed into the model.

Distance matrix procurement
Google API used, for distance matrix must be collected to accurately calculate transportation distances between various locations.

OR Model development
Capturing the objectives and converting operational conditions into constraints effectively.

Testing

Full-scale implementation

Conclusion and future scope

Objective function, Decision variable and Constraints

- Decision variables (with notations)

- **prod_plant('plant', p,w)** - Production quantity of **part p** at the plant during the week w
- **transport_vars(i,p,t,w)** - Quantity delivered from plant to Distribution **center i**, part p, transportation **company t**, during **week**
- **inventory_dist2('plant',p,w)**- Inventory levels of products needed to be maintained at the **plant** of part p during week w
- **inventory_dist1(i,p,w)**- Inventory levels of part p that is needed to be maintained at the distribution center i during week w

Objective function:

Minimize prob = transport_vars * cost_price + inventory_dist *inventory_holding_cost1 +inventory_dist2 * inventory_holding_cost +prod_plant * prod_price

Constraints:

- **Demand**: transport_vars >= demand
- **Inventory**: For w=0, inventory_dist = initial_inventory,
  Otherwise, inventory_dist = inventory_dist - demand + transport_vars
- inventory_dist >= 0
- **Transportation**: transport_vars * weight_per_unit <= transport_capacity * truck_capacity
- **Production**: transport_vars <= production_capacity
- **Production Matching**: transport_vars = prod_plant
- **Inventory Capacity:**inventory_dist <= inventory_capacity
- inventory_dist >= inventory_min

Formulation:

Objective Function and **Constraints** are devised to yield an effective model for supply chain management decision-making, ensuring practical and **optimal** outcomes.

Implementation in Solver:

Using **Python** with the library **PuLP** (Python Linear Programming)

Code Link:
https://colab.research.google.com/drive/1co62krxi8y-kQ1N_ypeREdQ89JzoLCO2?usp=sharing

Result

- Total cost after optimization is **Rs. 1,58,394.38**
- The output from the solver is in figure 1
- `Inventory_(0,_'part1',_'week2') = 40.0`

  It indicates Inventory stored in Distribution Center 1 for part 1 in week 2 is 40

- `Transport_(0,_'plant',_'part2',_'comp4',_'week1') = 249.0`

  The quantity of part 2 to transported from plant to distribution center 1 by transporter company 4 in week 1 is 249

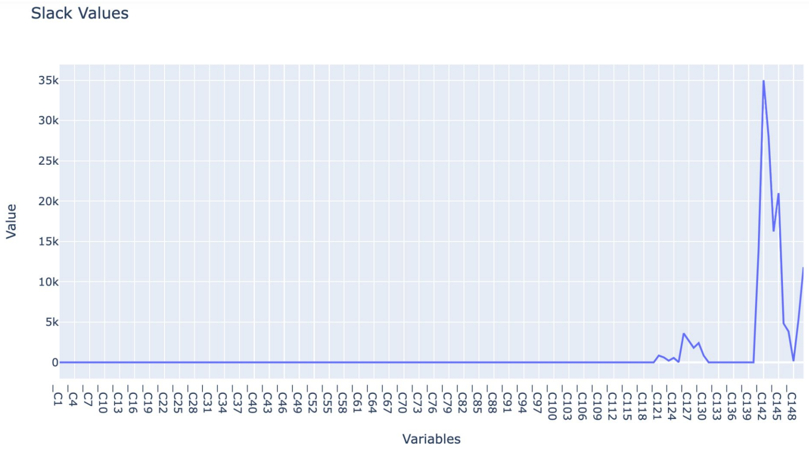
```
Total cost: 158394.37999999998
Inventory_(0,_'part1',_'week2') = 40.0
Inventory_(0,_'part1',_'week3') = 40.0
Inventory_(0,_'part1',_'week4') = 40.0
Inventory_(0,_'part2',_'week2') = 33.0
Inventory_(0,_'part2',_'week3') = 33.0
Inventory_(0,_'part2',_'week4') = 34.0
Inventory_(0,_'part3',_'week2') = 16.0
Inventory_(0,_'part3',_'week3') = 17.0
Inventory_(0,_'part3',_'week4') = 17.0
Inventory_(0,_'part4',_'week2') = 30.0
Inventory_(0,_'part4',_'week3') = 30.0
Inventory_(0,_'part4',_'week4') = 30.0
Inventory_(0,_'part5',_'week2') = 66.0
Inventory_(0,_'part5',_'week3') = 67.0
Inventory_(0,_'part5',_'week4') = 67.0
Transport_(0,_'plant',_'part1',_'comp4',_'week1') = 16.0
Transport_(0,_'plant',_'part1',_'comp4',_'week2') = 56.0
Transport_(0,_'plant',_'part1',_'comp4',_'week3') = 15.0
Transport_(0,_'plant',_'part1',_'comp4',_'week4') = 15.0
Transport_(0,_'plant',_'part2',_'comp4',_'week1') = 249.0
Transport_(0,_'plant',_'part2',_'comp4',_'week2') = 296.0
Transport_(0,_'plant',_'part2',_'comp4',_'week3') = 248.0
Transport_(0,_'plant',_'part2',_'comp4',_'week4') = 301.0
Transport_(0,_'plant',_'part3',_'comp4',_'week1') = 226.0
Transport_(0,_'plant',_'part3',_'comp4',_'week2') = 262.0
Transport_(0,_'plant',_'part3',_'comp4',_'week3') = 227.0
Transport_(0,_'plant',_'part3',_'comp4',_'week4') = 290.0
Transport_(0,_'plant',_'part4',_'comp4',_'week1') = 376.0
Transport_(0,_'plant',_'part4',_'comp4',_'week2') = 448.0
Transport_(0,_'plant',_'part4',_'comp4',_'week3') = 350.0
Transport_(0,_'plant',_'part4',_'comp4',_'week4') = 459.0
Transport_(0,_'plant',_'part5',_'comp4',_'week1') = 28.0
Transport_(0,_'plant',_'part5',_'comp4',_'week2') = 94.0
```

Figure 1

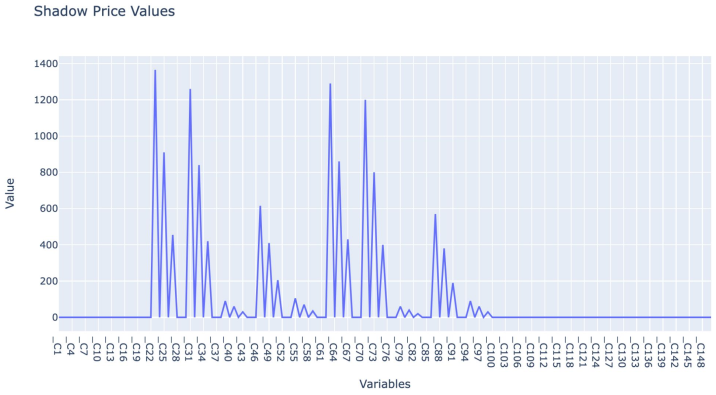
Sensitivity Analysis

160 constraints only **62** constraints are **slack** variables exhibited non zero values

Shadow Price is how much the objective function value would change for each unit in the right-hand side of a constraint



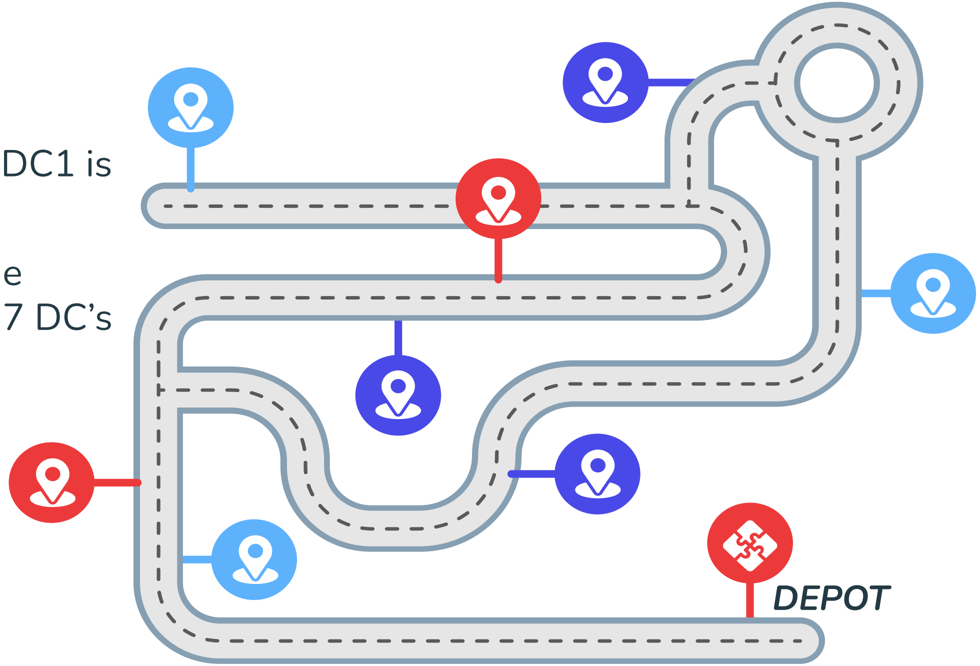

```
Total number of constraints: 160
Number of slack variables greater than zero: 29
Number of slack variables lesser than zero: 23
```




```
Total number of variables: 160
Number of points of shadow price greater than 1: 30
```

Capacitated Vehicle Routing

- Total weight of the parts transported to DC1 is **2300 KG**
- Total 8 DC's are there, Assume that same quantity is transported to the remaining 7 DC's
- Total truck capacity is **7000 KG**
- There are **5 transportes**, transport **company 4** has **minimum cost** of transportation there is **3 trucks** available with them



Distance Matrix Using Google Maps API

	Hosur	Chennai	Salem	Madurai	Erode	Trichy	Tirunelveli	Villupuram	Coimbatore
Hosur	0	316	172	413	235	301	546	237	331
Chennai	316	0	339	463	404	317	615	165	500
Salem	151	338	0	241	67	129	374	174	163
Madurai	387	463	236	0	199	146	156	299	208
Erode	214	406	69	205	0	140	338	242	95
Trichy	281	317	130	146	140	0	299	153	209
Tirunelveli	525	615	374	156	338	299	0	451	346
Villupuram	239	165	174	299	240	152	451	0	336
Coimbatore	310	502	165	217	98	208	351	338	0

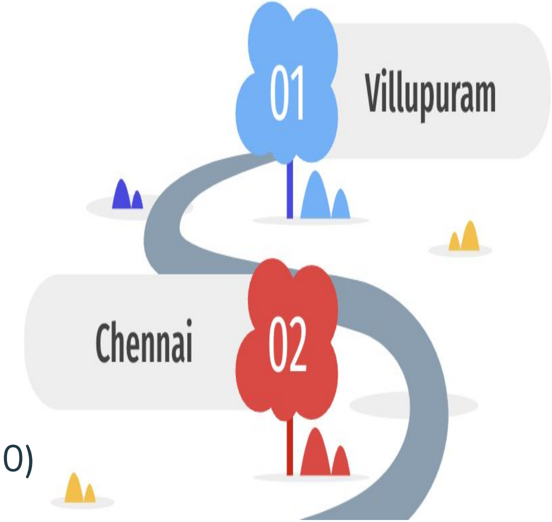
Routing

- Every Route starts and ends at the main plant Hosur

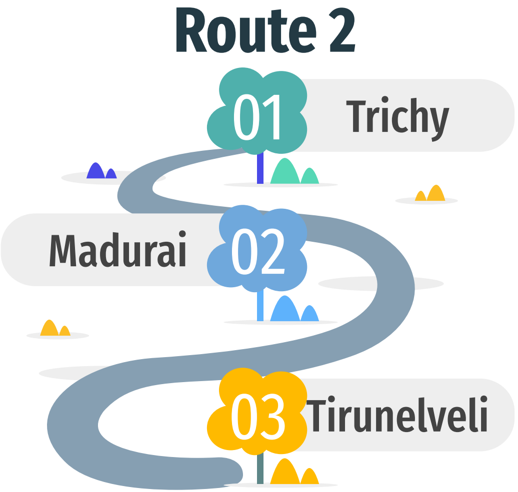
```
Route for vehicle 2:
 0 Load(0) ->  7 Load(2300) ->  1 Load(4600) ->  0 Load(4600)
Distance of the route: 718050m
Load of the route: 4600

Route for vehicle 3:
 0 Load(0) ->  5 Load(2300) ->  3 Load(4600) ->  6 Load(6900) ->  0 Load(6900)
Distance of the route: 1130661m
Load of the route: 6900

Route for vehicle 4:
 0 Load(0) ->  2 Load(2300) ->  4 Load(4600) ->  8 Load(6900) ->  0 Load(6900)
Distance of the route: 645695m
Load of the route: 6900
```

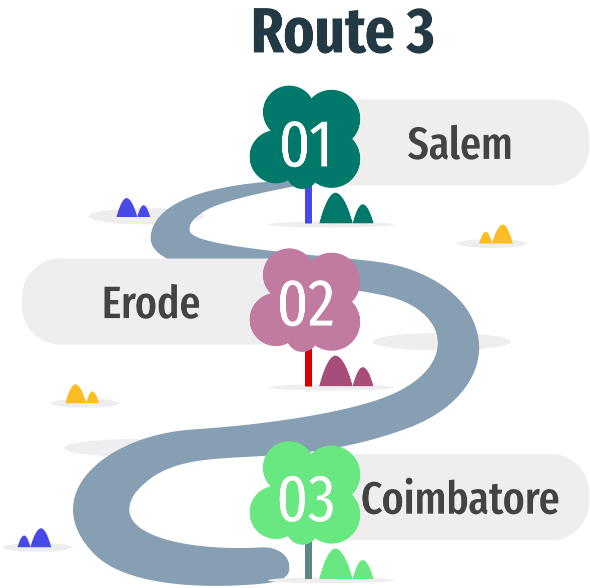
- Figure 2 shows the route followed by each truck
  0 Load(0) -> 7 Load(2300) -> 1 Load(4600) -> 0 Load(4600)
- Indicates Start from Hosur -> Villupuram -> Chennai -> Hosur

Route 1



Conclusion

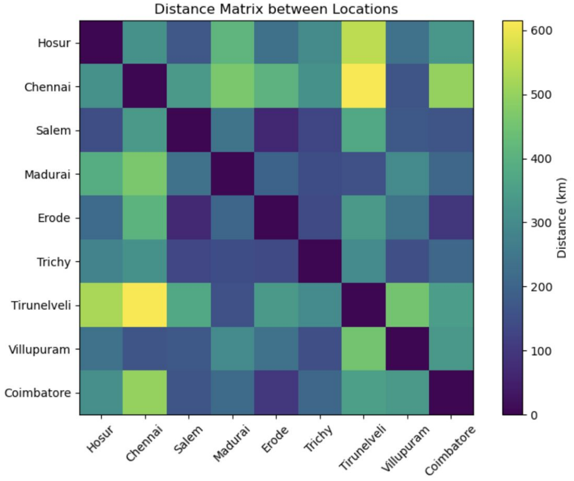




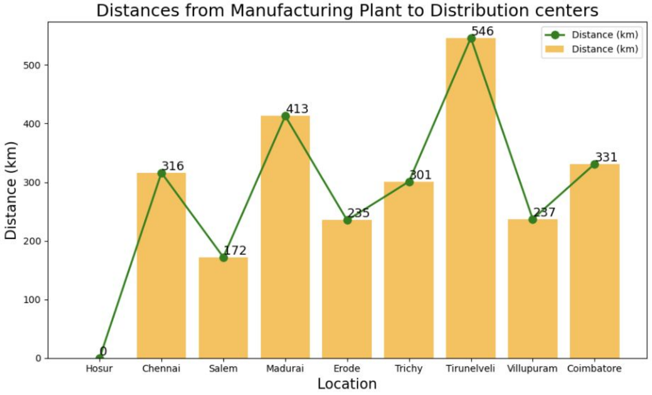
Due to route optimization, the total distance traveled significantly decreased from **3554.0 km** to **2497.4 km**, representing a **reduction of 1056.6 km**, or distance reduce by **29.73%**

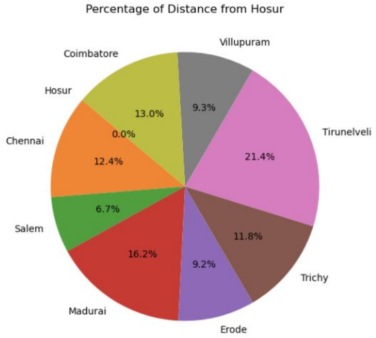
Data Visualisation

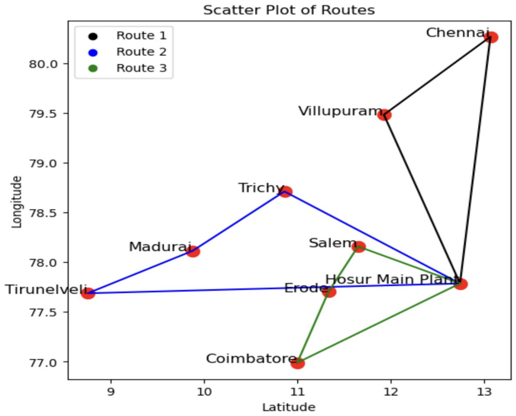
Visual Representation of distances from **Hosur** to the 8 distribution center



Heat Map of Distance Matrix

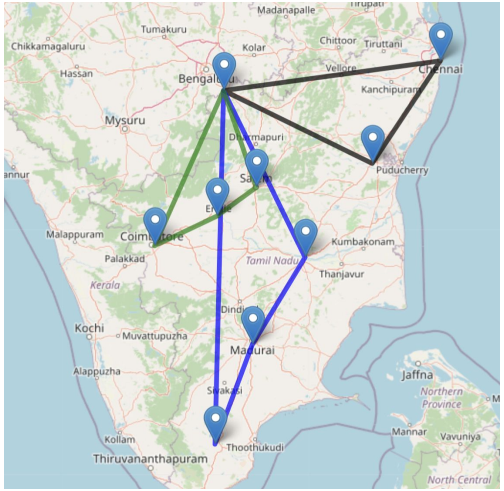




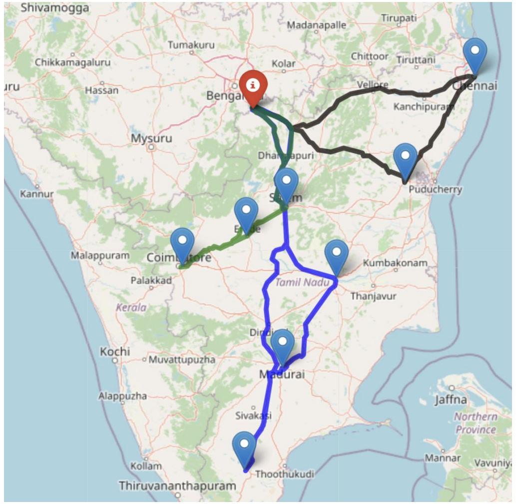


Scatter Plot of routes followed by the 3 trucks

- Total distance traveled was estimated through Haversine distance **2052.22 km**
- Actual distance travelled is **2497.408 km** calculated by google maps with distance matrix
- Rectified the error percentage in the distances are **17.79%**



Distance calculated by Haversine distance



Route by Google Maps

Future Scope

- If one more plant was opened in Tamil Nadu due to the high demand of product finding the proper location by reducing transportation costs and inventory costs
- Time window constraints can be added for loading and unloading for efficiently reaching the product
- Identify the traffic and tame taken for the travel in the routes where truck travel using Google Maps
- Different sizes of items can packed into a fixed volume of bins, in a way that minimizes the number of bins used by utilising the volume truck.

THANK YOU