
Project Report

On

MULTI MODEL CAPACITATED VEHICLE ROUTING AND SUGGESTIONS ON EFFICIENT ROUTE PLANNING

At



**BELIEVE IN THE
POWER OF US**

Submitted by

PANKAJ KUMAR

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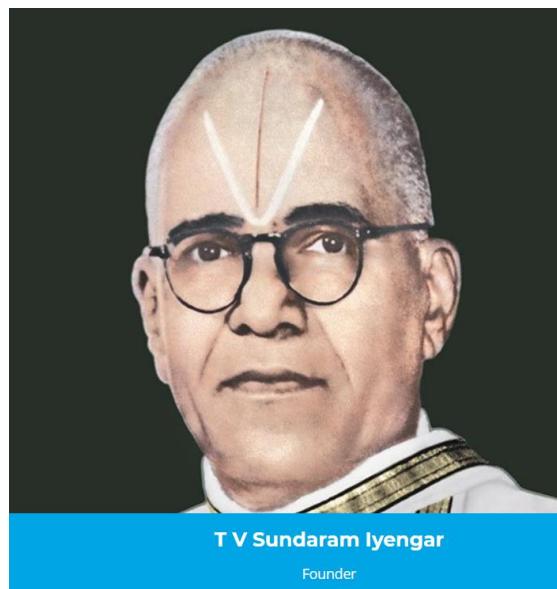
TVS SCS was promoted by the erstwhile **TVS & Sons**, which had over 100 years of operating history. It commenced its operations as '**TVS Logistics**' in **1995** before being incorporated as a separate company in **2004**. TVS SCS's business is focused on helping customers achieve their cost and revenue goals by aiming to deliver high levels of productivity, ensure customer experience with efficiency and provide digital-ready platform and innovation driven solutions.



HISTORY

FROM A SINGLE MAN'S DREAM TO A BUSINESS CONGLOMERATE

T V Sundaram Iyengar started his entrepreneurial journey in 1911. He wanted to build a business that would create a family of like-minded individuals pursuing only the best in quality and standards. The success of the company is deeply rooted in our founder's personal belief of commitment to the values of trust and customer service. Although the company was named after the founder, the letters TVS have always stood for Trust, Value, and Service within the company. It was only natural that success and market leadership followed.



Attention to finest detail:

When TVS started plying buses, way back in 1912, it not only ensured the journey is smooth for passengers but also ensured the buses start on time and reach the destination on time. Those were the days when other bus operators would wait for a particular number of seats to get filled-in before they start operating their buses. TVS also regularised the system by issuing tickets for the fare they collected, probably for the first time in those days, for travel from point A to point B. To top it all, TVS used to send out a pilot vehicle, fitted with a magnet, that catches all the iron nails on the road. This ensured that TVS buses reach the destination 'on-time', every time. TVS buses are so reliable that people set their watches right on seeing the TVS bus pass by their places.

Innovation effort during Wartime:

During World War II there was a severe oil shortage all-over-the-world and India was not spared either. But, TVS played its part through innovation where it engineered a Gas plant that could fit inside a car to combat fuel shortage. The plant produced charcoal gas as a substitute for petrol. The gas plant was an instant hit among users with many cars and even trucks attached this Gas plant to their vehicles.

Introduced the concept of test drive:

When TVS took the General Motors dealership in 1929, it did not wait for the customers to come to their dealership. Instead, it tried various innovative methods to sell vehicles. Its salesmen were given the task to take the vehicles to Zamindars (rich people) house where they would leave the vehicle with a chauffeur at their house and return with Zamindar's horse/bullock cart. This would allow the royal families to use the vehicle for a stipulated time. Today, the concept of test drive has become a buzzword in the automobile industry. But TVS used this as USP way back in the 1930s.

Director's Report

Nineteenth annual report of TVS Supply Chain Solutions Limited for the year ended March 31, 2023.

Financial Results:

Particulars	Standalone		Consolidated	
	2022-23	2021-22	2022-23	2021-22
Revenues from operations (including other income)	1978.44	1561.03	10311.01	9299.94
Profit/(Loss) before tax from continuing operations	(10.82)	(30.91)	40.05	11.14
Profit/(Loss) after tax from continuing operations	(29.26)	(21.22)	41.76	(46.48)
Profit/(Loss) before tax from discontinued operations	-	-	-	(0.92)
Profit/(Loss) after tax from discontinued operations	-	-	-	(0.92)
Profit/(Loss) for the year	(29.26)	(21.22)	41.76	(47.40)
Other comprehensive income, net of tax	(1.83)	(0.98)	(50.64)	(21.47)
Total comprehensive income	(31.09)	(22.20)	(8.88)	(68.87)

Board of Directors:



R Dinesh
Executive Chairman



Ravi Viswanathan
Managing Director



**Shobhana
Ramachandhran**
Non-Executive Director



Anand Kumar
Nominee Director



Ashish Kaushik
Nominee Director



B. Sriram
Independent Director



Gauri Kumar
Independent Director



Tarun Khanna
Independent Director



K Ananth Krishnan
Independent Director



Narayan K Seshadri
Independent Director

Global Leadership Team:



R Dinesh
Executive Chairman - TVS SCS



Ravi Viswanathan
Managing Director - TVS SCS



**Ravi Prakash
Bhagavathula**
Global CFO - TVS SCS



Andrew Jones
CEO – TVS SCS Europe



Sukumar K
CEO – TVS SCS India



Vittorio Favati
CEO - TVS GFS



Richard Vieites
CEO - TVS SCS North America



Jon Croyden
CEO - TVS SCS Rico



E. Balaji
Global CHRO - TVS SCS



Baminee Viswanat
Global General Counsel - TVS SCS



Dinesh Narayan
Global CIO - TVS SCS

Awards & Certifications

Certifications:



Ecovadis

INVESTORS IN PEOPLE
We invest in people Standard

Investors in People



ISO9001 (Quality)



ISO14001 (Environmental)



ISO27001 (Information Security)



ISO45001 (Occupational Health & Safety)



ISO22301 (Business Continuity)



Cyber Essentials PLUS

Awards:



Defence Employer Recognition Scheme



GM Supplier Award



CILT - Finalists 2014 - Supply Chain Operations



Lancashire Chamber of Commerce (BIBAs) - 2015



SHD Logistics - Winner 2014 - Operations (Large)



ELSC Leadership Awards - Winner 2014 - Best 3PL



BMW - Gold Award - Excellence in Service Delivery 2014



ENWL - Certificate of Recognition - 2016

COMMITMENT TO A SUSTAINABLE FUTURE

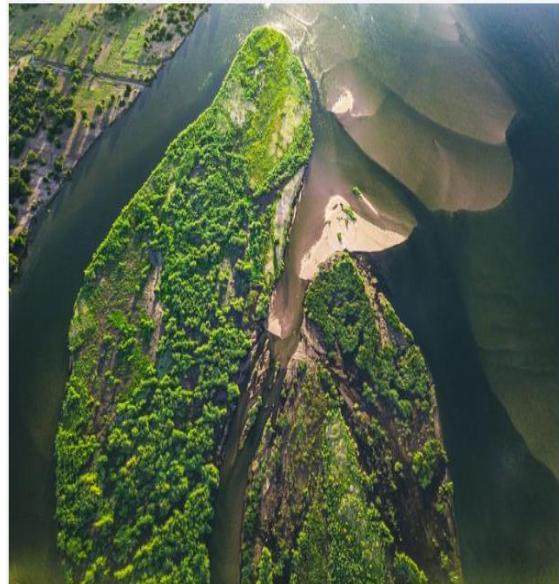
Changes cannot be done alone. TVS SCS has committed to playing its part by making short and long-term changes to its operations. This, along with strategic partnerships working with all key stakeholders and suppliers are doing what they can to create & encourage change. This will ensure the ongoing sustainability of the Company whilst contributing to the global issues around sustainability.

Environment

The environment is one of the most critical issues our world is currently facing.

TVS SCS is always working on innovative ways to reduce our carbon footprint across the globe, a number of initiatives have been launched to help work towards becoming a more sustainable organisation. Company's initiatives include:

- Working towards being carbon neutral by 2025.
- Packaging Solutions – Exploring alternate sources for packaging to minimise waste.
- Sustainable solutions – Provide a number of solutions that support environmentally friendly practise.
- Ethical Procurement – Engaging with partners to reduce carbon through the supply chain as well as constantly developing a sustainable network of suppliers.
- Investment in new technologies which will help support the reduction of carbon footprint.



Business Strategy

Company has been able to achieve significant business growth and scale by following the 'C3 Framework' and implementing the strategies of encirclement, new business development and acquisitions, which has led to:

Growth in our existing core sectors. Company has been able to grow in our existing core sectors, such as automotive, industrial and consumer sectors, by offering our capabilities to existing customers in new geographies as well as by offering capabilities to new customers engaged in such industries.

Scout for adjacent sectors. Company has the ability to take a common set of processes, capability and technology, and customize them for a new set of customers to solve complexity of their business. Company have leveraged this and developed capabilities to address adjacent segments, such as the electric vehicle sector as an adjacency to the automotive sector and smart metering as an adjacency to the utilities sectors.

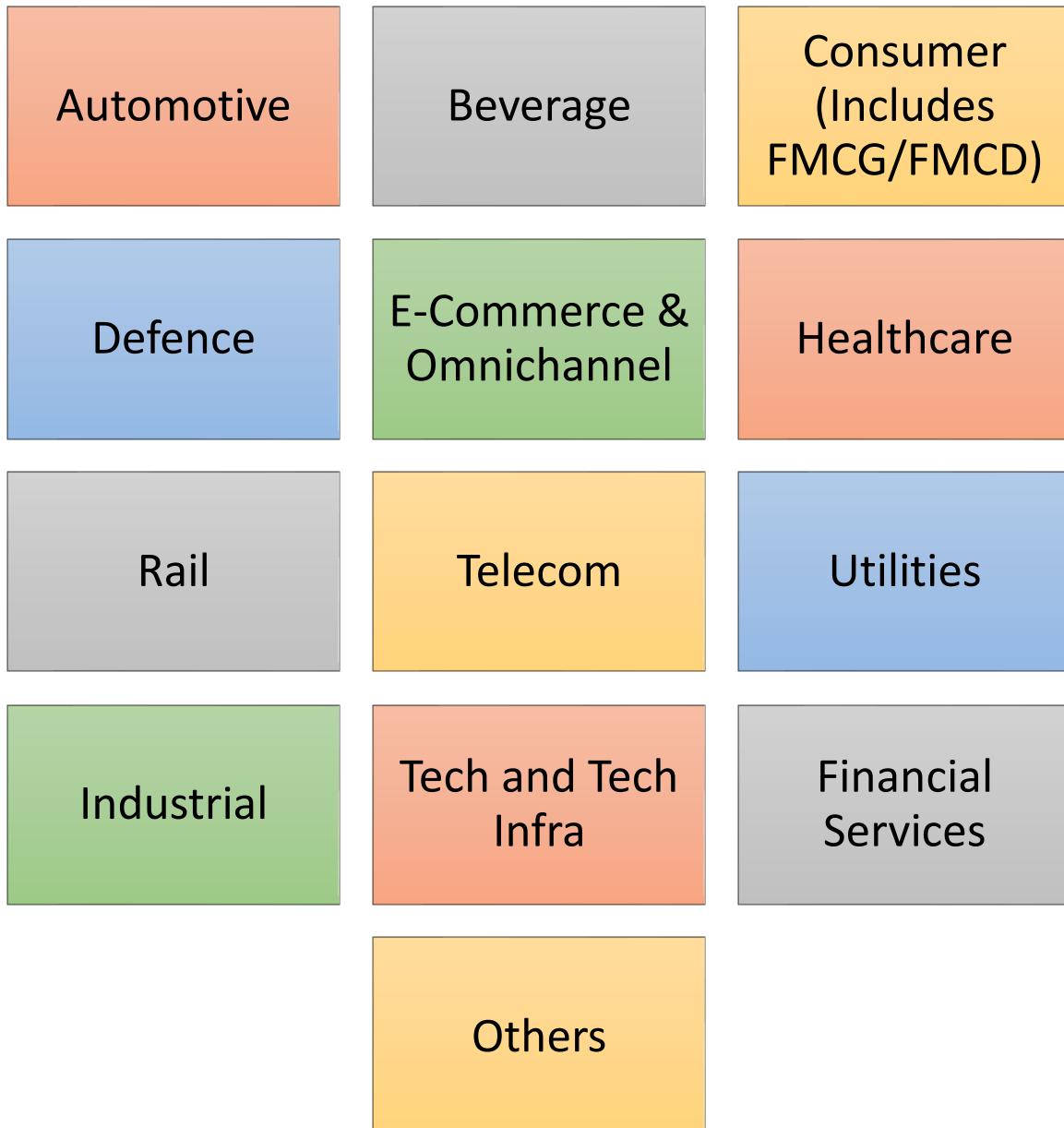
Pivot to new age and fast emerging sectors. Company is further developing their existing capabilities and technology infrastructure and leverage them to pivot into new sectors such as electric vehicles, health tech, clean energy and utilities. For example, company has leveraged their ability of inventory purchase, technology services and time critical services for the healthcare sector. Further, in the United Kingdom, company has won a contract where they deployed their NS capabilities for managing reverse logistics of COVID-19 test samples.



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Industries Serve



Automotive



TVS SCS has been providing world-class end-to-end supply chain solution to the automotive sector for over 100 years. We work closely with some of the largest vehicle manufacturers and Tier 1 suppliers throughout the world, many of which are household names in the car, bus and commercial vehicle market.

Company's automotive-related solutions include aftermarket support, spare parts distribution, point of use feeding, Value-add assembly, kitting, and sequencing. Whether you would like a single solution or a complete end-to-end supply chain design, TVS SCS can deploy a customised solution to meet your requirements.

Parts provision – Original Equipment (OE) or Aftermarket, is supported through Inventory Planning, allowing for reduced inventory costs while preserving service levels and parts availability. It is creating a supply chain that is responsive throughout the product lifecycle, global procurement, Warehousing and Distribution to support dealer and distribution networks and supporting line side.

Our customers:



Beverage



TVS SCS is a global provider of world-class, end-to-end supply chain services to the beverage and catering sectors.

Your brands are our business. We understand that to gain a competitive edge, you must be different. We tailor our supply chain solutions so that they deliver what you need. Whether your market is beer, soft drinks, coffee or events catering, we help you take control of your supply chain. We ensure that the right part is delivered to the right place at the right time, every time. We drive down costs and provide technical expertise, from the sourcing of raw materials right through to the installation and support of your equipment. Ensuring your clients receive an outstanding customer service experience whilst allowing you to focus on the core competency of your business.

We offer an E-commerce style catalogue which provides a comprehensive range of quality dispense equipment parts and provides a 'one-stop-shop' to support your business. Parts range from dispense parts through to cellar parts and everything in between. A selection of parts and equipment can be purchased either as new or as refurbished.

Our customers:



DIAGEO



Defence



TVS SCS offer Government Defence Departments and Prime Contractors advice and a comprehensive range of solutions to give advantage in the military environment.

We develop effective supply chain solutions and deliver them via a range of service delivery models. Our innovation, capabilities, reputation and performance enable us to manage technical and logistic information in a secure and scalable environment. In addition, we are entrusted to transform supply chains and decide what to buy, when to buy and how to buy inventory and services to ensure maximum availability at a minimal cost.

Today, we manage more than 400,000 items (NATO Stock Numbers) across a wide range of military equipment including; armoured fighting vehicles, construction vehicles, workshop spares, warships consumables, clothing, food, fuel, medical equipment, field catering, pharmaceuticals and general engineering hardware.

Our customers:



What company do?

INTEGRATED SUPPLY CHAIN SOLUTIONS

TVS SCS offers end to end supply chain services from Sourcing and procurement, integrated transportation, Logistics Operation Centre and In Plant Logistics, – Finished Goods and After Market Fulfilment, Consultancy and Professional Services, Product Management Solutions. All supported by our Information Systems.

We address supply chain challenges for international organisations, government departments, large and medium-sized businesses and trade on an ability to reduce our client's operating costs and improve their performance through

- Reduced operating costs
- Improved performance through efficiencies
- End-to-end visibility
- A collaborative approach to doing business
- Efficient and seamless solutions
- Deliver first-class service
- Growth and innovation

Services:

- Consultancy & Professional Services
- Product Management Solutions
- Manufacturing Support
- Warehousing, Storage & Distribution
- Transportation & Integrated Logistics
- Integrated Packaging Solutions
- Sourcing and Procurement



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NETWORK SOLUTIONS

As part of our Network Solutions, we offer customers Global Freight Solutions and Time Critical Final Mile Solutions.

GFS: We offer a range of services under our GFS business, with an objective to manage end-to-end freight forwarding solutions across ocean, air and land. Our team also supports all the logistic needs between the origin and destination including customs brokerage, warehousing and storage, value added services and intermodal and multimodal road transport.

TCFMS: We offer a wide range of services under our TCFMS business, such as closed loop logistics (including spare parts logistics services, break-fix, return, refurbishment and engineering support) and courier services (including same-day and next day) to both large ('B2B') and small ('B2b') businesses in various industries.

We train our network partners and their employees on topics such as customer service skills, communication skills, and etiquette. Our business partners' engagement program seeks to develop and maintain strong ties with all business partners.

We have defined and applied certain standards of service and quality of assets for our network partners across all our transportation and warehousing operations. We also require our network partners to carry out periodic preventive maintenance to ensure longer vehicle life, performance reliability and standard warehouse quality and safety.

Services:

GLOBAL FORWARDING SOLUTIONS: Our Global Forwarding Solutions professionals are the experts in moving goods of all kind via air, ocean and land freight. We provide an end-to-end solution with our additional, complementary land freight and tailored solutions.

TIME CRITICAL FINAL MILE SOLUTIONS: TVS SCS provides comprehensive last mile solutions which, assisted by our latest technological inputs, drastically improves the speed and efficiency of delivering goods to our end customers on the same day.

Press Releases:



May 8, 2024

TVS SCS wins new Business Deal for Eicher's Bus Facility in Baggad

[Press Release](#)



TVS SCS - News & Press

April 17, 2024

TVS Supply Chain Solutions North America earns recognition as a John Deere "Partner-level Supplier"

[Press Release](#)



April 12, 2024

TVS SCS achieves milestone of 500,000 two-wheeler CKD kits for its customer

[Press Release](#)



August 30, 2023

R. Dinesh takes over as Chairman of TVS Supply Chain Solutions Ltd

[Press Release](#)



TVS SCS - News & Press

July 25, 2023

TVS SCS secures a deal from the UK based 'Centrica plc' to transform their Supply Chain

[Press Release](#)



June 9, 2023

TVS Rail Spares Launched

[Press Releases](#)



March 7, 2023

UK Ministry of Defence, acting through its Agent, Babcock Land Defence Ltd Award Land Rover Spares Contract to TVS Supply Chain Solutions.

[Press Releases](#)



February 6, 2023

UK Ministry of Defence Award Maritime Spares Procurement Contract to TVS Supply Chain Solutions.

[Press Releases](#)



November 17, 2022

TVS SCS secures long-term contract from Dennis Eagle in the UK for aftermarket services

[Press Releases](#)



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Vehicle Routing Problem

Many of us have been regularly ordering from Swiggy InstaMart (IM) and are pretty happy with the delivery experience from both scheduled & instant delivery.

Have you ever wondered how Swiggy InstaMart (IM) fulfils your order by selecting the right Delivery Executive (DE) for your order? Or how is a trip (aka route or batch) decided for a given DE (i.e. if Mr. Yuvraj's order should be delivered first or Mr. Kohli's)?

Consider, if Yuvraj and Kohli both ordered from the same IM store and only 1 DE is available, then we can fulfil their orders in the following combinations:

- *DE → Store → Yuvraj → Kohli*
- *DE → Store → Kohli → Yuvraj*
- *DE → Store → Yuvraj → Store → Kohli*
- *DE → Store → Kohli → Store → Yuvraj*

Now, imagine if you have just 100 DEs, then these combinations will be replicated for all DEs (besides combinations where each order can be delivered by separate DEs). Further, we also have multiple IM fulfilment stores.

Even for a handful of orders and DEs, it becomes a daunting task to devise such plans within a short time manually. Imagine if you have to solve for more than 200K+ Orders with 150K+ DEs and 100+ IM stores every day. We definitely need an algorithm to automate this process, right?

Abstract:

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. Here, we will discuss the exact method and the heuristics and meta-heuristics used to solve the VRP and its variants.

Vehicle Routing Problem (VRP) and Its Variants: A Comprehensive Report

Introduction

The Vehicle Routing Problem (VRP) is a complex combinatorial optimization problem that aims to determine the most efficient routes for a fleet of vehicles to deliver goods or services to a set of customers, given a set of constraints. The VRP is used in supply chain management in the physical delivery of goods and services. There are several variants to the VRP. These are formulated based on the nature of the transported goods, the quality of service required and the characteristics of the customers and the vehicles. The VRP is of the NP-hard type.

The vehicle routing problem (VRP) has been very extensively studied in the optimization literature. 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. Today, exact VRP methods have a size limit of 50 - 100 orders depending on the VRP variant and the time-response 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.

Basic Vehicle Routing Problem (VRP)

Problem Definition

The classical VRP is defined as follows: Let $G = (V, A)$ be a directed graph where $V = \{0, \dots, n\}$ is the vertex set and $A = \{(i, j) : i, j \in V, i \neq j\}$ is the arc set. Vertex 0 represents the depot whereas the remaining vertices correspond to customers. A fleet of m identical vehicles of capacity Q is based at the depot. The fleet size is given a priori or is a decision variable. Each customer i has a non-negative demand q_i .

Solution Approaches

Solving the basic VRP is computationally challenging due to its NP-hard nature. Various solution approaches have been developed:

1. **Exact Methods:** These include branch-and-bound, branch-and-cut, and dynamic programming. They guarantee an optimal solution but are computationally expensive for large instances.
2. **Heuristic Methods:** These methods provide good solutions within reasonable computation times. Common heuristics include:
 - Savings Algorithm (Clarke-Wright)
 - Sweep Algorithm
 - Nearest Neighbor Algorithm
3. **Metaheuristic Methods:** These are more advanced heuristic methods that combine local search with higher-level strategies to escape local optima. Examples include:
 - Genetic Algorithms
 - Simulated Annealing
 - Tabu Search
 - Ant Colony Optimization

Variants of VRP

The basic VRP can be extended and adapted to various real-world scenarios, resulting in several important variants:

Capacitated VRP (CVRP)

Definition: Each vehicle has a fixed capacity, and the objective is to minimize the total distance traveled while respecting vehicle capacity constraints.

Key Features:

- Focus on capacity constraints.
- Common in distribution where vehicle load limits are critical.

VRP with Time Windows (VRPTW)

Definition: Customers must be served within specific time windows, adding a layer of complexity to route planning.

Key Features:

- Time window constraints for each customer.
- Often used in delivery services where timing is crucial.

Solution Approaches:

- Insertion heuristics
- Time-oriented sweep algorithm
- Metaheuristics like Genetic Algorithms adapted for time windows

VRP with Pickup and Delivery (VRPPD)

Definition: Vehicles must pick up items from certain locations and deliver them to others, often involving complex constraints related to load balance and route feasibility.

Key Features:

- Distinct pickup and delivery points.
- Load balancing and sequence constraints.

Applications:

- Courier services
- Ride-sharing services

Split Delivery VRP (SDVRP)

Definition: Allows splitting deliveries across multiple routes if it leads to a reduction in total travel cost.

Key Features:

- Multiple visits to the same customer allowed.
- Useful in scenarios with high-demand customers.

Multi-Depot VRP (MDVRP)

Definition: Involves multiple depots, adding complexity in deciding which depot a vehicle should start from and return to.

Key Features:

- Multiple starting and ending points for routes.
- Balancing load among depots.

Periodic VRP (PVRP)

Definition: Customers must be visited periodically, not necessarily every day, creating a schedule over a planning horizon.

Key Features:

- Scheduling over multiple periods.
- Common in waste collection, maintenance services.

Stochastic VRP (SVRP)

Definition: Considers uncertainty in travel times, demand, or service times, requiring robust planning.

Key Features:

- Uncertainty modeling.
- Risk management in route planning.

VRP with Backhauls (VRPB)

Definition: Combines deliveries and pickups in the same route, typically requiring deliveries to be made before pickups.

Key Features:

- Combined forward and reverse logistics.
- Often used in recycling, returnable containers.

Applications of VRP and Its Variants

Logistics and Supply Chain Management

VRP is extensively used in logistics to optimize the delivery of goods, reducing transportation costs and improving service levels. Applications include:

- Distribution centers
- Retail chains
- E-commerce delivery

Public Transportation and Ride-Sharing

In public transportation and ride-sharing services, VRP variants like VRPTW and VRPPD help in route planning to maximize efficiency and customer satisfaction.

Waste Collection

Periodic VRP is crucial in waste collection services, where routes are planned over multiple periods to ensure timely and efficient waste collection.

Conclusion

The Vehicle Routing Problem and its variants represent a vital area of research with significant practical implications across various industries. Advances in algorithms and computational techniques continue to improve the ability to solve these complex problems, driving efficiencies in logistics, transportation, and beyond. Understanding the nuances of each VRP variant and applying the appropriate solution methods can lead to substantial cost savings and operational improvements.

References

- Toth, P., & Vigo, D. (Eds.). (2014). *Vehicle Routing: Problems, Methods, and Applications*. SIAM.
- Laporte, G. (2009). Fifty Years of Vehicle Routing. *Transportation Science*, 43(4), 408-416.
- Golden, B., Raghavan, S., & Wasil, E. (Eds.). (2008). *The Vehicle Routing Problem: Latest Advances and New Challenges*. Springer.





Problem statement:

Company has PAN India warehouses. And PAN India customers where we have to deliver some packages, dimensions (weight/volume/quantity) of each package are given. We have tie up with a company which provide us different type of vehicles (with different capacities) for the same. Let us assume demand at each customer node is known in advance. Company has to do routing for each of the warehouse such that each customer should be served and minimize the total distance to be covered. Suggest the number of vehicles of each type to be rented for efficient routing.

There are two types of routings to be done:

1. **Incity Routing** (Two – way)
2. **Upcountry Routing** (One – way)

Problem Formulation:

Consider a network $G = [V, A]$, where V is the set of nodes/customers and A is the set of arcs.

Decision variables:

- $x_{ijk} \rightarrow$ binary variable indicating an active arc from node i to node j covered by vehicle k.
- $y_{ik} \rightarrow$ binary variable indicating that demand at node i is fulfilled by vehicle k.

Indices:

- $V \rightarrow$ set of nodes
- $W \rightarrow$ set of warehouse nodes
- $K \rightarrow$ set of vehicles

Incity Problem:

Features:

- Vehicle left the warehouse for the delivery should return to the same warehouse.
- Serve only locations which are within 60km from the warehouse.

Parameters:

- $q_i \rightarrow$ demand at node i .
- $W \rightarrow$ maximum weight holding capacity of vehicle.
- $V \rightarrow$ maximum volume holding capacity of vehicle.
- $d_{ij} \rightarrow$ distance between node i to node j .
- $D \rightarrow$ maximum distance a vehicle can travel in a route.
- $K \rightarrow$ number of vehicles.

Constraints – Incity (Two-way)(within 60km from warehouse):

- Each *customer i* is visited once, therefore has one active arc which starts from it and one that arrives on it.
- If any arc variable indexed by *vehicle k* goes into one *node i* or out of it, the *demand* of this node is assigned to *vehicle k*.
- The total demand (weight) assigned to a vehicle must not exceed its *capacity W*.
- The total demand (volume) assigned to a vehicle must not exceed its *capacity V*.
- The distance assigned to any vehicle in a route should not exceed its maximum travelling capacity.
- Exactly k vehicles should start and arrive at the *warehouse*.
- There are no subtours.
- All the decision variables are binary.

Objective Function:

$$\text{Min} \sum_{i \in V} \sum_{j \in V} \sum_{k \in K} x_{ijk} d_{ij}$$

Constraints:

$$\sum_{k \in K} \sum_{j \in V} x_{ijk} = \sum_{k \in K} \sum_{j \in V} x_{jik} = 1 \quad \forall i \in V - \{0\}$$

$$\sum_{j \in V} x_{ijk} = \sum_{j \in V} x_{jik} = y_{ik} \quad \forall i \in V - \{0\}, \quad k \in K$$

$$\sum_{i \in V} w_i y_{ik} \leq W \quad \forall k \in K$$

$$\sum_{i \in V} v_i y_{ik} \leq V \quad \forall k \in K$$

$$\sum_{i \in V} \sum_{j \in V} x_{ijk} d_{ij} \leq D \quad \forall k \in K$$

$$\sum_{k \in K} \sum_{j \in V} x_{0jk} = \sum_{k \in K} \sum_{i \in V} x_{i0k} = |K|$$

$$\sum_{i \in S} \sum_{j \notin S} x_{ijk} \geq y_{hk} \quad \forall S \subseteq V - \{0\}, \quad h \in S, \quad k \in K$$

$$x_{ijk} \in \{0,1\} \quad \forall i, j \in V, \quad k \in K$$

$$y_{ik} \in \{0,1\} \quad \forall i \in V, \quad k \in K$$

Note: This formulation is for single warehouse(depot), we have to extend it to multiple warehouses by using it multiple times to all the warehouses or use python loops to do it for all.

Upcountry Problem:

Features:

- Vehicle left the warehouse for the delivery should not return to the warehouse.
- Serve only locations which are outside 60km from the warehouse.

Parameters:

- $q_i \rightarrow$ demand at node i .
- $W \rightarrow$ maximum weight holding capacity of vehicle.
- $V \rightarrow$ maximum volume holding capacity of vehicle.
- $d_{ij} \rightarrow$ distance between node i to node j .
- $D \rightarrow$ maximum distance between any two locations in a route.
- $K \rightarrow$ number of vehicles.

Constraints – Upcountry (One-way)(outside 60km):

- Each *customer i* is visited once, therefore has one active arc which starts from it and one that arrives on it except one arc which ends at depot.
- If any arc variable indexed by *vehicle k* goes into one *node i* or out of it, the *demand* of this node is assigned to *vehicle k*.
- The total demand (weight) assigned to a vehicle must not exceed its *capacity W*.
- The total demand (volume) assigned to a vehicle must not exceed its *capacity V*.
- The distance of any arc containing any two locations except depot should not exceed the maximum distance assigned to the arc.
- No more than 3 customers should be assigned to any particular route/vehicle.
- Exactly k vehicles should start from the *warehouse*.
- No vehicle should return to the depot.
- There are no subtours.
- All the decision variables are binary.



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Objective Function:

$$\text{Min} \sum_{i \in V} \sum_{j \in V} \sum_{k \in K} x_{ijk} d_{ij}$$

Constraints:

$$\sum_{k \in K} \sum_{j \in V - \{0\}} x_{ijk} = \sum_{k \in K} \sum_{j \in V} x_{jik} = 1 \quad \forall i \in V - \{0\}$$

$$\sum_{j \in V} x_{ijk} = \sum_{j \in V} x_{jik} = y_{ik} \quad \forall i \in V - \{0\}, \quad k \in K$$

$$\sum_{i \in V} w_i y_{ik} \leq W \quad \forall k \in K$$

$$\sum_{i \in V} v_i y_{ik} \leq V \quad \forall k \in K$$

$$x_{ijk} d_{ij} \leq D \quad \forall i \in V - \{0\}, \quad j \in V - \{0\}, \quad k \in K$$

$$\sum_{i \in V} \sum_{j \in V - \{0\}} x_{ijk} \leq 3 \quad \forall k \in K$$

$$\sum_{k \in K} \sum_{j \in V} x_{0jk} = |K|$$

$$\sum_{k \in K} \sum_{i \in V - \{0\}} x_{i0k} = 0$$

$$\sum_{i \in S} \sum_{j \notin S} x_{ijk} \geq y_{hk} \quad \forall S \subseteq V - \{0\}, \quad h \in S, \quad k \in K$$

$$x_{ijk} \in \{0,1\} \quad \forall i, j \in V, \quad k \in K$$

$$y_{ik} \in \{0,1\} \quad \forall i \in V, \quad k \in K$$

Note: This formulation is for single warehouse(depot), we have to extend it to multiple warehouses by using it multiple times to all the warehouses or use python loops to do it for all.

Vehicle and their Capacities

Truck Type	Length	Width	Height	Max Weight (Ton)	Maximum CFT	Usable CFT
Tata Ace (100KM)	7	4.8	4.8	0.85	161	80.64
Mahindra Bolero pickup (250KM)	8	4.8	4.8	1.5	184	92.16
Eicher 14 Feet (400KM)	14	6	6.5	4	546	409.5
Eicher 17 Feet	17	6	7	5	714	535.5
EICHER 20 FEET	20	8	7	7	1,120	840
CONTAINER 32 FT SXL	32	8	8	7	2,048	1536

Warehouses and their pin code:

Sr. No.	Region	Pin
1	Bhiwandi MWH	421301
2	OEM Warehouse - Dehradun	248001
3	OEM Warehouse - Ghiloth	301001
4	OEM Warehouse - Noida	201305
5	RWH-Bangalore	560001
6	RWH-Bhuwaneshwar	751001
7	RWH-Chennai	600001
8	RWH-Coimbatore	641016
9	RWH-Guwahati	781035
10	RWH-Hyderabad	501511
11	RWH-Jaipur	302026
12	RWH-Jharkhand	834001
13	RWH-Kerala	680001
14	RWH-Kolkata	711302
15	RWH-Lucknow	226001
16	RWH-Mohali	140417
17	RWH-Nagpur	440034
18	RWH-Patna	854102
19	RWH-Pune	411060
20	RWH-Raipur	493111
21	RWH-Vijaywada	521139
22	Sonipat MWH	136118

Solving Vehicle Routing Problem:

Clarke and Wright Savings Algorithm Heuristics:

Let there be N demand points in a given area, each with demand w_i and v_i , $i = 1, 2, 3, \dots, N$ of goods to be delivered to it. Goods are assumed to be indistinguishable for their demands. Goods are stored at depot where a fleet of vehicles is also stationed. Vehicles have some distance and capacity constraints with them.

The objective is to obtain a set of delivery routes to the various demand points so as to minimize the total distance covered by the fleet. It is assumed that demands w_i and v_i , $i = 1, 2, 3, \dots, N$ of the quantities demanded are less than the max capacity of vehicles and whole quantity w_i and v_i must be delivered by a single vehicle.

How Clarke and Wright savings algorithm works?

- 1) Calculate the savings $s_{ij} = c_{1j} + c_{1i} - c_{ij}$ $\forall i, j = 1, 2, \dots, N$ where 1 is the depot node and the rest of the i, j are demand points.
- 2) Rank the savings and list them in descending order of magnitude which creates the savings list.
- 3) Process the savings list beginning with the topmost entry in the list. For the savings s_{ij} under consideration, include the link $i - j$ in a route if no route constraints are violated and if (i) either, neither i nor j have already been assigned to a route in which case a new route is initiated through i and j or (ii) exactly one of the two points i or j has already been included in an existing route and that the point is not interior to that route. (A point is considered interior to a route if it is not adjacent to the depot d in the order of traversal of points), in which case the link $i - j$ is added to that route or, (iii) both i and j have already been included in two different existing routes and neither point is interior to its routes, in which case the two routes are merged.
- 4) If the savings list is not exhausted, go to step 3 and process the next entry in the list, otherwise stop.

Results

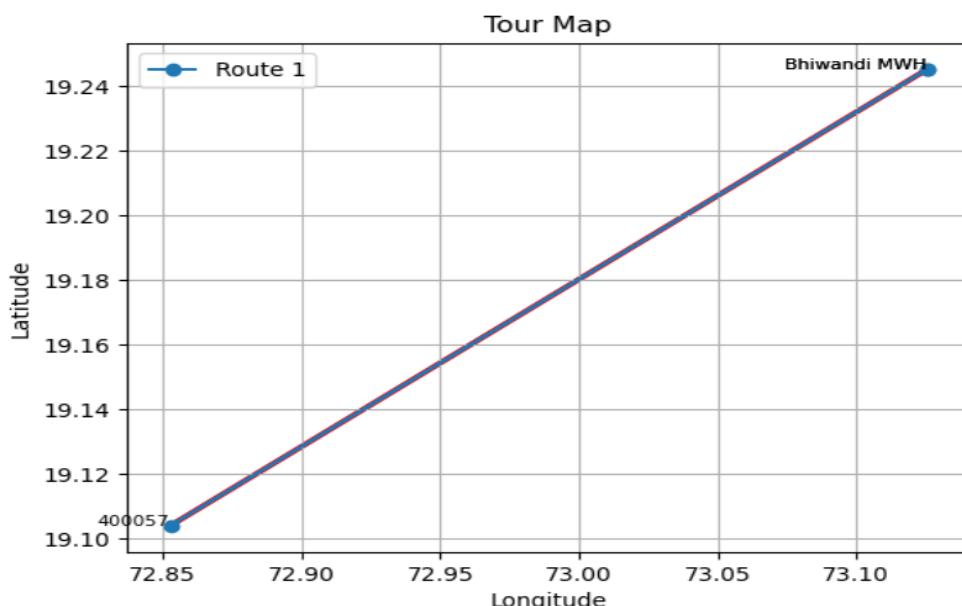
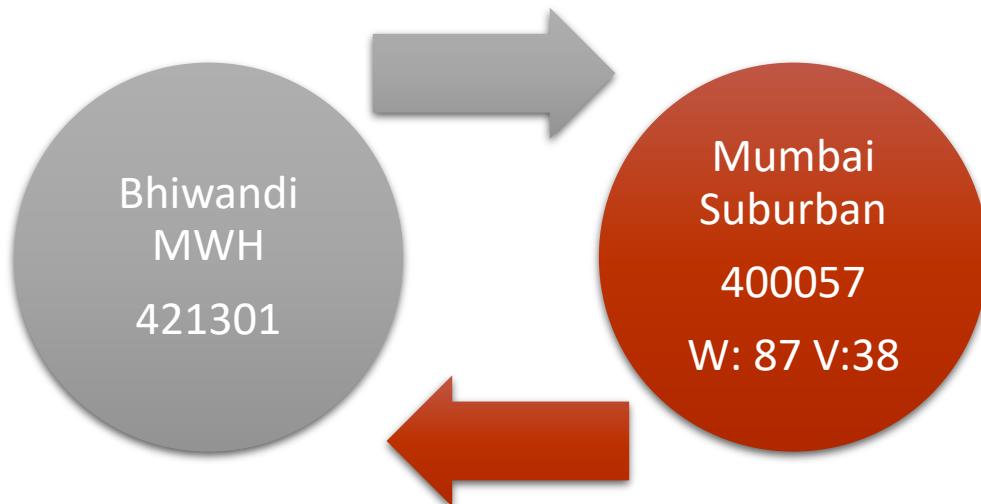
For Warehouse: Bhiwandi MWH

Incity Routing:

Vehicle 1: Tata Ace



Distance covered: 82 KM



Upcountry Routing:

Vehicle 1: Elcher 17 Feet



Distance covered: 607 KM

Bhiwandi MWH
421301



Indore
452010
W: 70
V: 18

Vehicle 2: Elcher 17 Feet



Distance covered: 983 KM

Bhiwandi MWH
421301



GONDIA
441601
W: 541
V: 262

Vehicle 3: Elcher 17 Feet



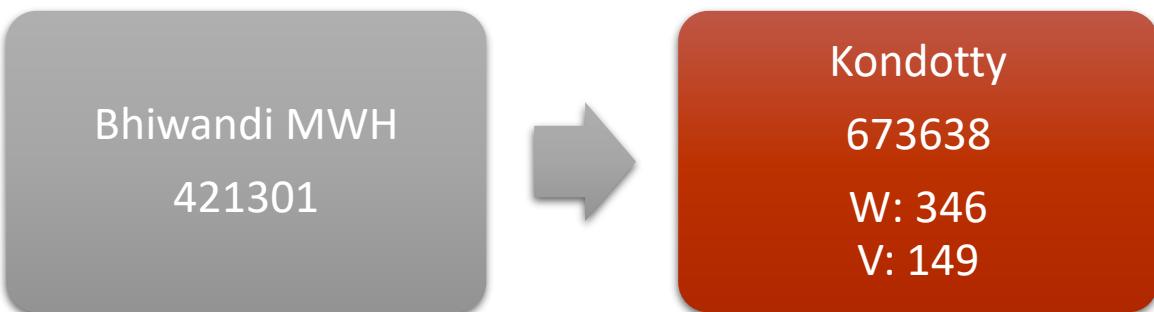
Distance covered: 1261 KM



Vehicle 4: Elcher 17 Feet



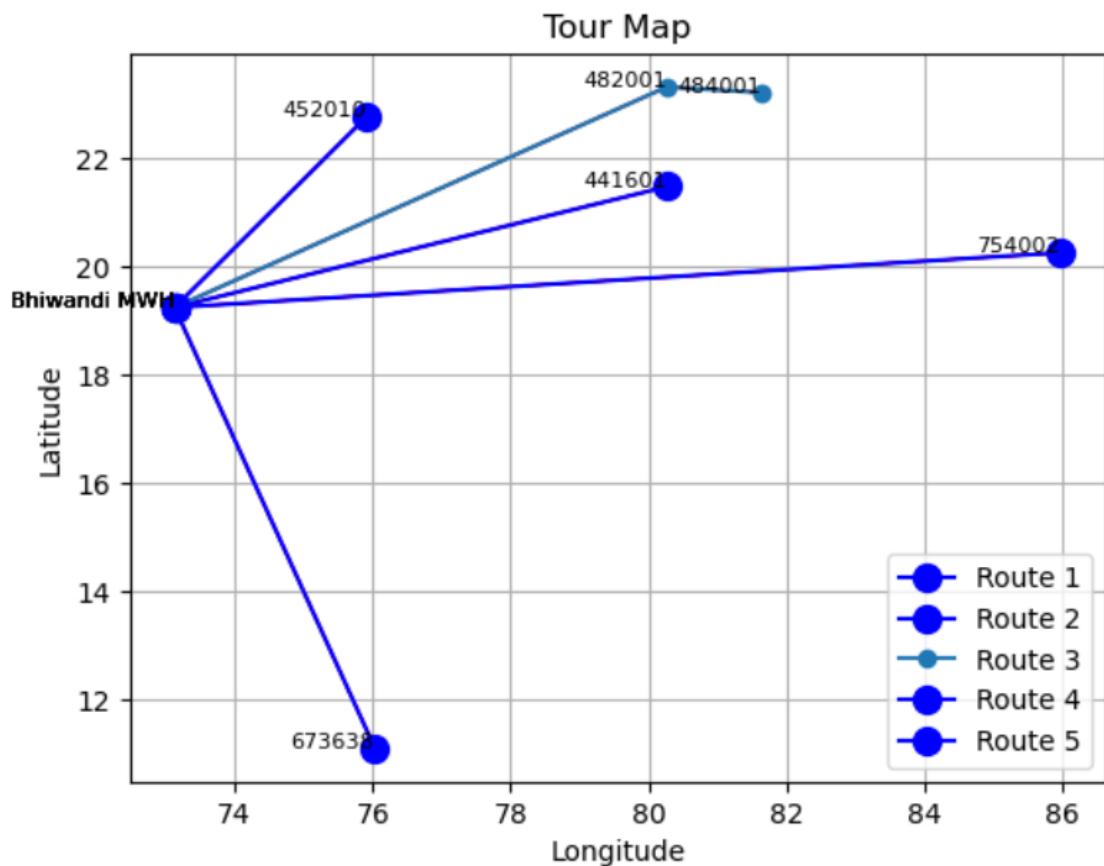
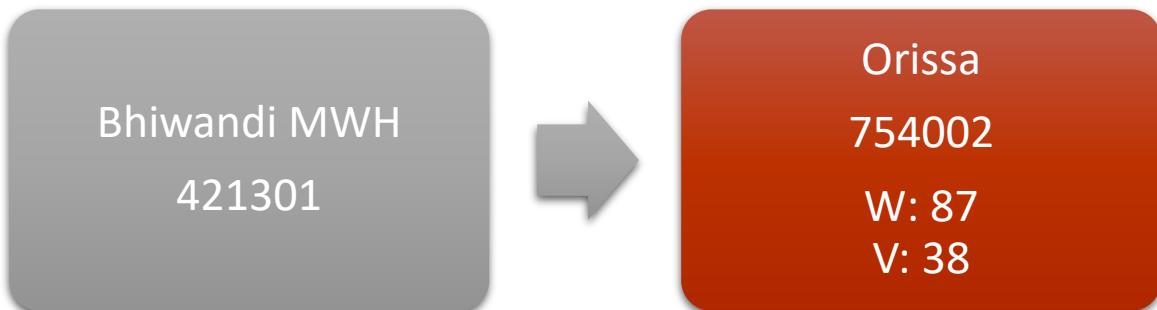
Distance covered: 1197 KM



Vehicle 5: Elcher 17 Feet



Distance covered: 1688 KM



For Warehouse: OEM Warehouse - Dehradun

Upcountry Routing:

Vehicle 1: Container 32 FT SXL



Distance covered: 190 KM

OEM Warehouse -
Dehradun
248001



Patiala
147002-1
W: 2471
V: 1520

Vehicle 2: Elcher 20 Feet



Distance covered: 221 KM

OEM Warehouse -
Dehradun
248001



MORADABAD
244001
W: 1358
V: 835



Vehicle 3: Elcher 20 Feet



Distance covered: 273 KM

OEM Warehouse -
Dehradun
248001



Ludhiana
141003
W: 1358
V: 835

Vehicle 4: Container 32 FT SXL



Distance covered: 372 KM

OEM
Warehouse -
Dehradun
248001



Patiala
147002
W: 245
V: 151



Patiala
151001
W: 1358
V: 835



Vehicle 5: Elcher 20 Feet



Distance covered: 409 KM

OEM Warehouse -
Dehradun
248001



CHIRAWA
333026
W: 1358
V: 835

Vehicle 6: Elcher 20 Feet



Distance covered: 543 KM

OEM Warehouse -
Dehradun
248001



BAREILLY
243001
W: 1358
V: 835

Vehicle 7: Elcher 20 Feet



Distance covered: 598 KM

OEM Warehouse -
Dehradun
248001



JAIPUR
302013
W: 1358
V: 835

Vehicle 8: Container 32 FT SXL



Distance covered: 599 KM

OEM Warehouse -
Dehradun
248001

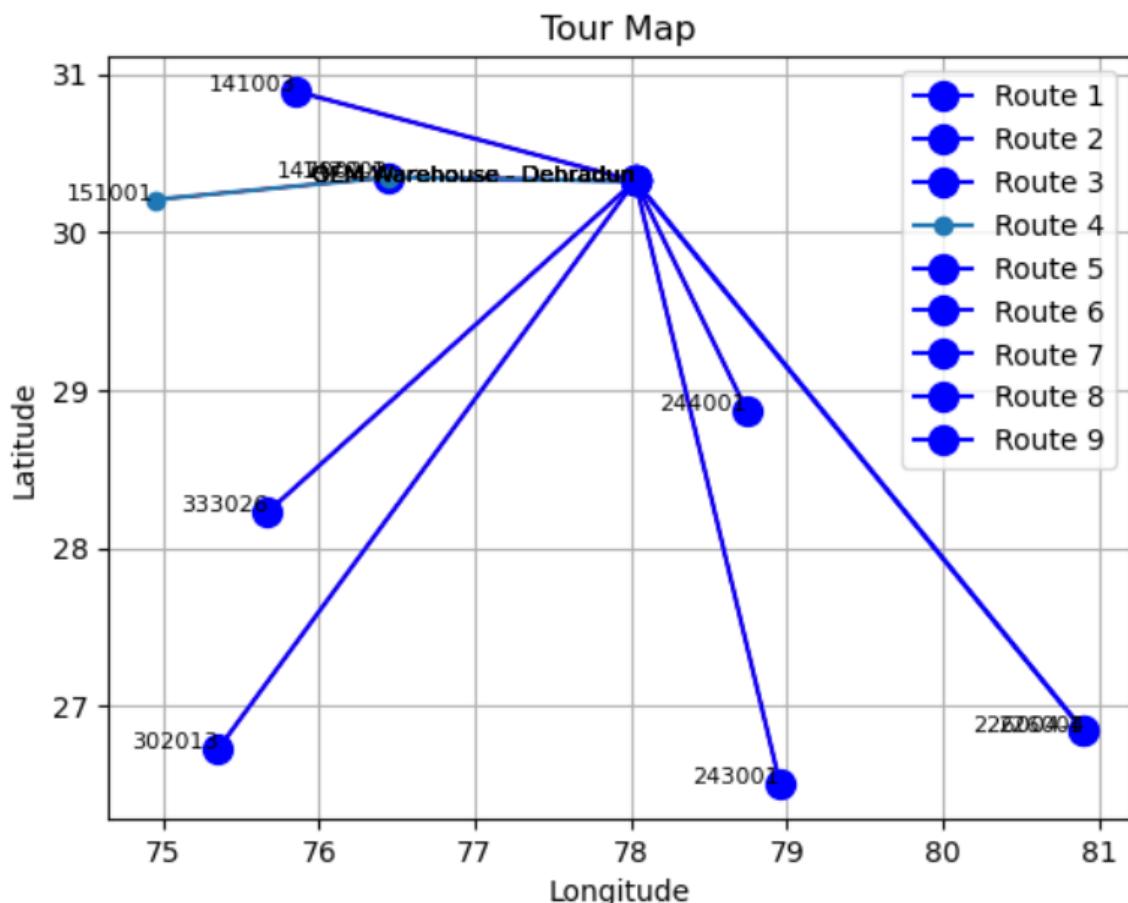
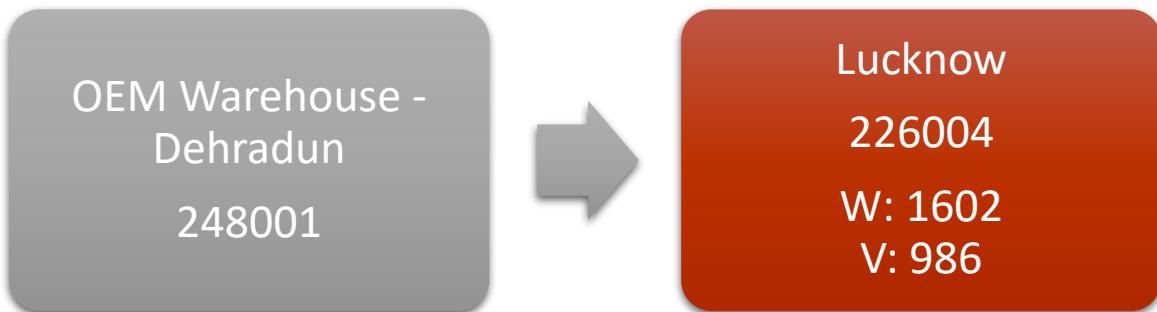


Lucknow
226004-1
W: 2471
V: 1520

Vehicle 9: Container 32 FT SXL



Distance covered: 599 KM



For Warehouse: OEM Warehouse - Ghiloth

Upcountry Routing:

Vehicle 1: Container 32 FT SXL



Distance covered: 2133 KM

OEM Warehouse -
Ghiloth
301001

MYSORE SOUTH
570008
W: 1872
V: 1304

Vehicle 2: Container 32 FT SXL



Distance covered: 2036 KM

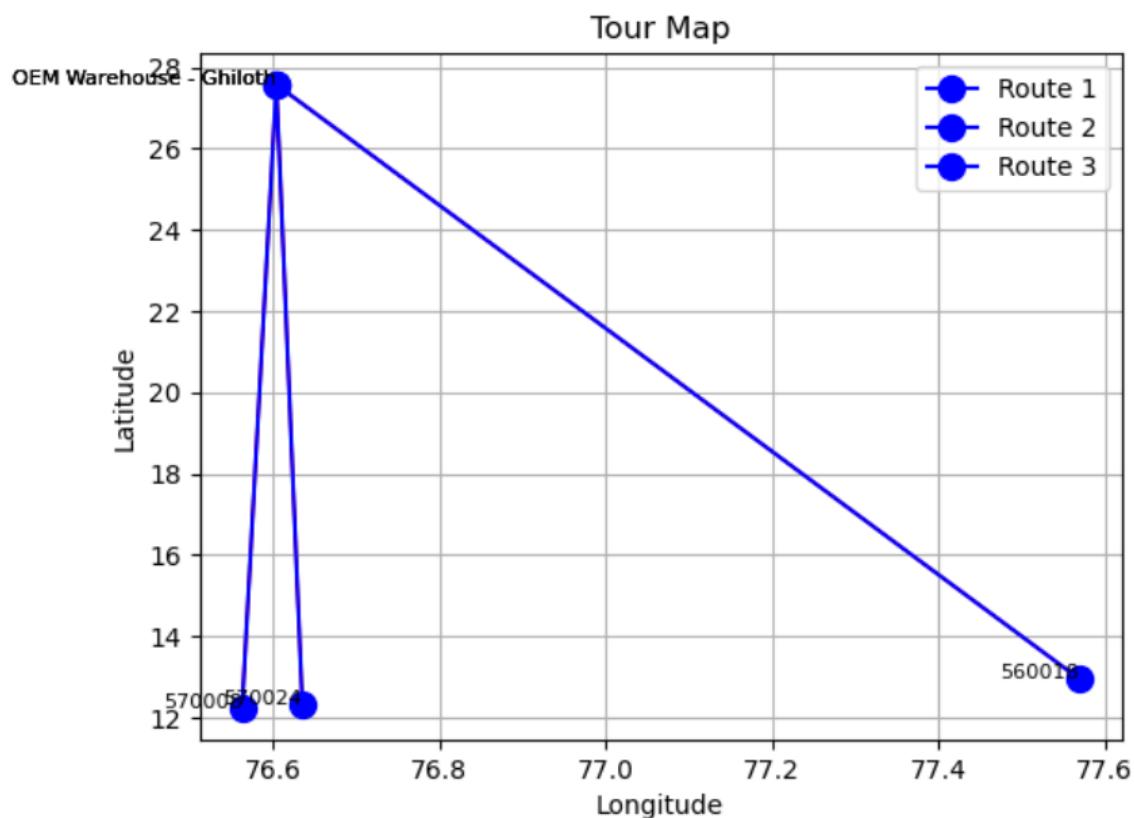
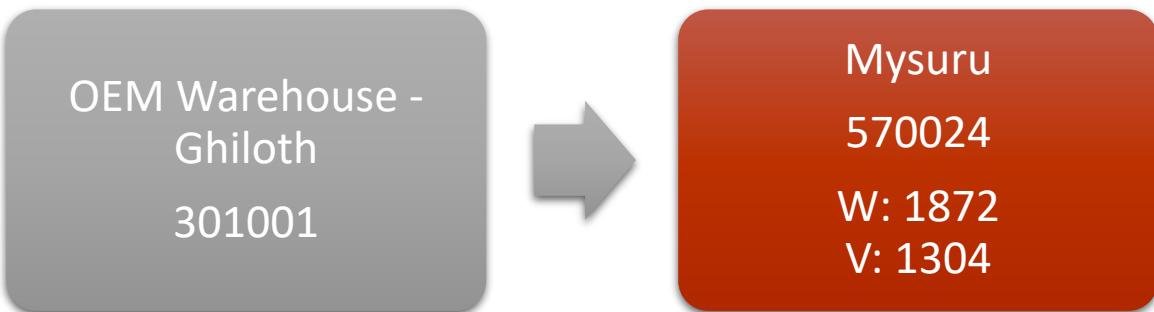
OEM Warehouse -
Ghiloth
301001

Bangalore
560018
W: 1872
V: 1304

Vehicle 3: Container 32 FT SXL



Distance covered: 2118 KM



For Warehouse: OEM Warehouse - Noida

Upcountry Routing:

Vehicle 1: Elcher 17 Feet



Distance covered: 89 KM

OEM Warehouse -
Noida
201305



PALWAL
121106
W: 919
V: 445

Vehicle 2: Elcher 20 Feet

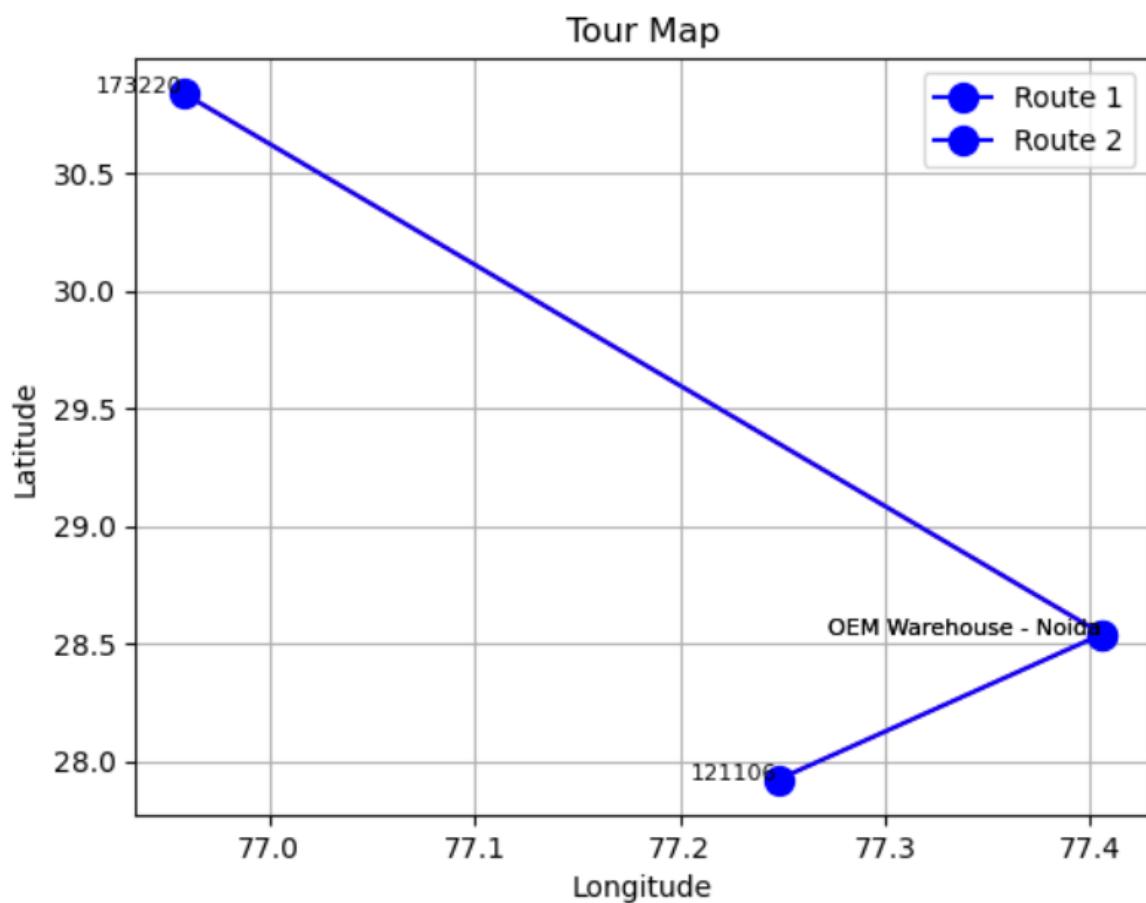


Distance covered: 325 KM

OEM Warehouse -
Noida
201305



Parwanoo
173220
W: 1195
V: 735



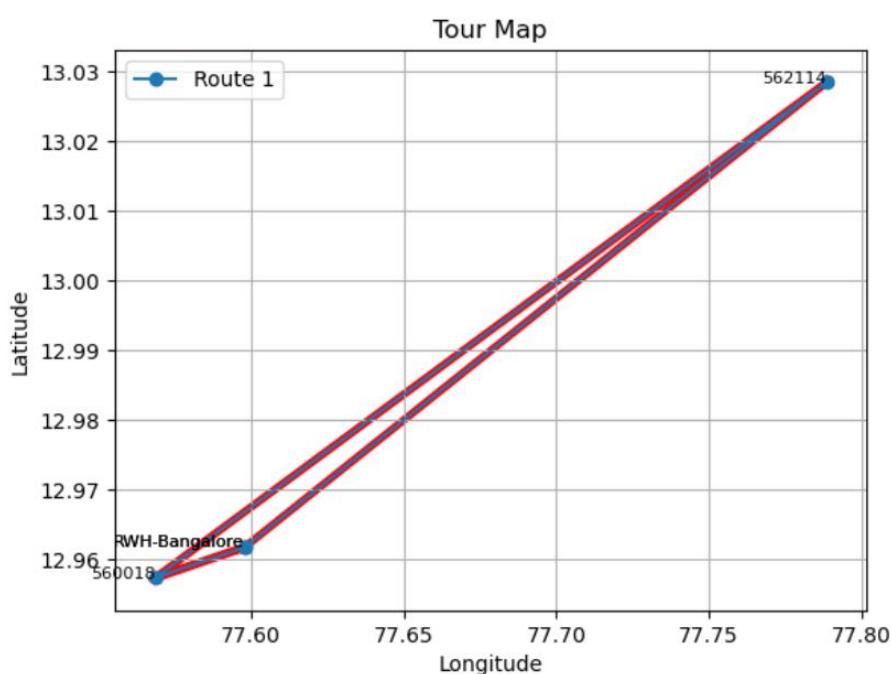
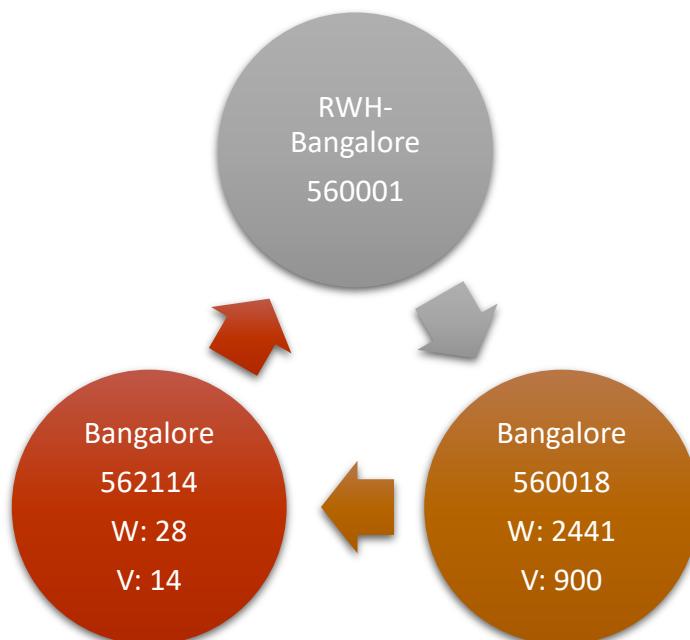
For Warehouse: RWH-Bangalore

Incity Routing:

Vehicle 1: Container 32 FT SXL



Distance covered: 82 KM



Upcountry Routing:

Vehicle 1: Container 32 FT SXL



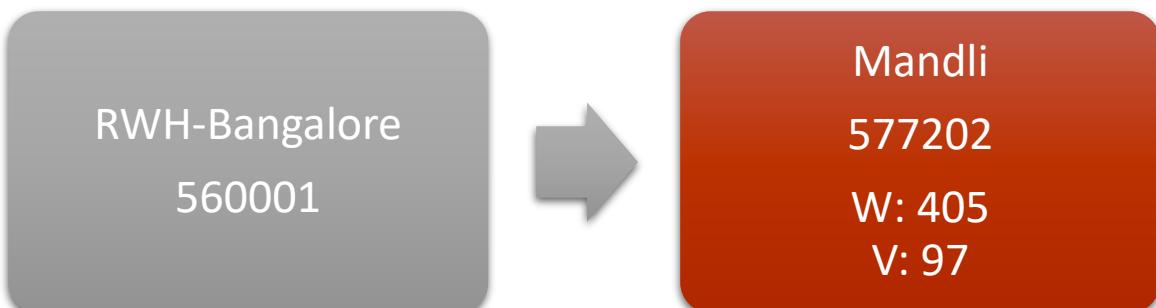
Distance covered: 175 KM



Vehicle 2: Elcher 14 Feet



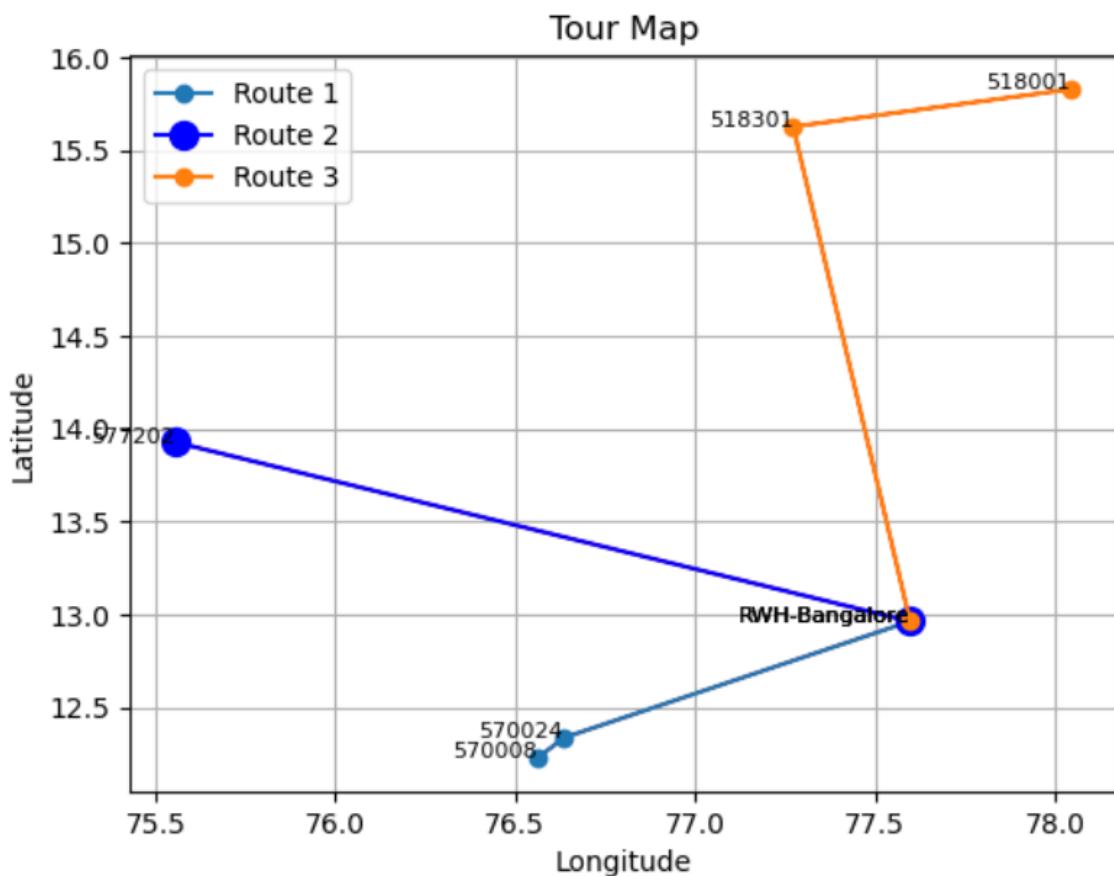
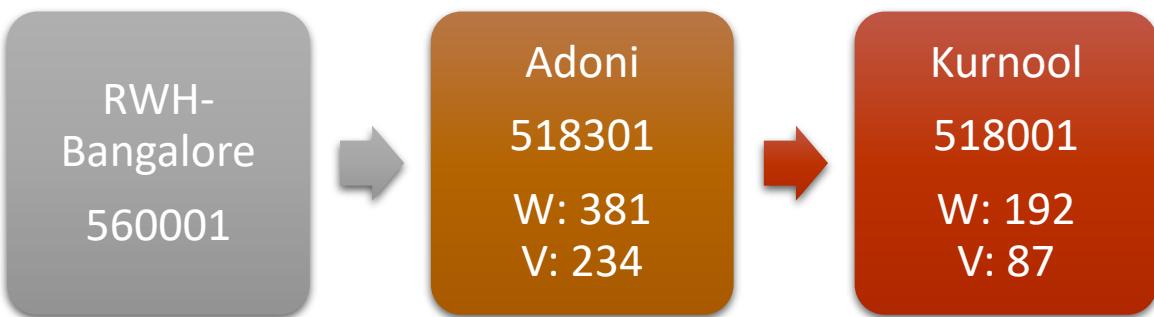
Distance covered: 307 KM



Vehicle 3: Elcher 17 Feet



Distance covered: 481 KM



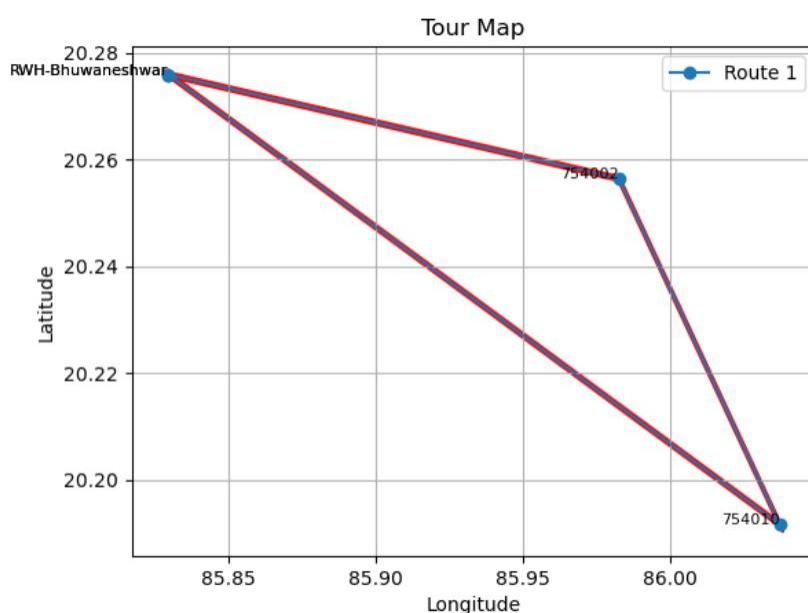
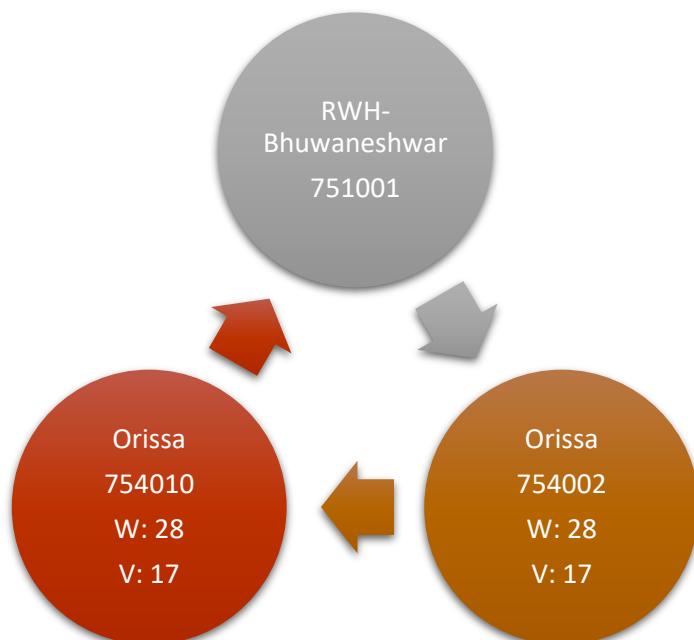
For Warehouse: RWH-Bhuwaneshwar

Incity Routing:

Vehicle 1: Tata Ace



Distance covered: 63 KM

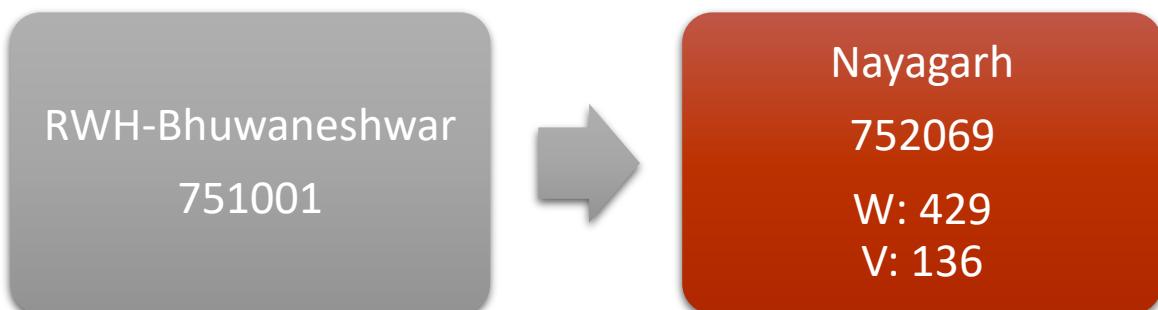


Upcountry Routing:

Vehicle 1: Elcher 14 Feet



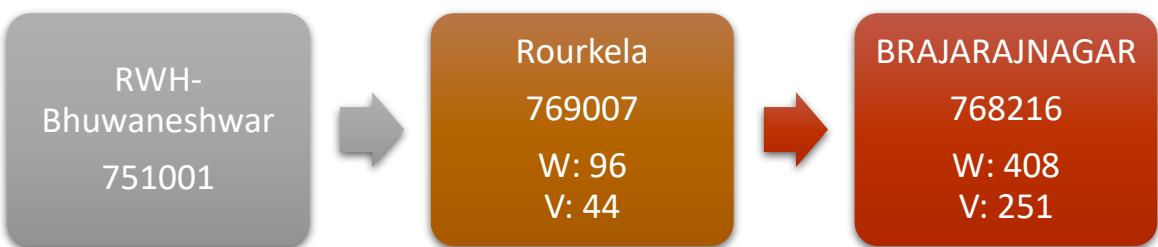
Distance covered: 97 KM



Vehicle 2: Elcher 17 Feet



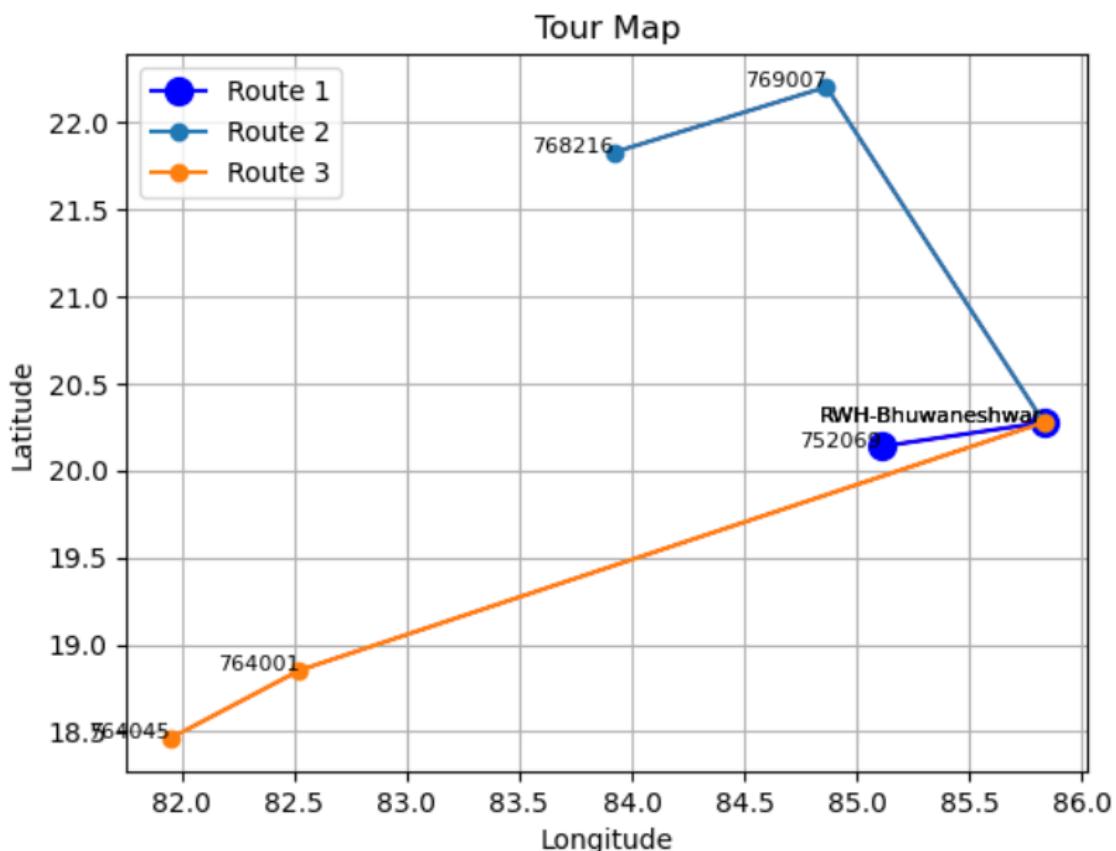
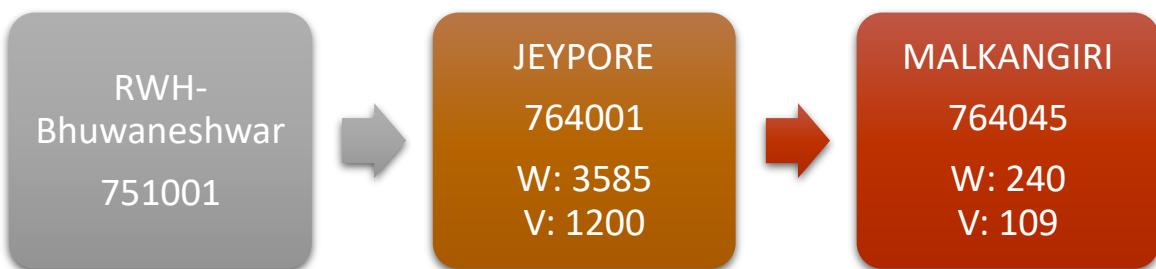
Distance covered: 429 KM



Vehicle 3: Container 32 FT SXL



Distance covered: 570 KM



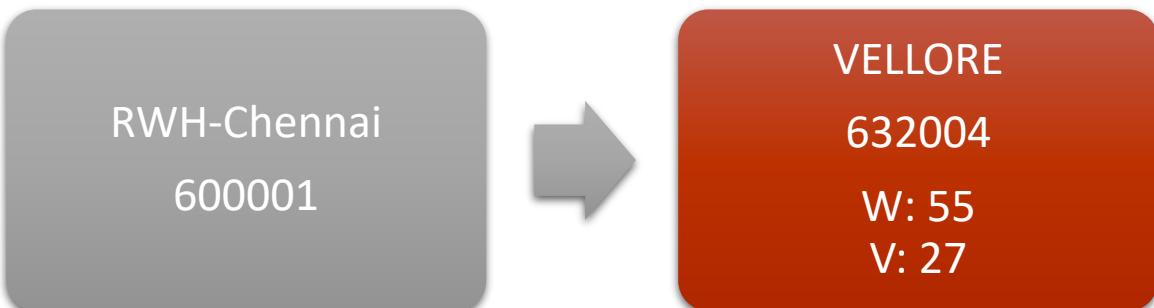
For Warehouse: RWH-Chennai

Upcountry Routing:

Vehicle 1: Mahindra Bolero Pickup



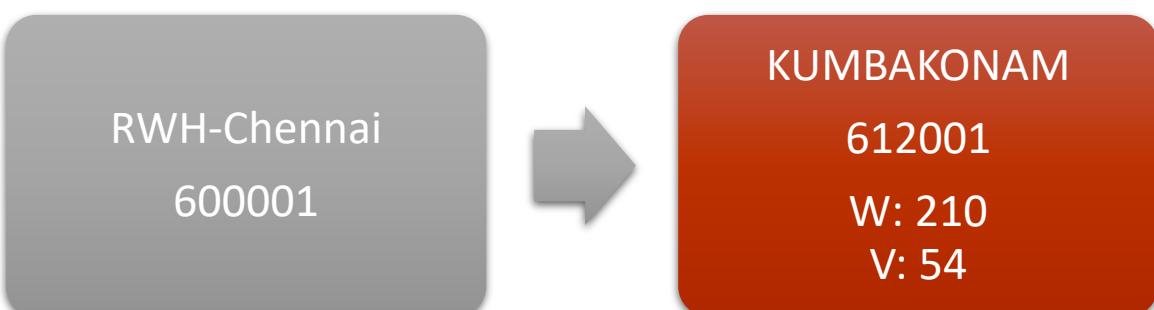
Distance covered: 158 KM



Vehicle 2: Elcher 14 Feet



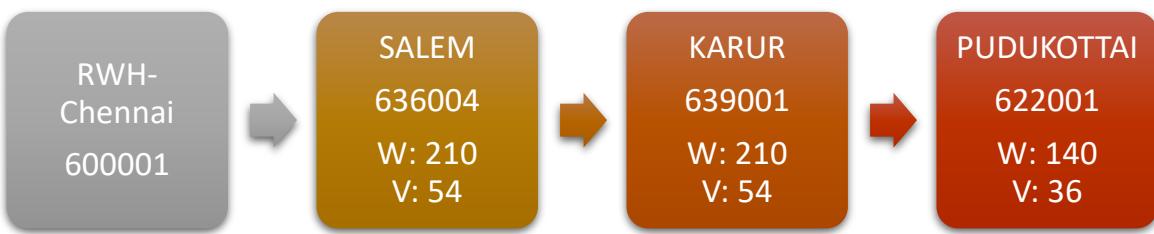
Distance covered: 324 KM



Vehicle 3: Elcher 17 Feet



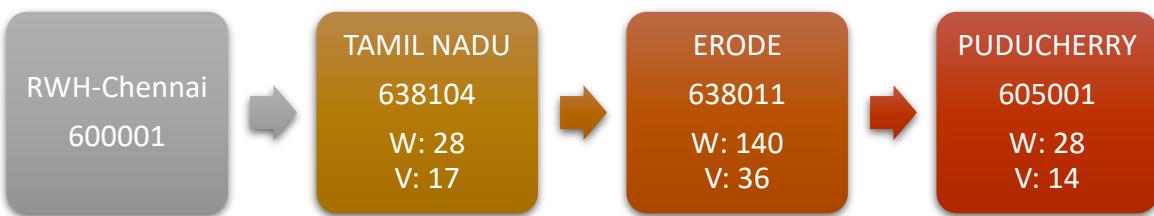
Distance covered: 583 KM



Vehicle 4: Elcher 17 Feet



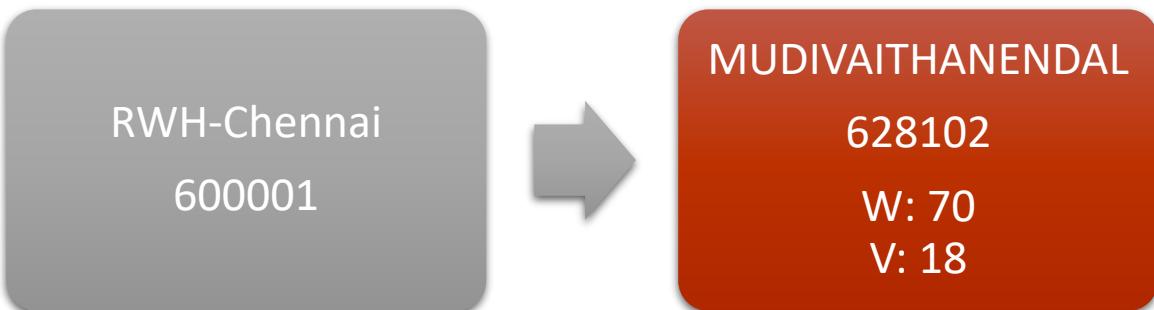
Distance covered: 592 KM



Vehicle 5: Elcher 17 Feet



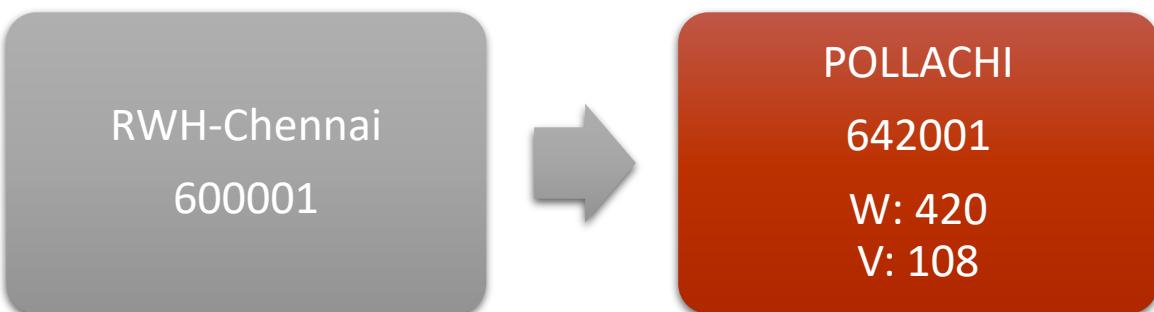
Distance covered: 685 KM

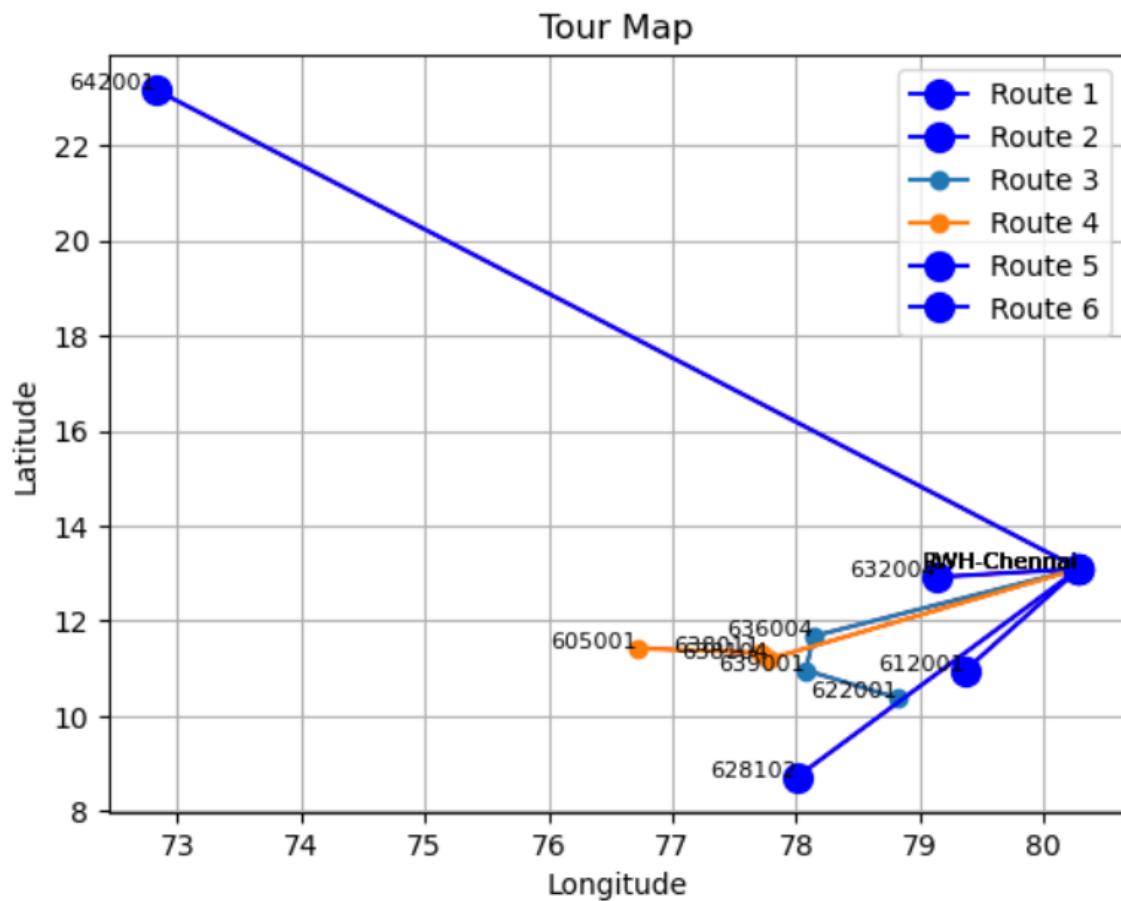


Vehicle 6: Elcher 17 Feet



Distance covered: 1712 KM





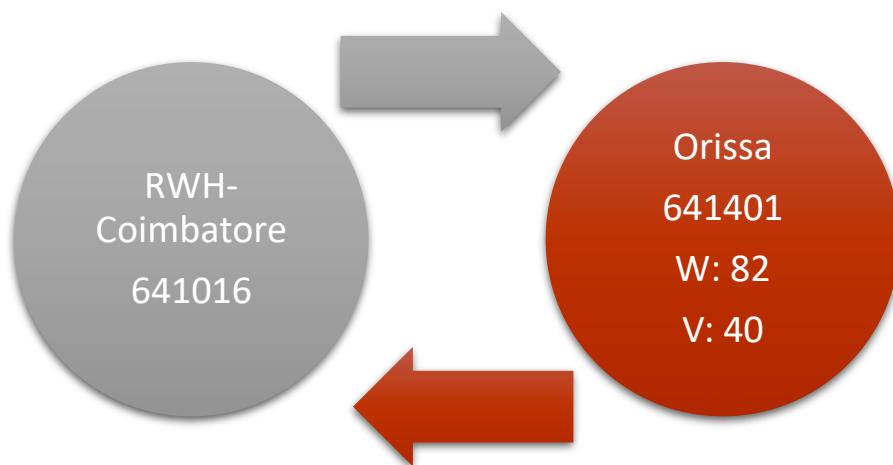
For Warehouse: RWH-Coimbatore

Incity Routing:

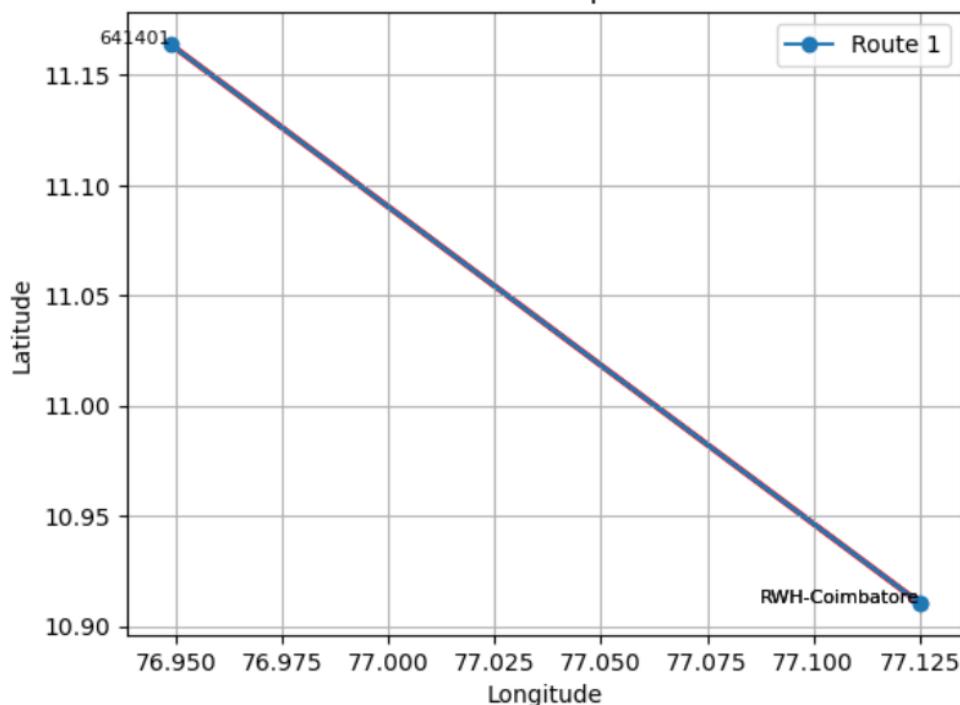
Vehicle 1: Tata Ace



Distance covered: 86 KM



Tour Map

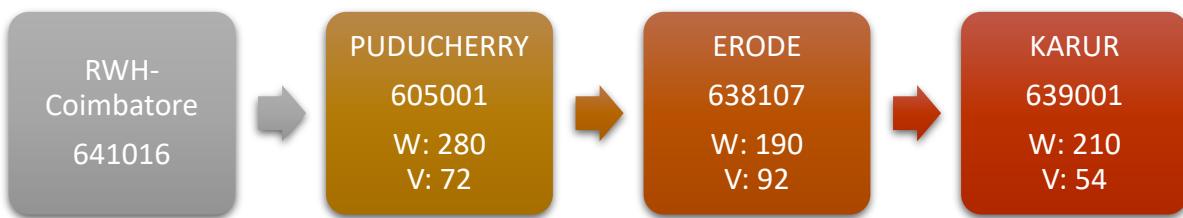


Upcountry Routing:

Vehicle 1: Elcher 14 Feet



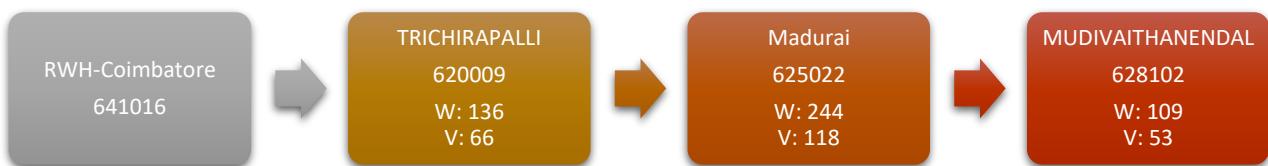
Distance covered: 296 KM



Vehicle 2: Elcher 17 Feet



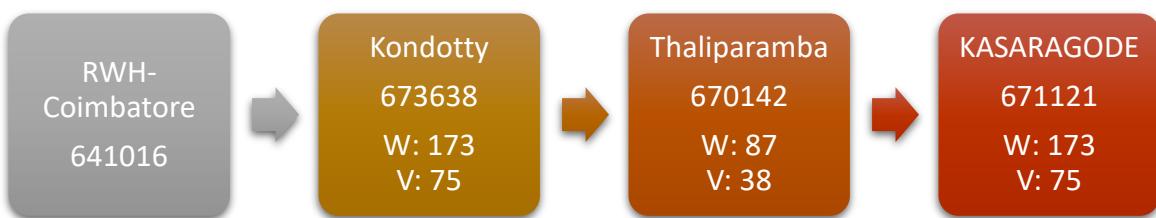
Distance covered: 503 KM



Vehicle 3: Elcher 14 Feet



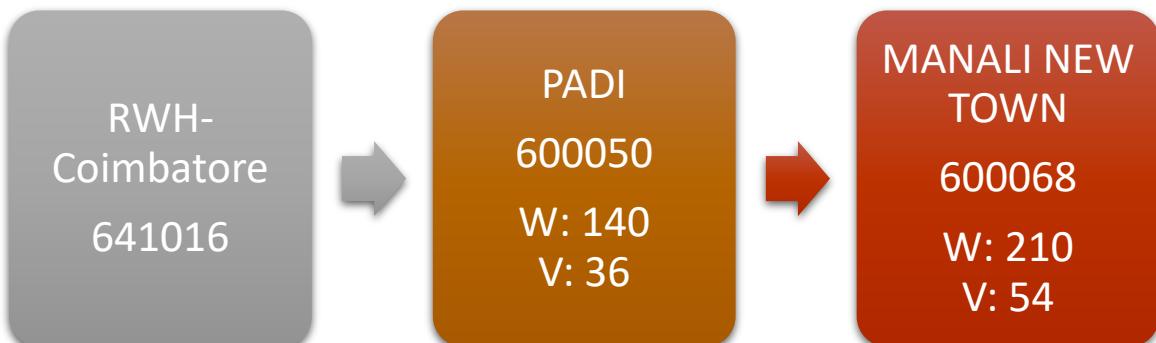
Distance covered: 398 KM



Vehicle 4: Elcher 17 Feet



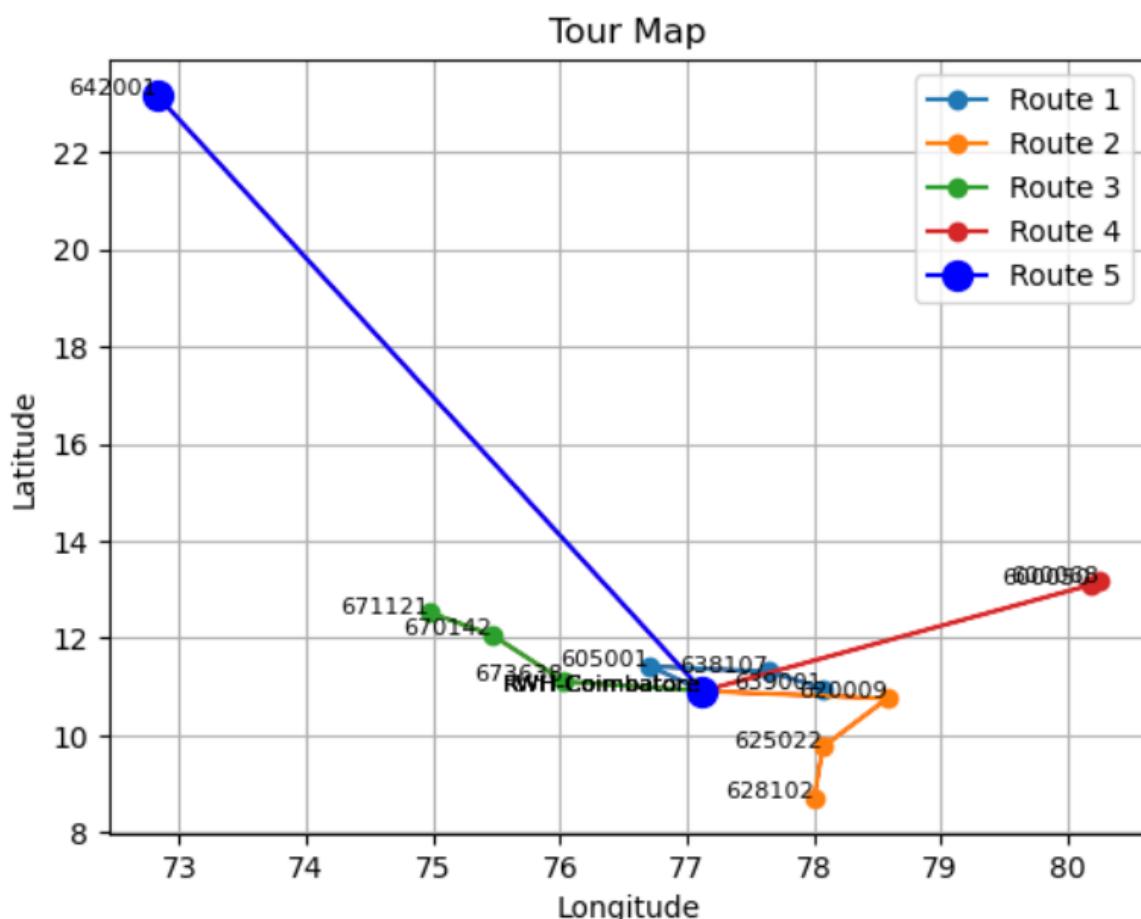
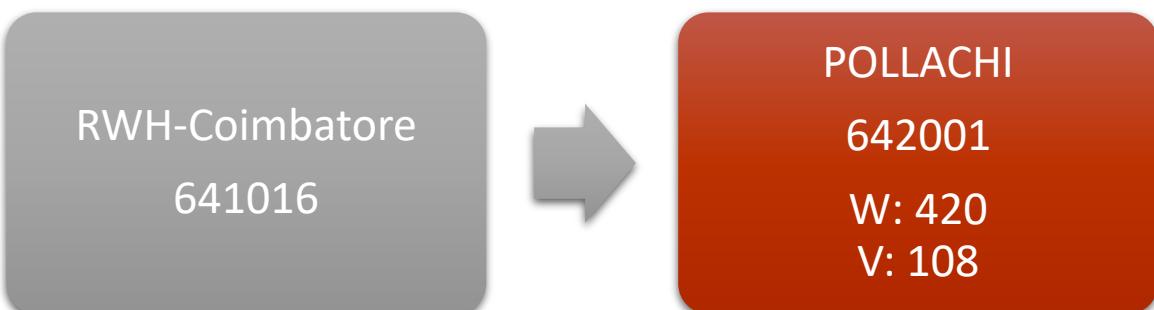
Distance covered: 531 KM



Vehicle 5: Elcher 17 Feet



Distance covered: 1797 KM



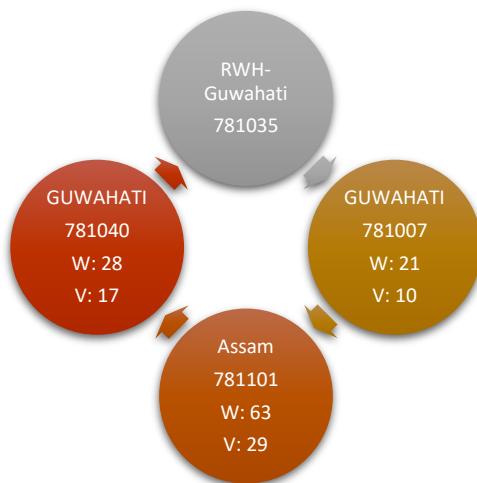
For Warehouse: RWH-Guwahati

Incity Routing:

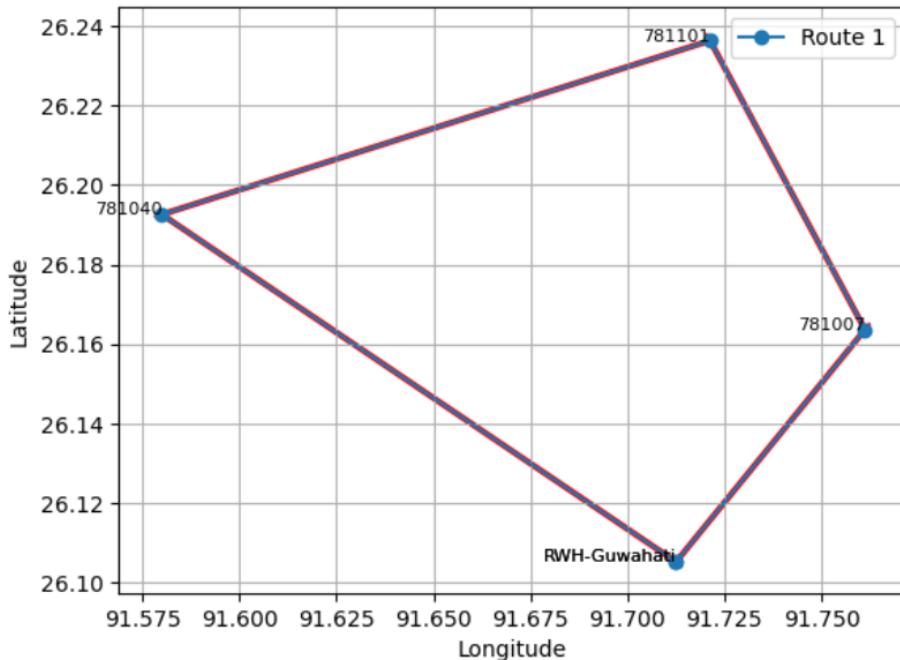
Vehicle 1: Tata Ace



Distance covered: 63 KM



Tour Map



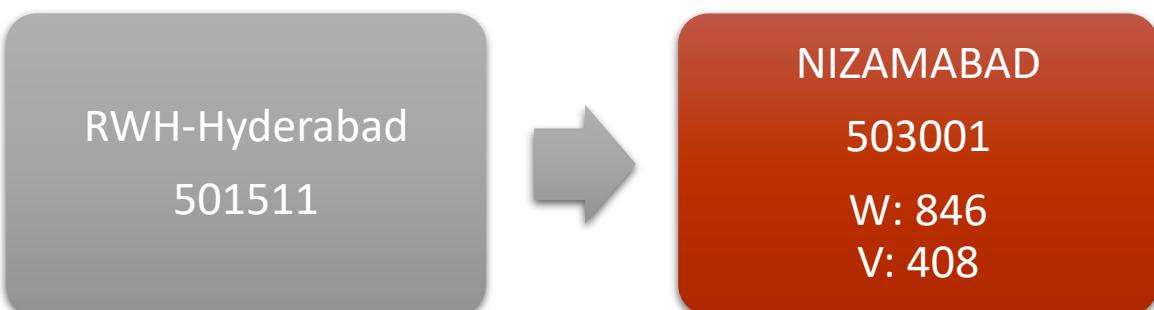
For Warehouse: RWH-Hyderabad

Upcountry Routing:

Vehicle 1: Elcher 14 Feet



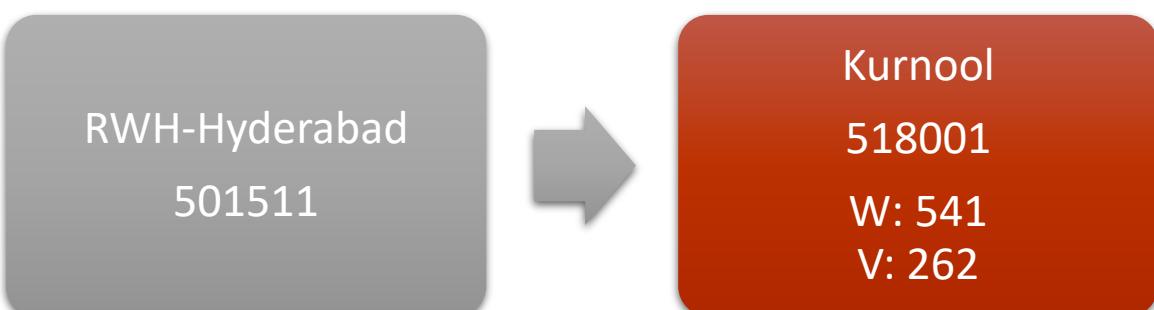
Distance covered: 206 KM



Vehicle 2: Elcher 14 Feet



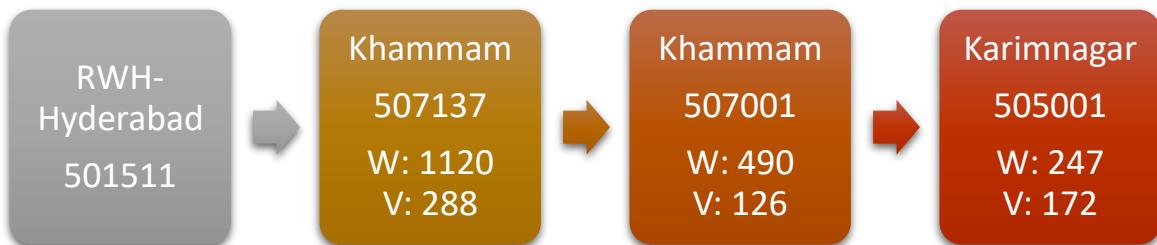
Distance covered: 217 KM



Vehicle 3: Elcher 20 Feet



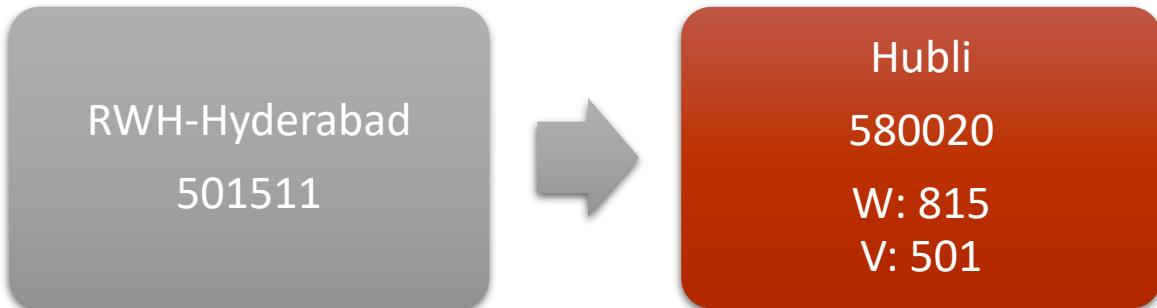
Distance covered: 640 KM



Vehicle 4: Elcher 17 Feet



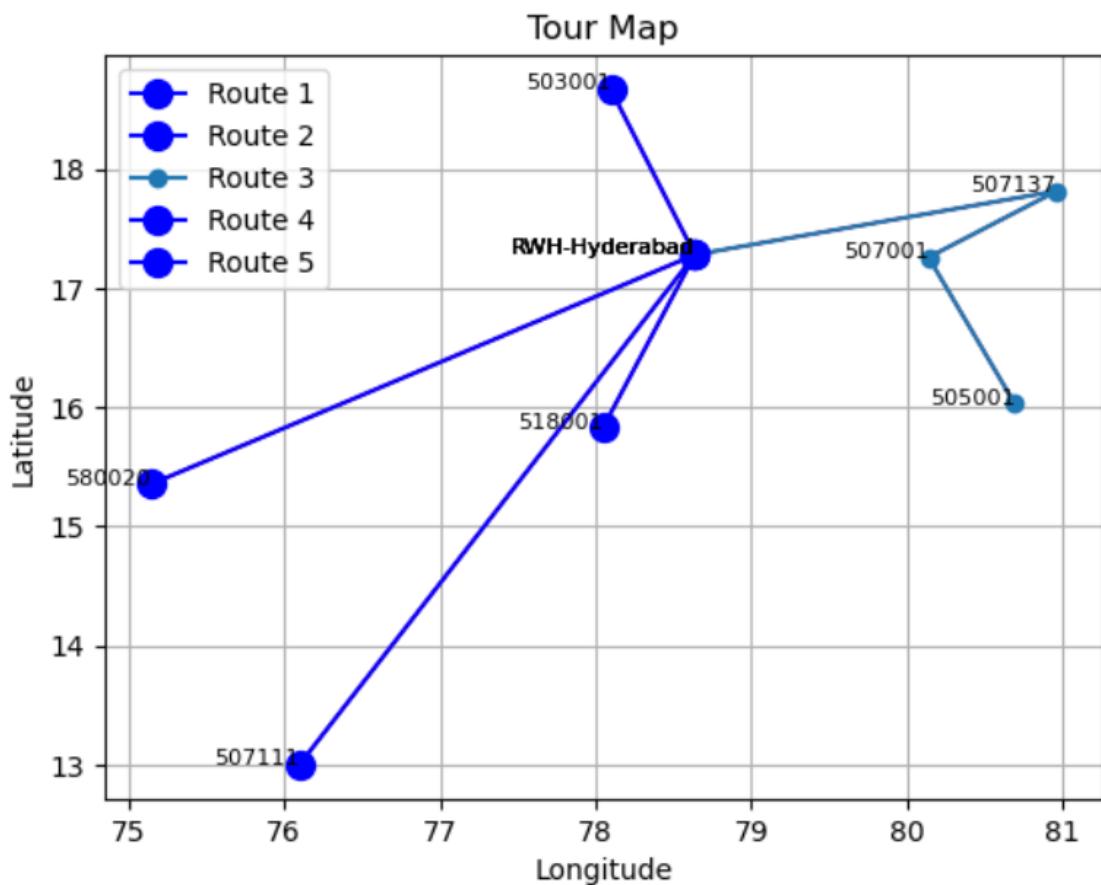
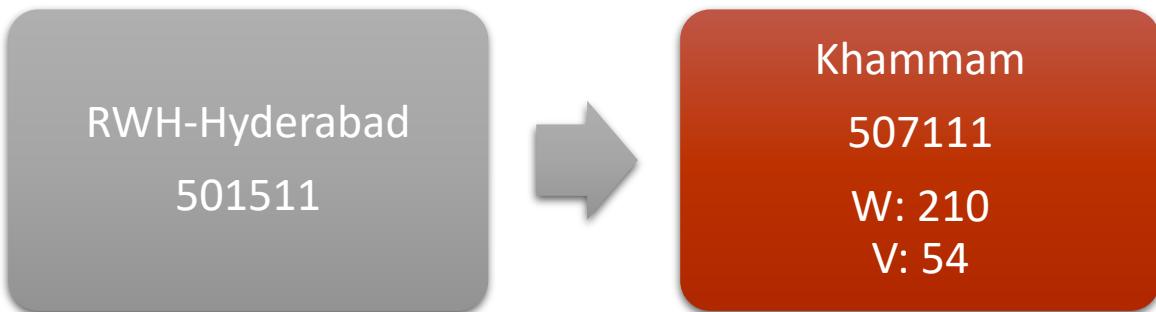
Distance covered: 538 KM



Vehicle 5: Elcher 17 Feet



Distance covered: 686 KM



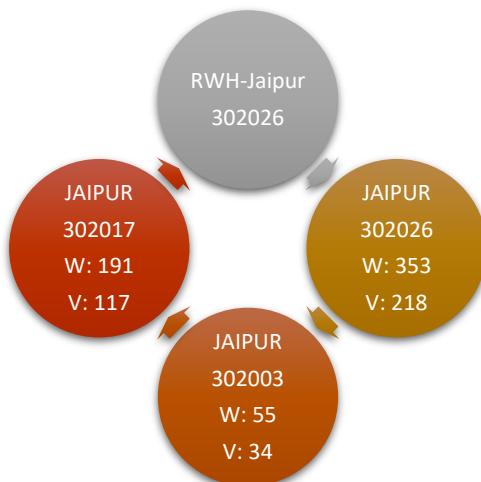
For Warehouse: RWH-Jaipur

Incity Routing:

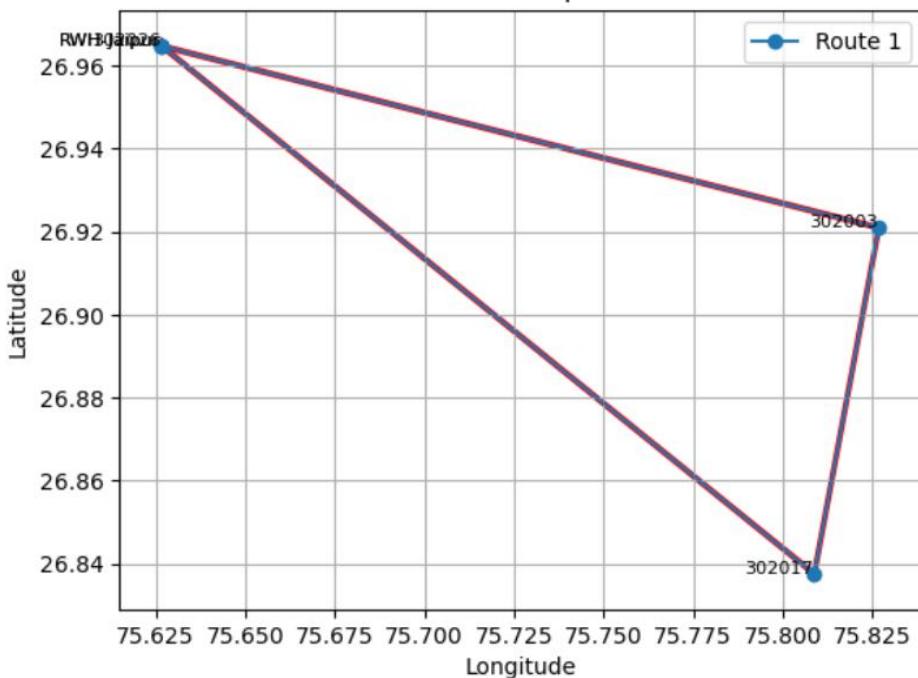
Vehicle 1: Elcher 14 Feet



Distance covered: 67 KM



Tour Map



Upcountry Routing:

Vehicle 1: Elcher 14 Feet



Distance covered: 395 KM



Vehicle 2: Elcher 17 Feet



Distance covered: 172 KM



TVS
Supply Chain
Solutions

BELIEVE IN THE
POWER OF US

Vehicle 3: Elcher 17 Feet



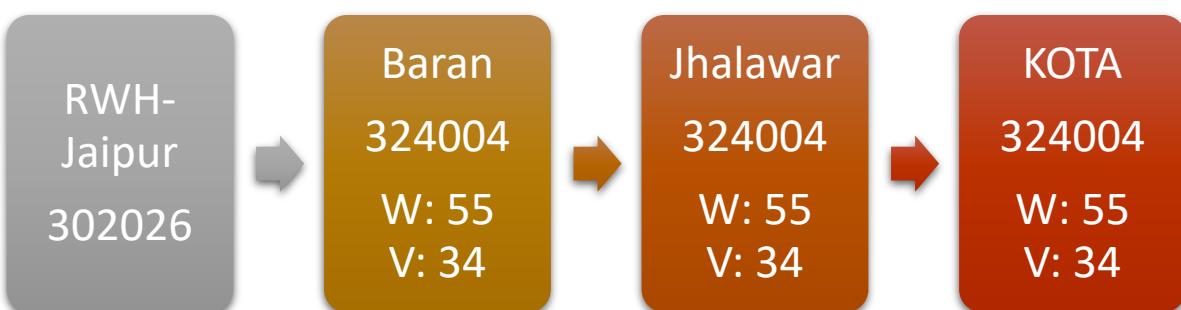
Distance covered: 233 KM



Vehicle 4: Elcher 14 Feet



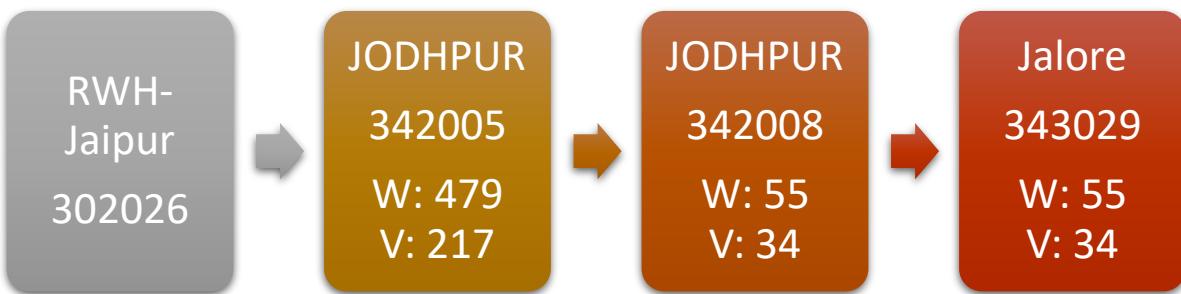
Distance covered: 256 KM



Vehicle 5: Elcher 17 Feet



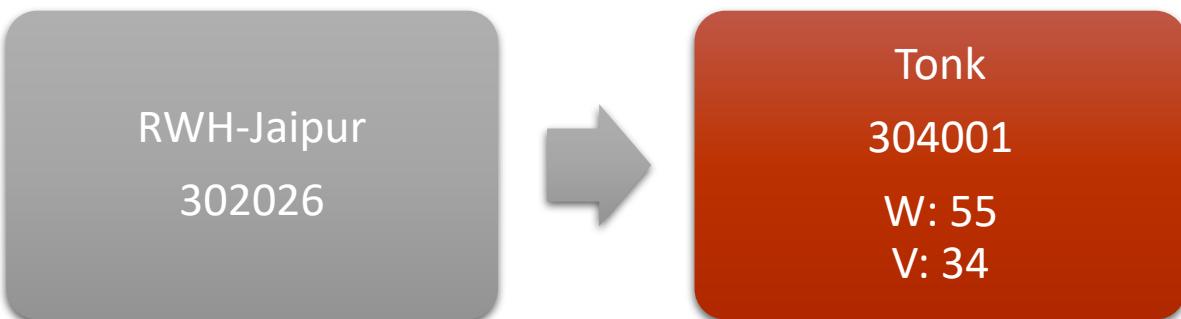
Distance covered: 548 KM



Vehicle 6: Mahindra Bolero Pickup



Distance covered: 113 KM



BELIEVE IN THE
POWER OF US

Vehicle 7: Elcher 17 Feet



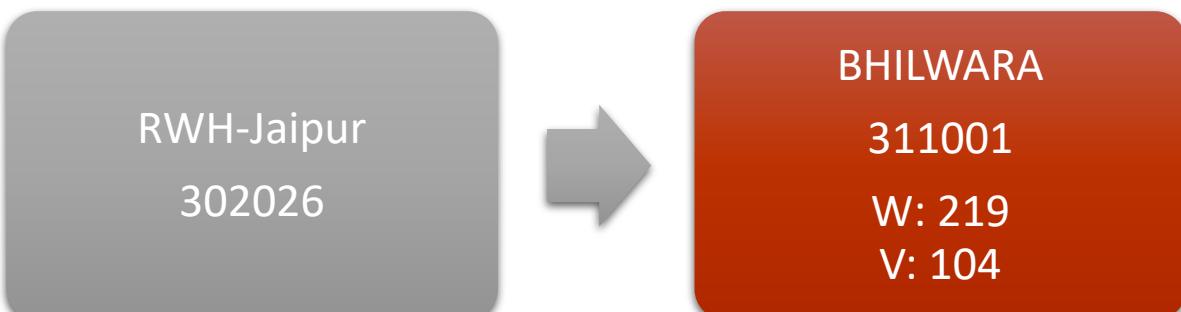
Distance covered: 418 KM



Vehicle 8: Elcher 17 Feet



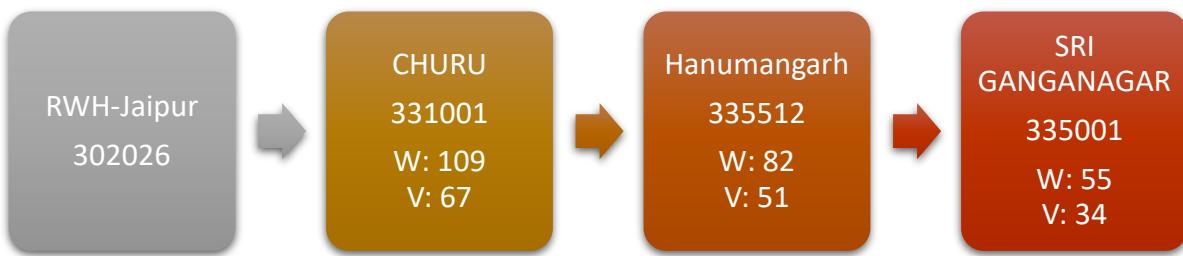
Distance covered: 2022 KM



Vehicle 9: Elcher 17 Feet



Distance covered: 476 KM



Vehicle 10: Elcher 17 Feet



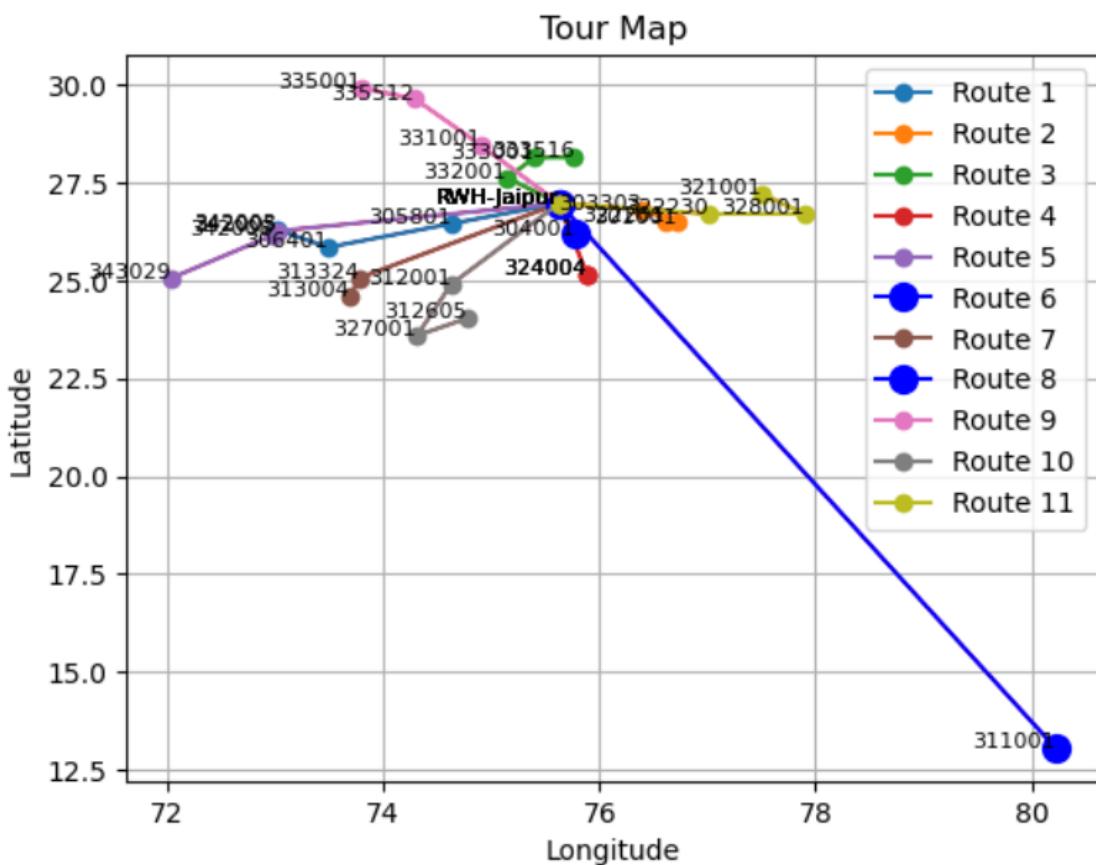
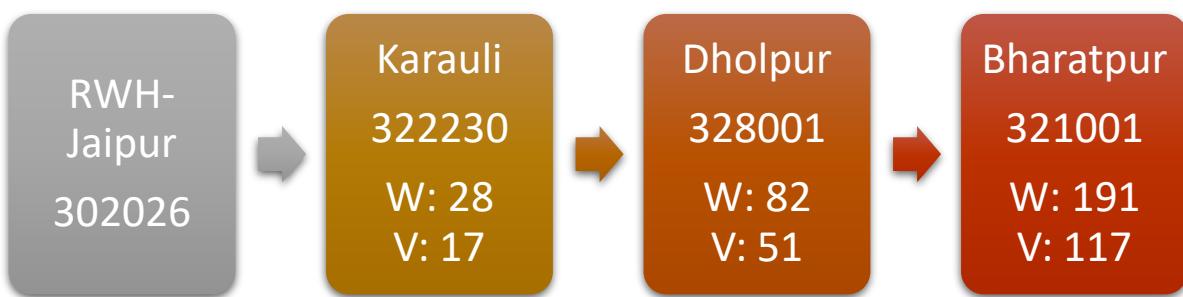
Distance covered: 586 KM



Vehicle 11: Elcher 14 Feet



Distance covered: 374 KM



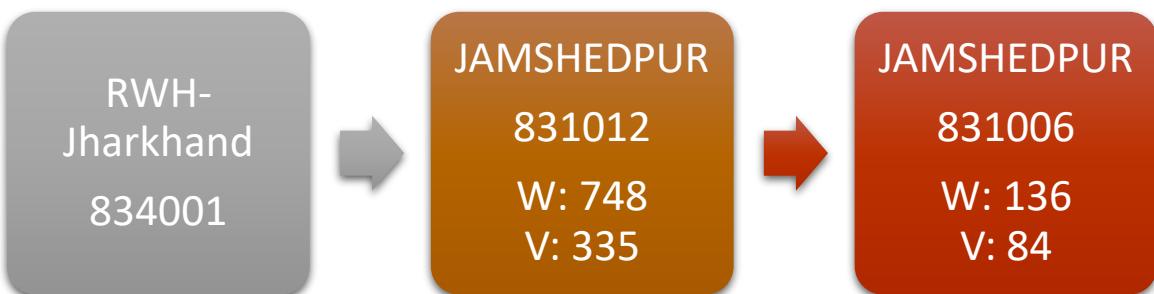
For Warehouse: RWH-Jharkhand

Upcountry Routing:

Vehicle 1: Elcher 17 Feet



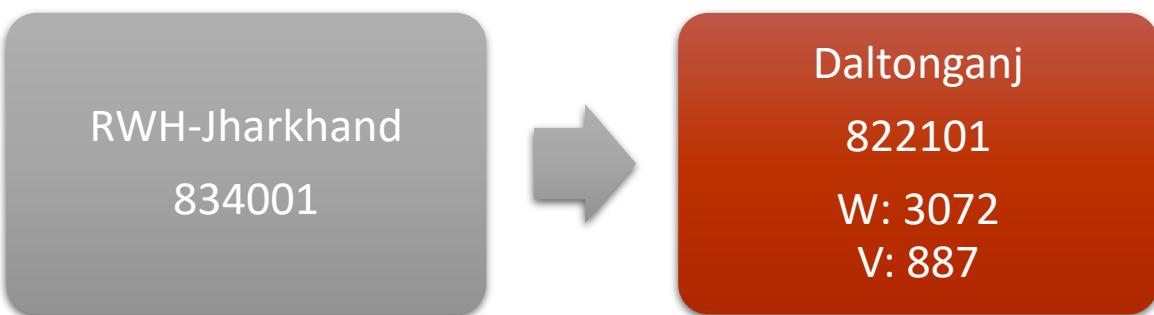
Distance covered: 141 KM



Vehicle 2: Elcher 17 Feet



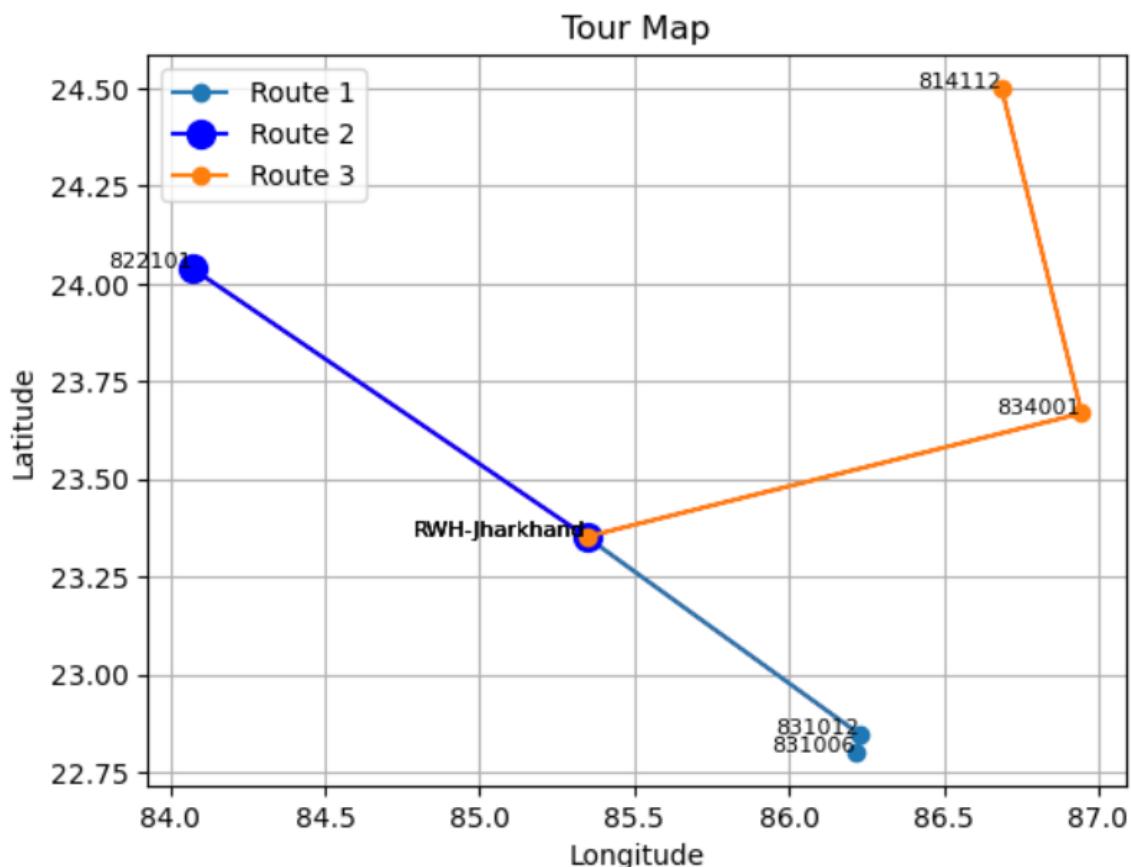
Distance covered: 188 KM



Vehicle 3: Elcher 20 Feet



Distance covered: 330 KM



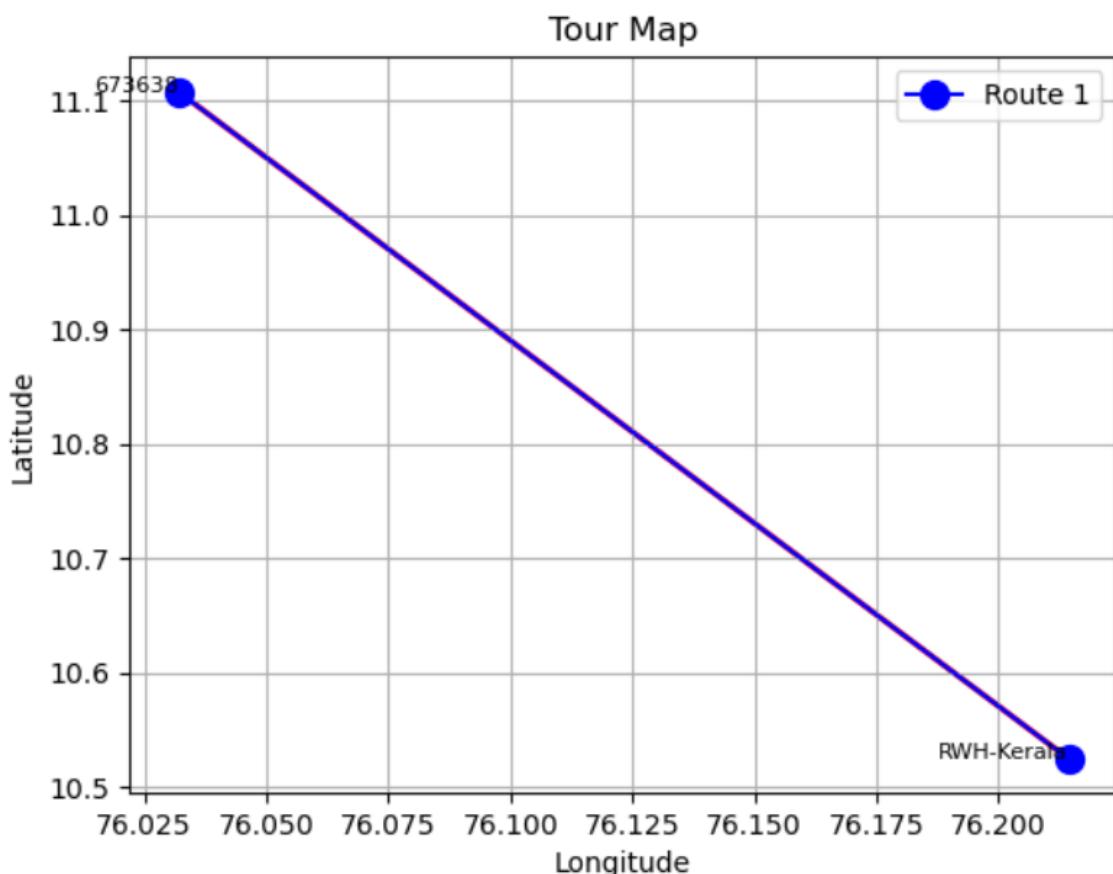
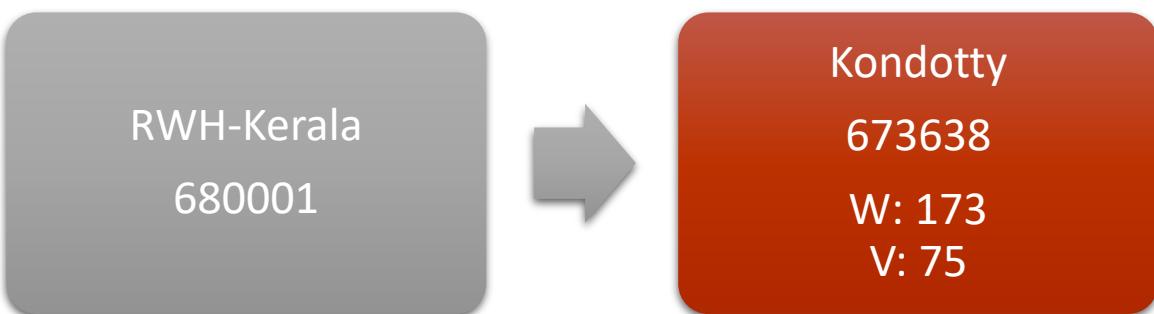
For Warehouse: RWH-Kerala

Upcountry Routing:

Vehicle 1: Tata Ace



Distance covered: 85 KM



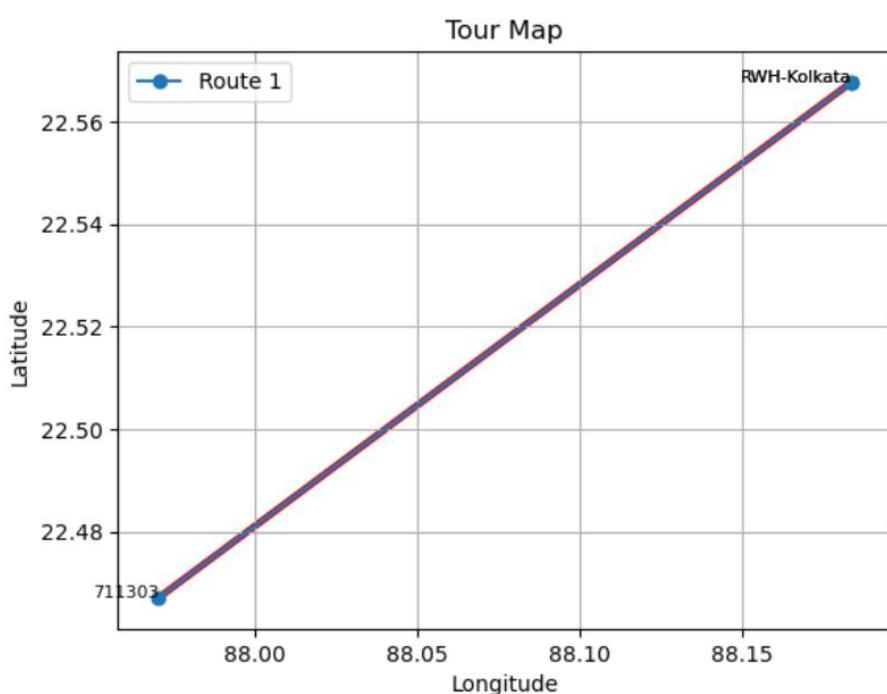
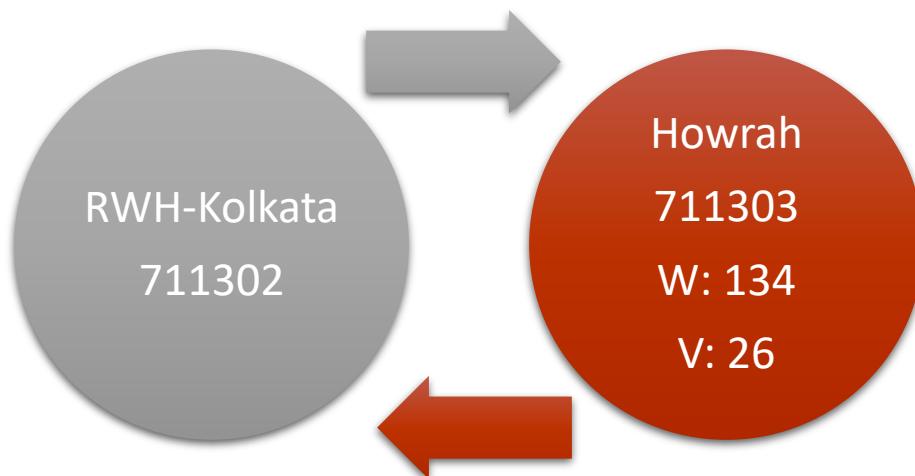
For Warehouse: RWH-Kolkata

Incity Routing:

Vehicle 1: Tata Ace



Distance covered: 62 KM

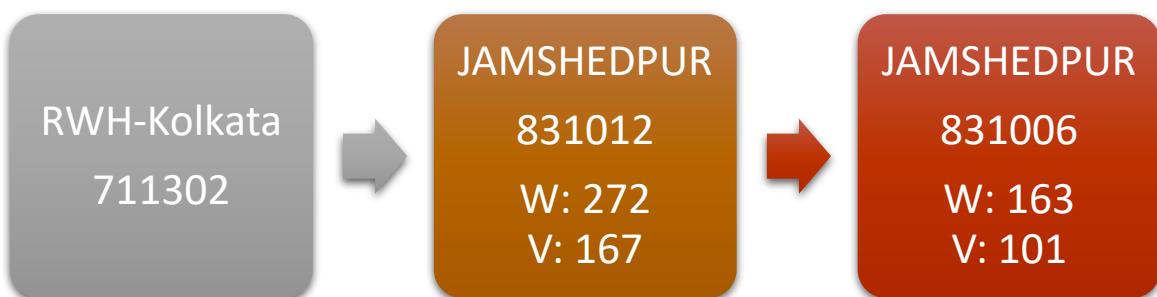


Upcountry Routing:

Vehicle 1: Elcher 14 Feet



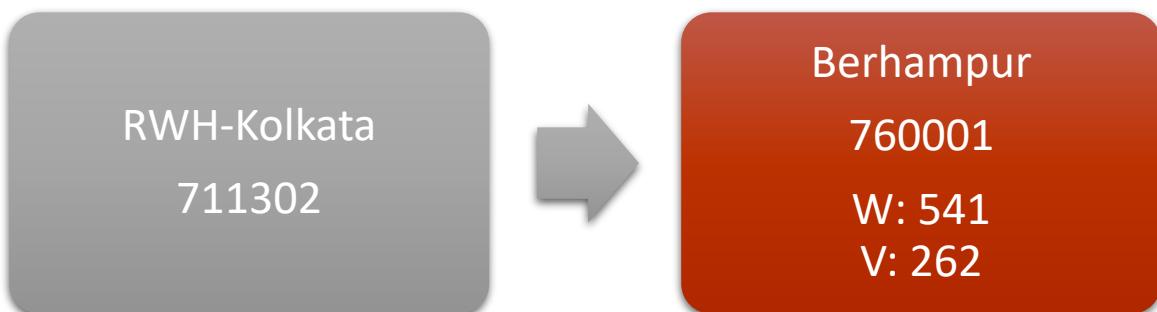
Distance covered: 261 KM



Vehicle 2: Elcher 17 Feet



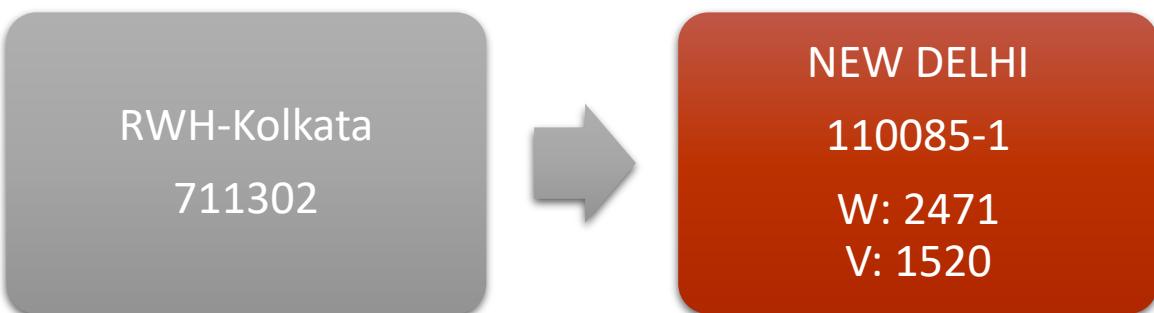
Distance covered: 631 KM



Vehicle 3: Container 32 FT SXL



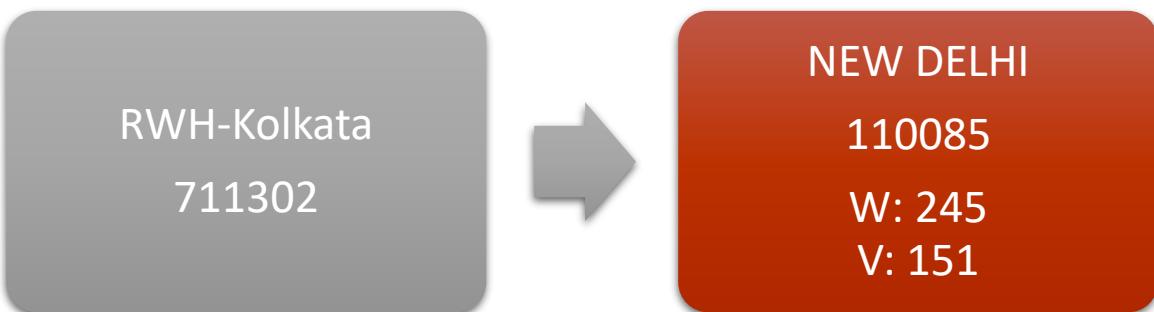
Distance covered: 1629 KM

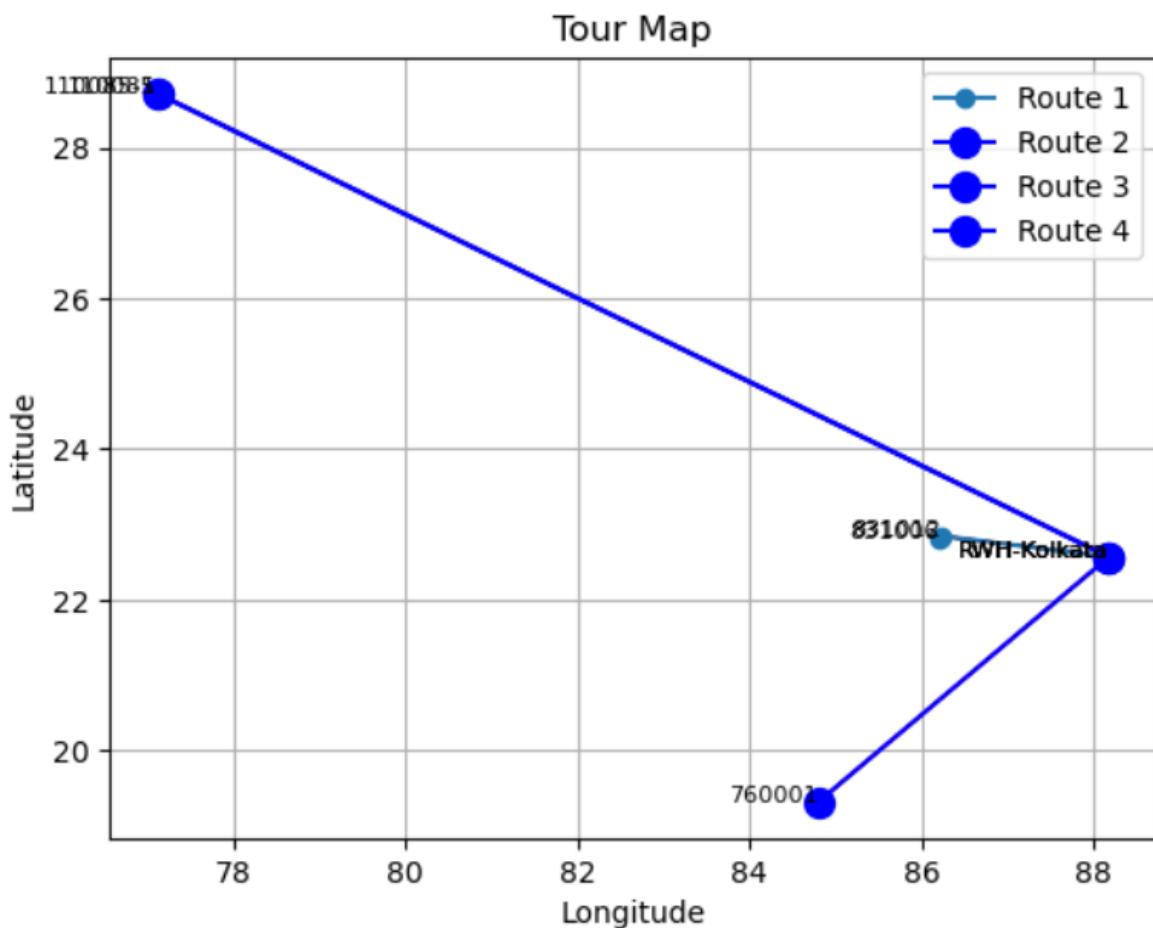


Vehicle 4: Elcher 17 Feet



Distance covered: 1629 KM





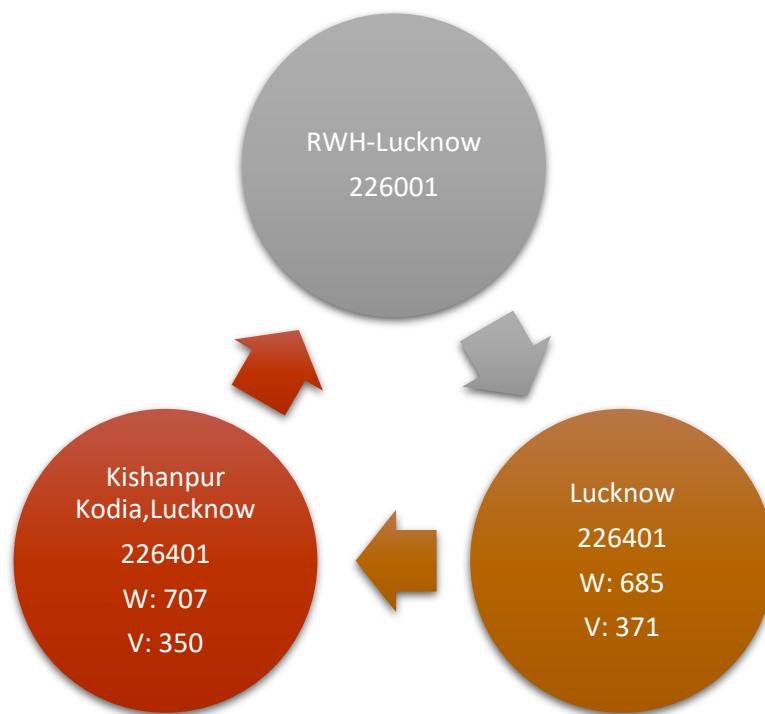
For Warehouse: RWH-Lucknow

Incity Routing:

Vehicle 1: Elcher 20 Feet



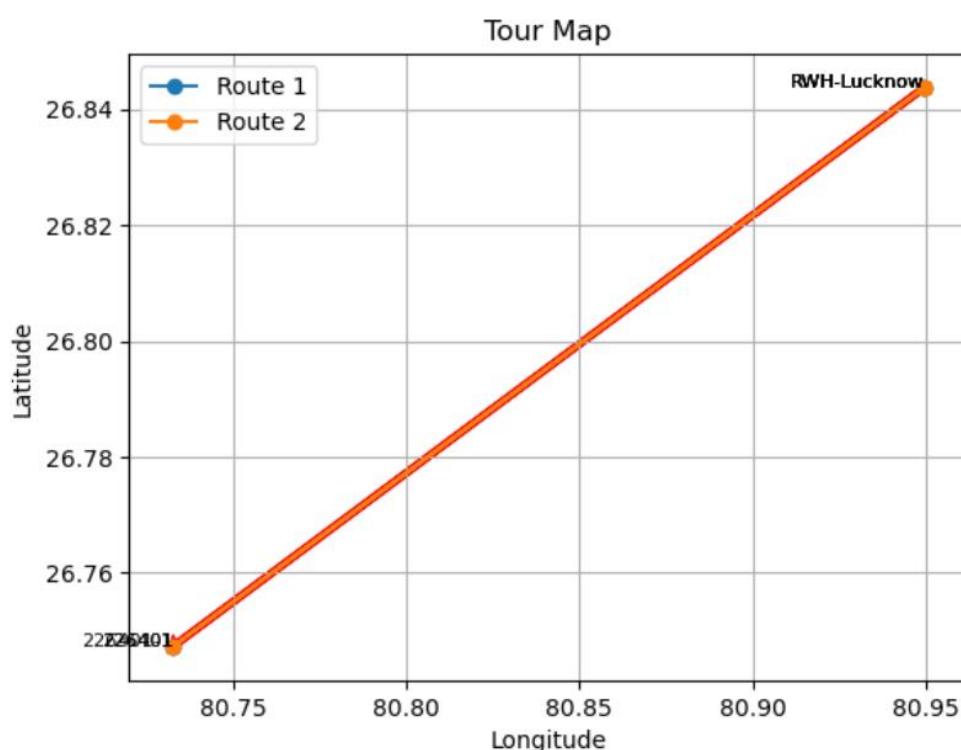
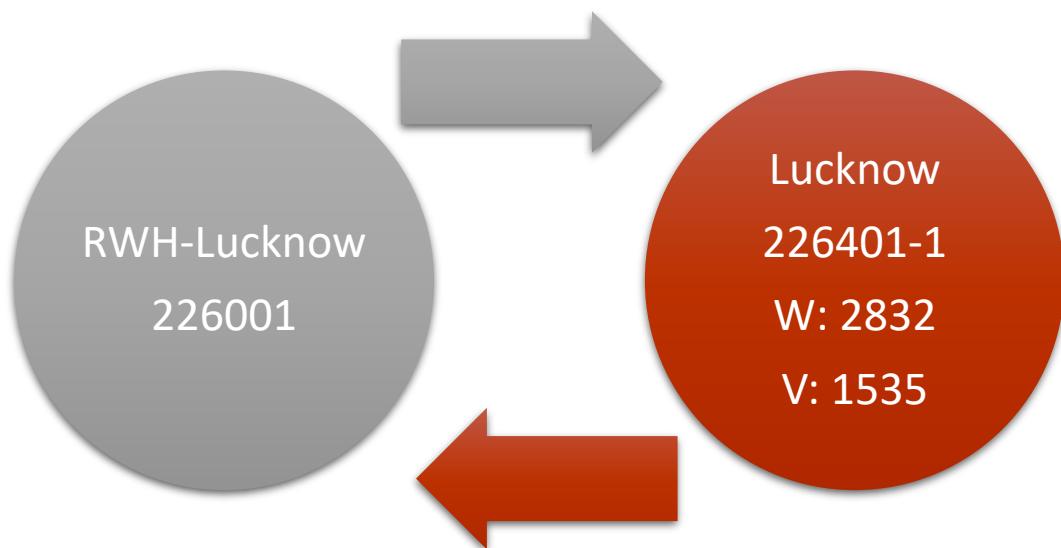
Distance covered: 72 KM



Vehicle 2: Container 32 FT SXL



Distance covered: 62 KM



Upcountry Routing:

Vehicle 1: Elcher 17 Feet



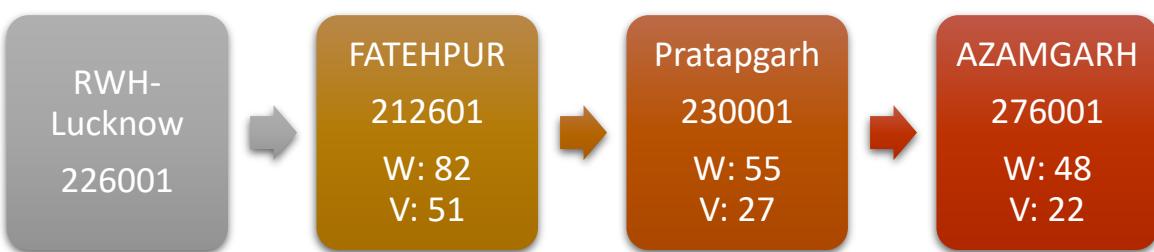
Distance covered: 248 KM



Vehicle 2: Elcher 17 Feet



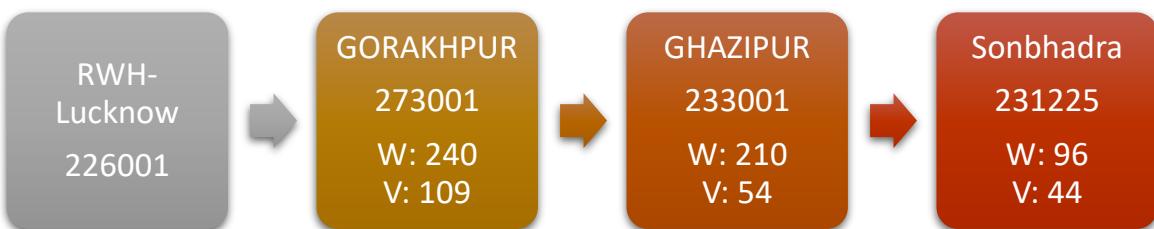
Distance covered: 427 KM



Vehicle 3: Elcher 17 Feet



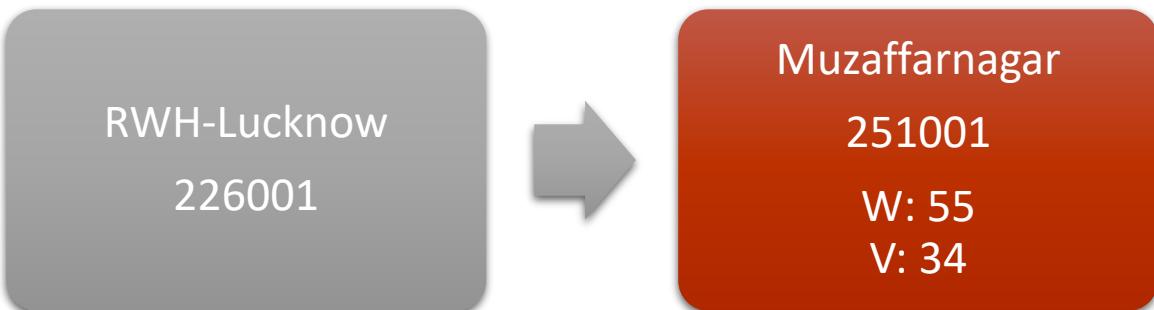
Distance covered: 617 KM

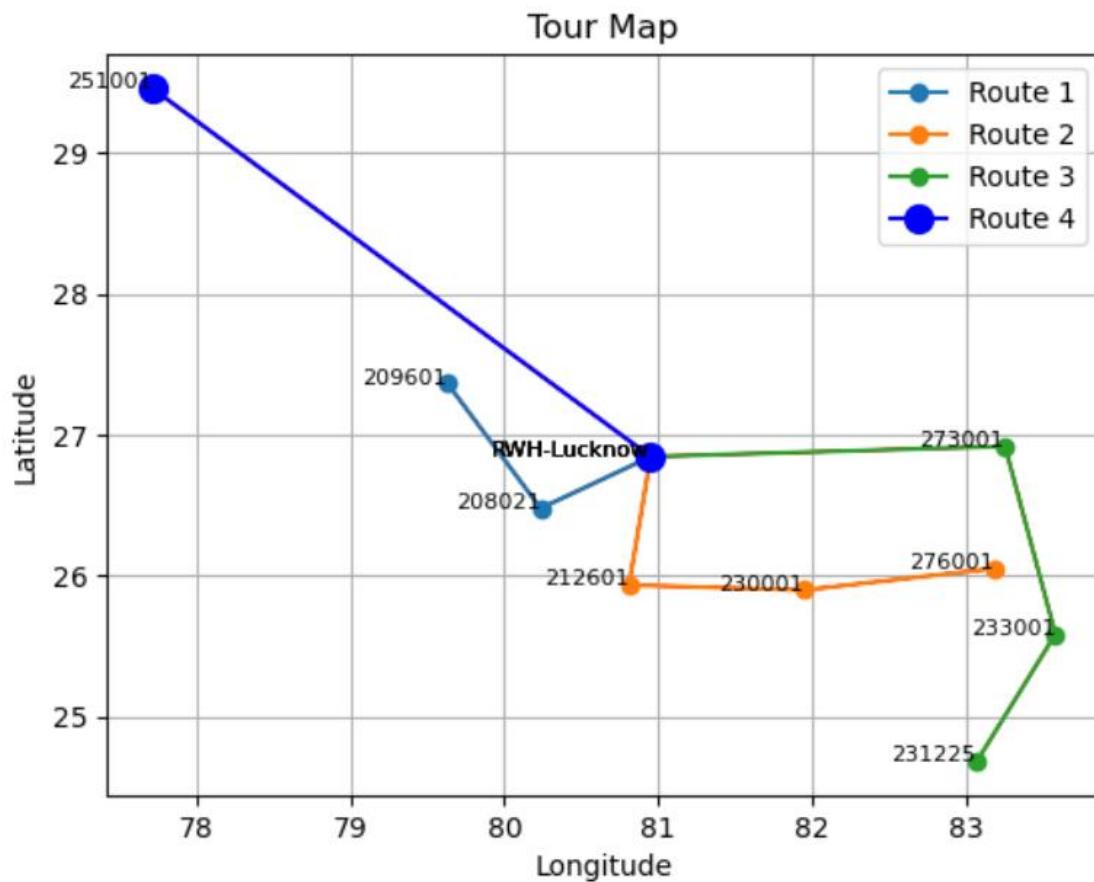


Vehicle 4: Elcher 17 Feet



Distance covered: 538 KM





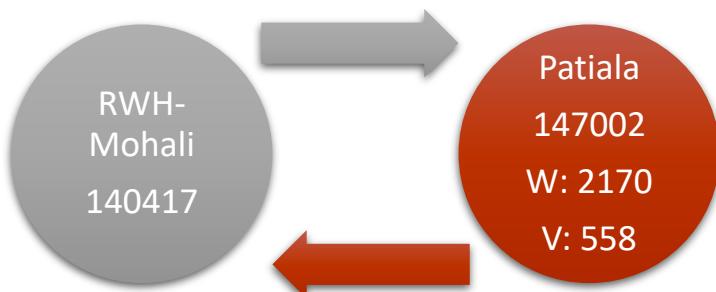
For Warehouse: RWH-Mohali

Incity Routing:

Vehicle 1: Elcher 20 Feet



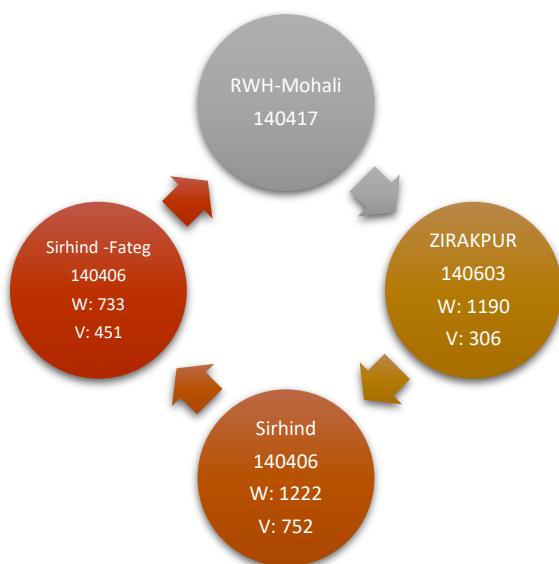
Distance covered: 64 KM



Vehicle 2: Container 32 FT SXL



Distance covered: 130 KM

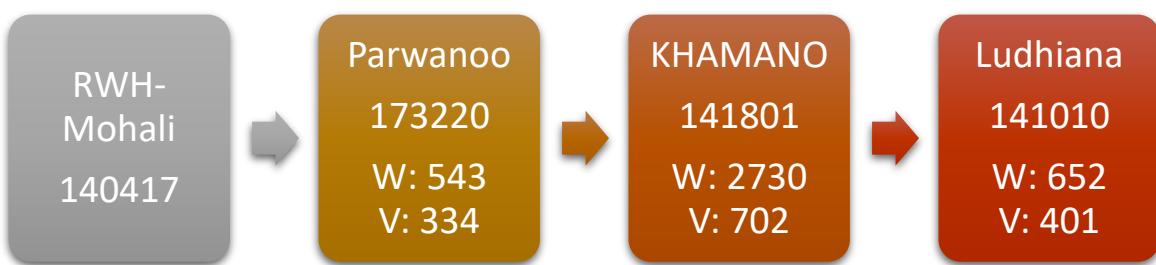


Upcountry Routing:

Vehicle 1: Container 32 FT SXL



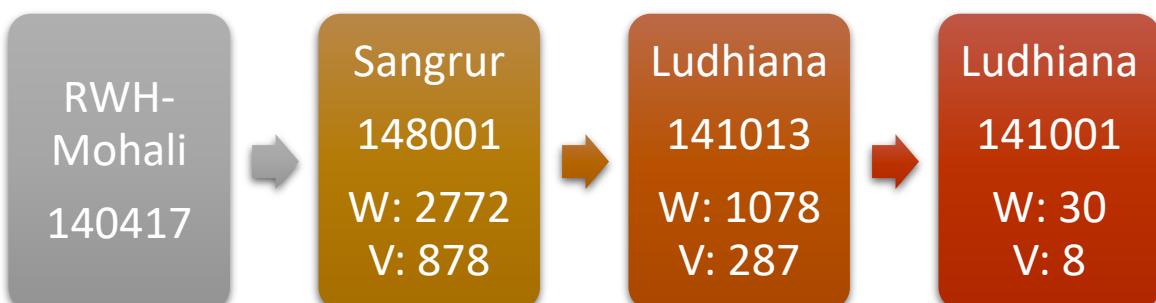
Distance covered: 196 KM



Vehicle 2: Container 32 FT SXL



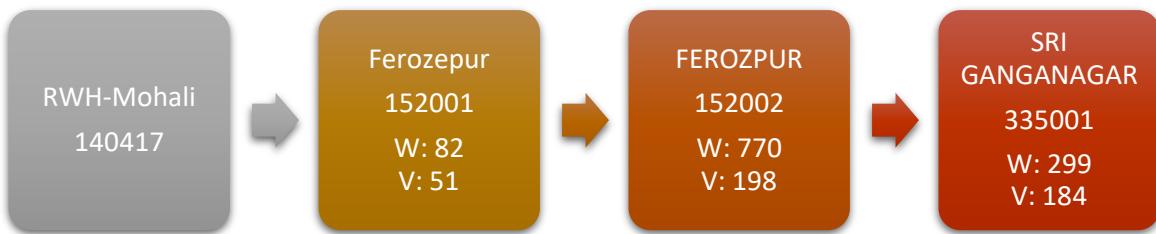
Distance covered: 199 KM



Vehicle 3: Elcher 17 Feet



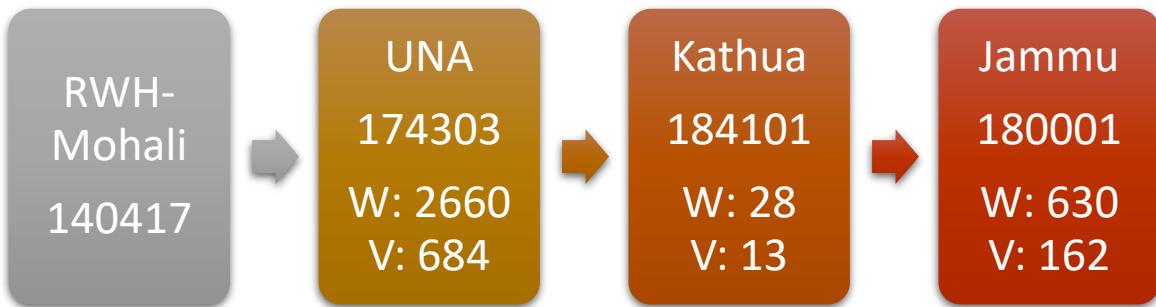
Distance covered: 437 KM

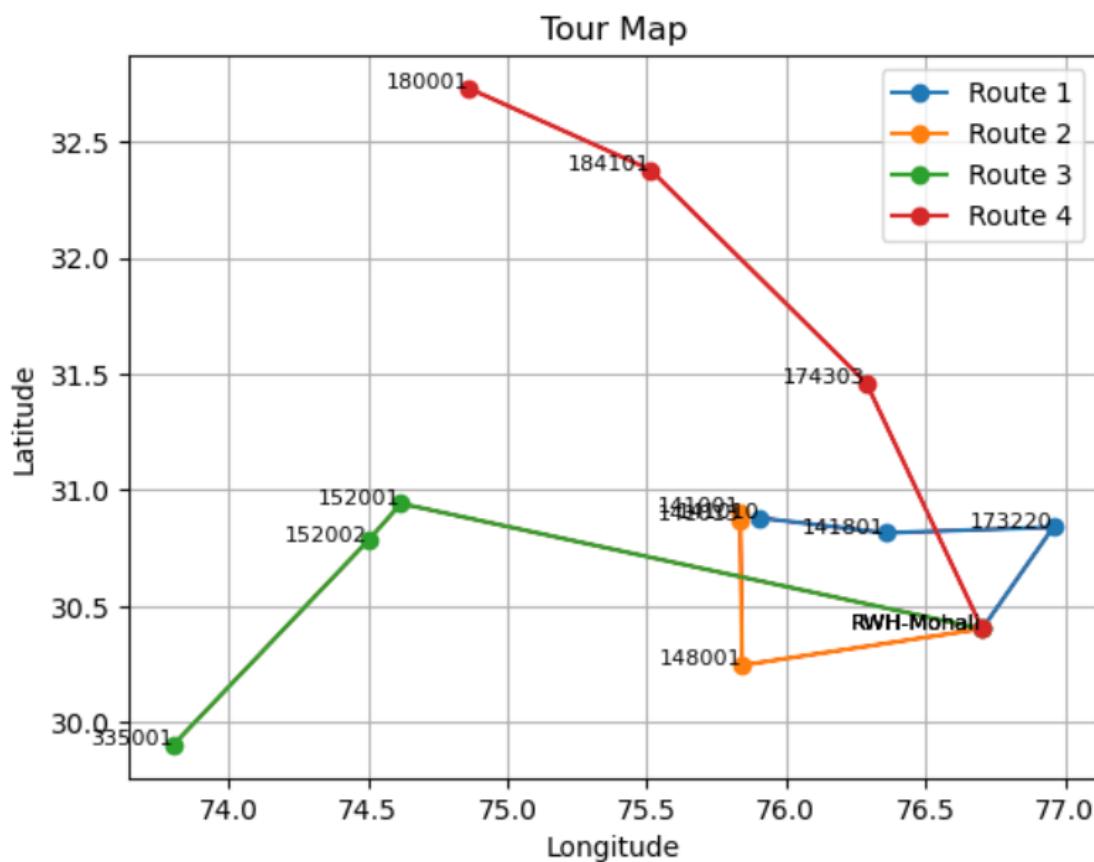


Vehicle 4: Container 32 FT SXL



Distance covered: 404 KM





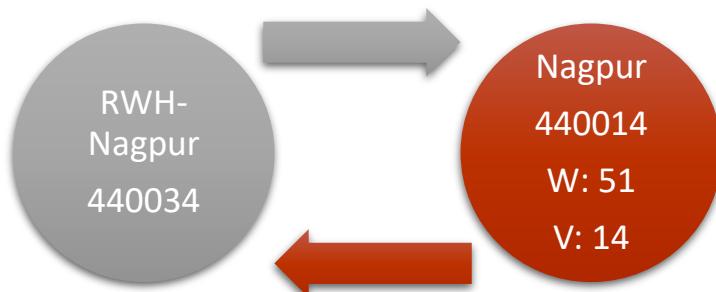
For Warehouse: RWH-Nagpur

Incity Routing:

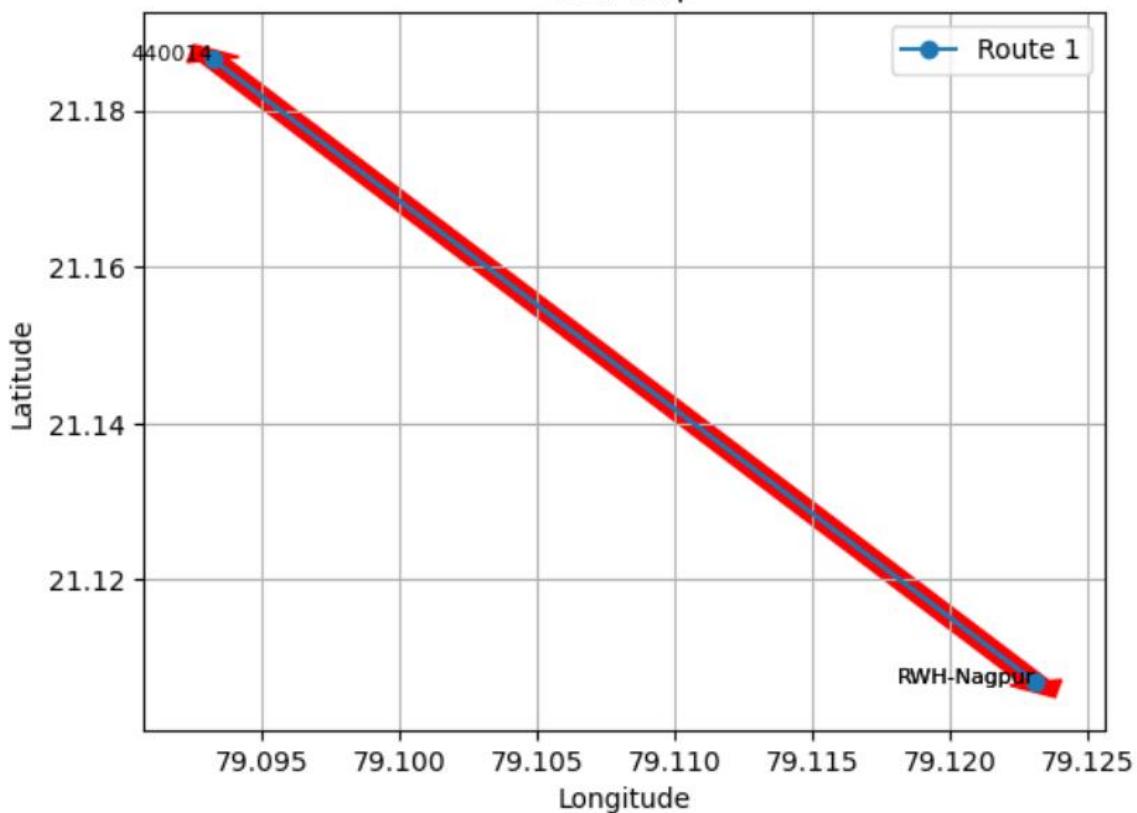
Vehicle 1: Tata Ace



Distance covered: 24 KM



Tour Map



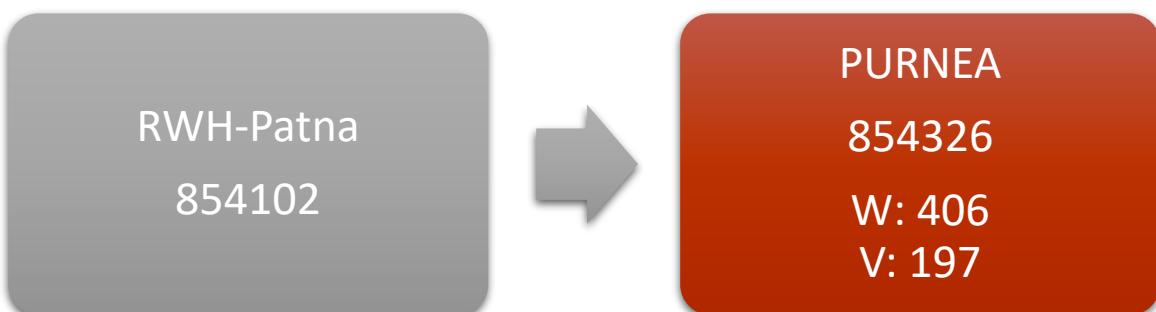
For Warehouse: RWH-Patna

Upcountry Routing:

Vehicle 1: Elcher 14 Feet



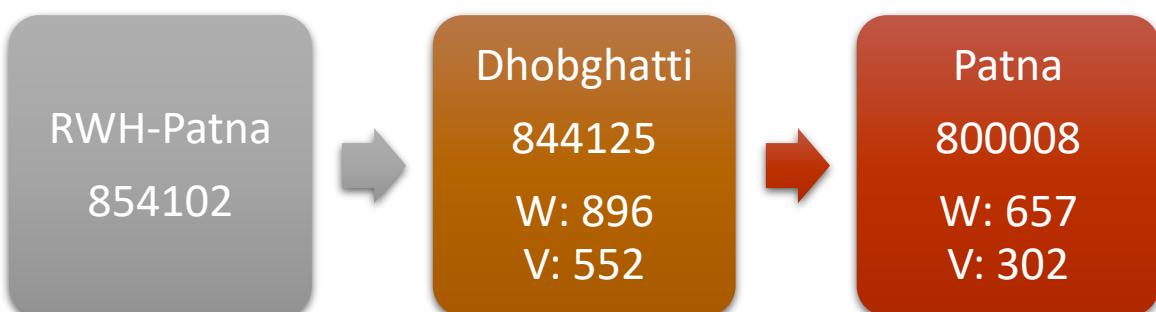
Distance covered: 65 KM

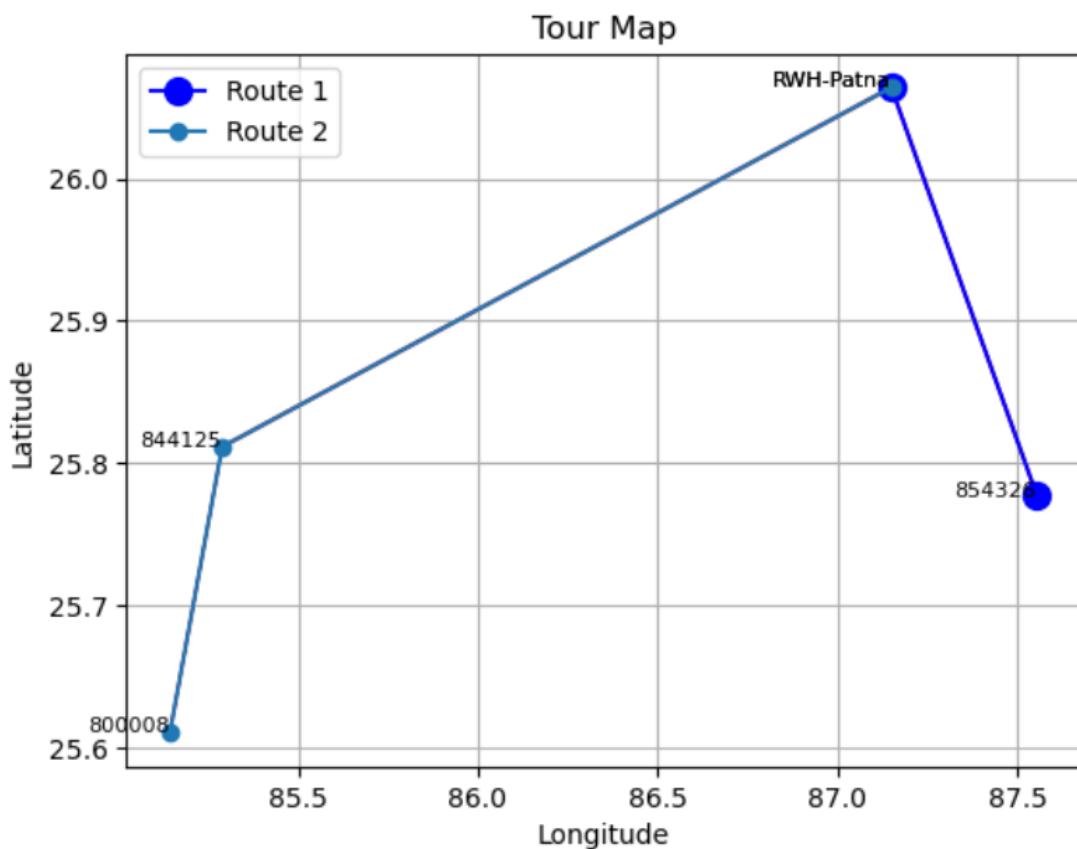


Vehicle 2: Container 32 FT SXL



Distance covered: 270 KM





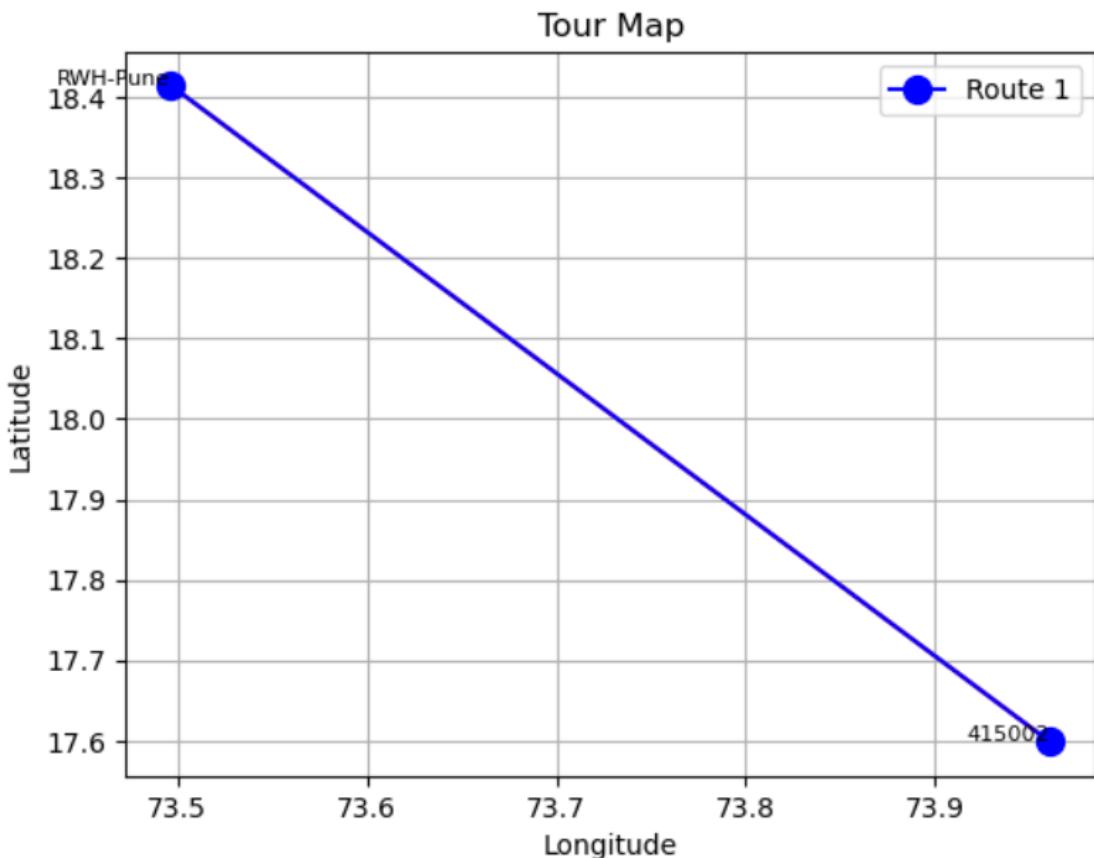
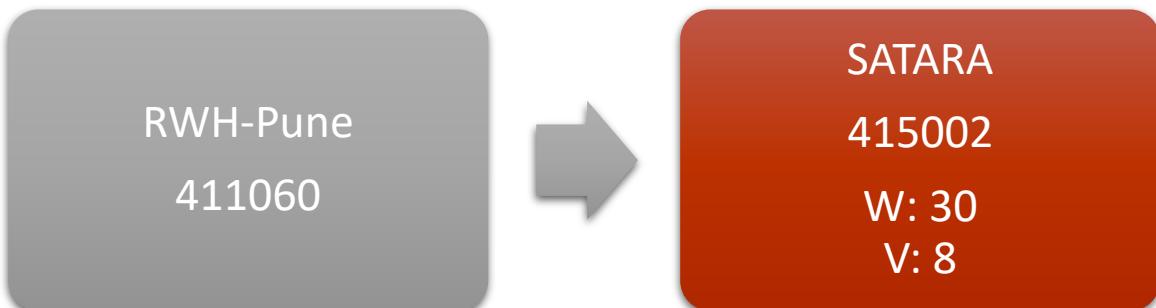
For Warehouse: RWH-Pune

Upcountry Routing:

Vehicle 1: Mahindra Bolero Pickup



Distance covered: 129 KM



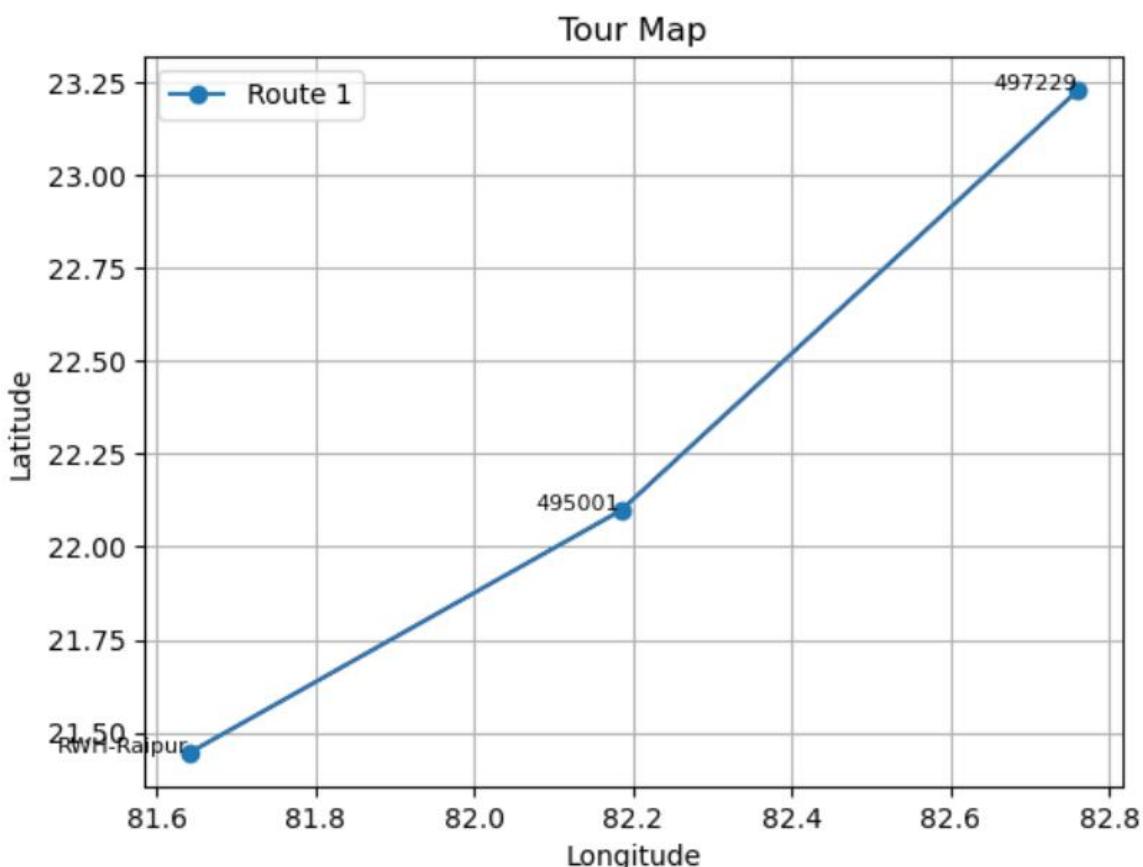
For Warehouse: RWH-Raipur

Upcountry Routing:

Vehicle 1: Elcher 20 Feet



Distance covered: 289 KM



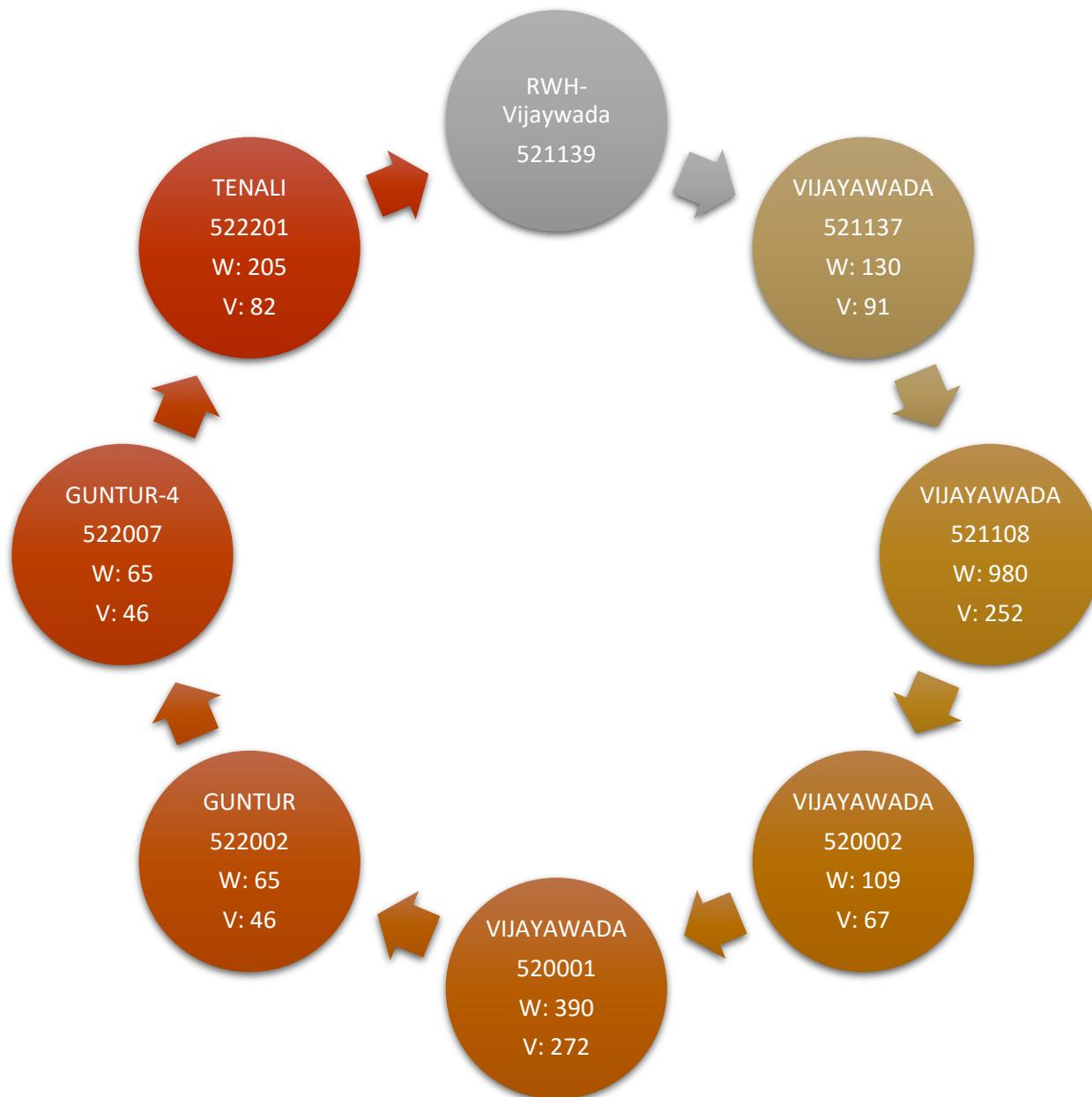
For Warehouse: RWH-Vijaywada

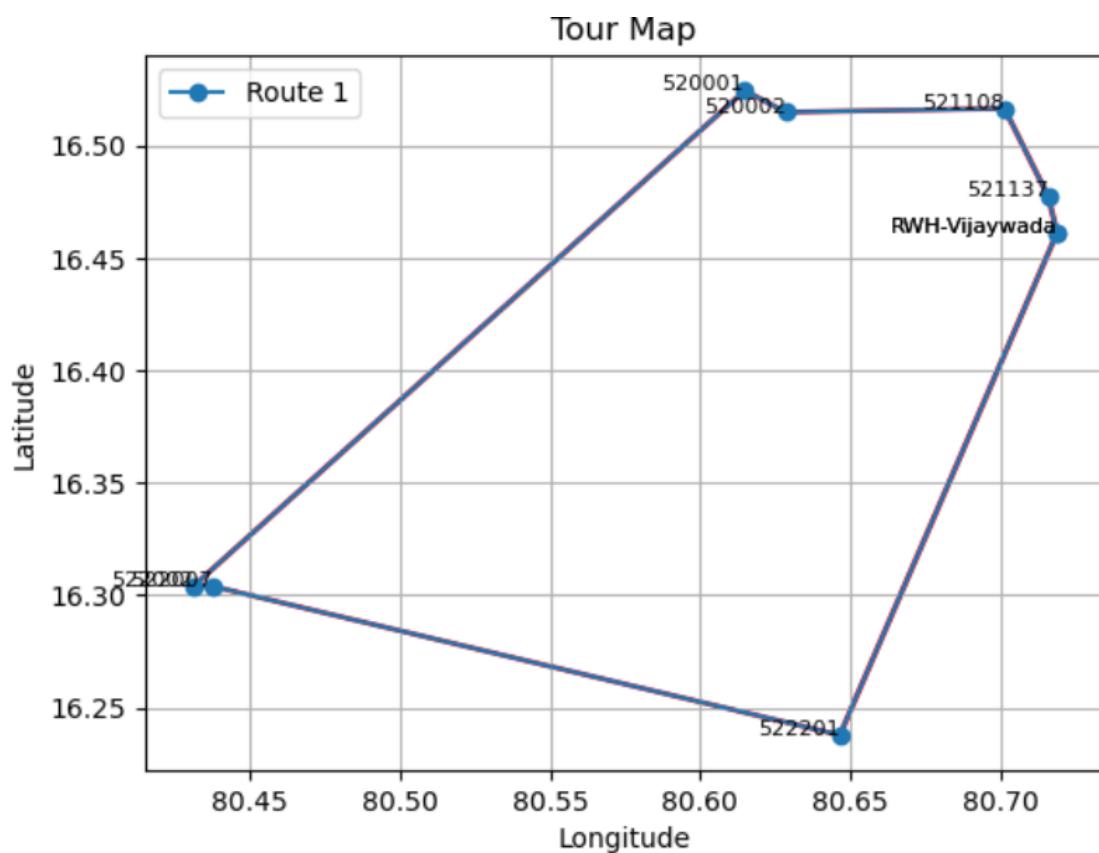
Incity Routing:

Vehicle 1: Container 32 FT SXL



Distance covered: 126 KM





TVS
Supply Chain
Solutions

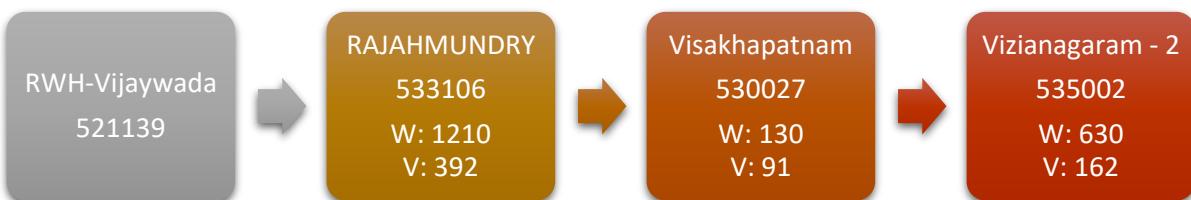
BELIEVE IN THE
POWER OF US

Upcountry Routing:

Vehicle 1: Elcher 20 Feet



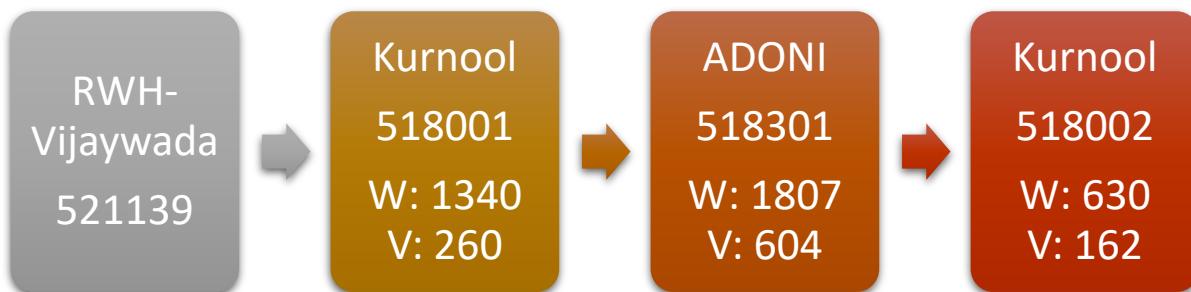
Distance covered: 431 KM



Vehicle 2: Container 32 FT SXL



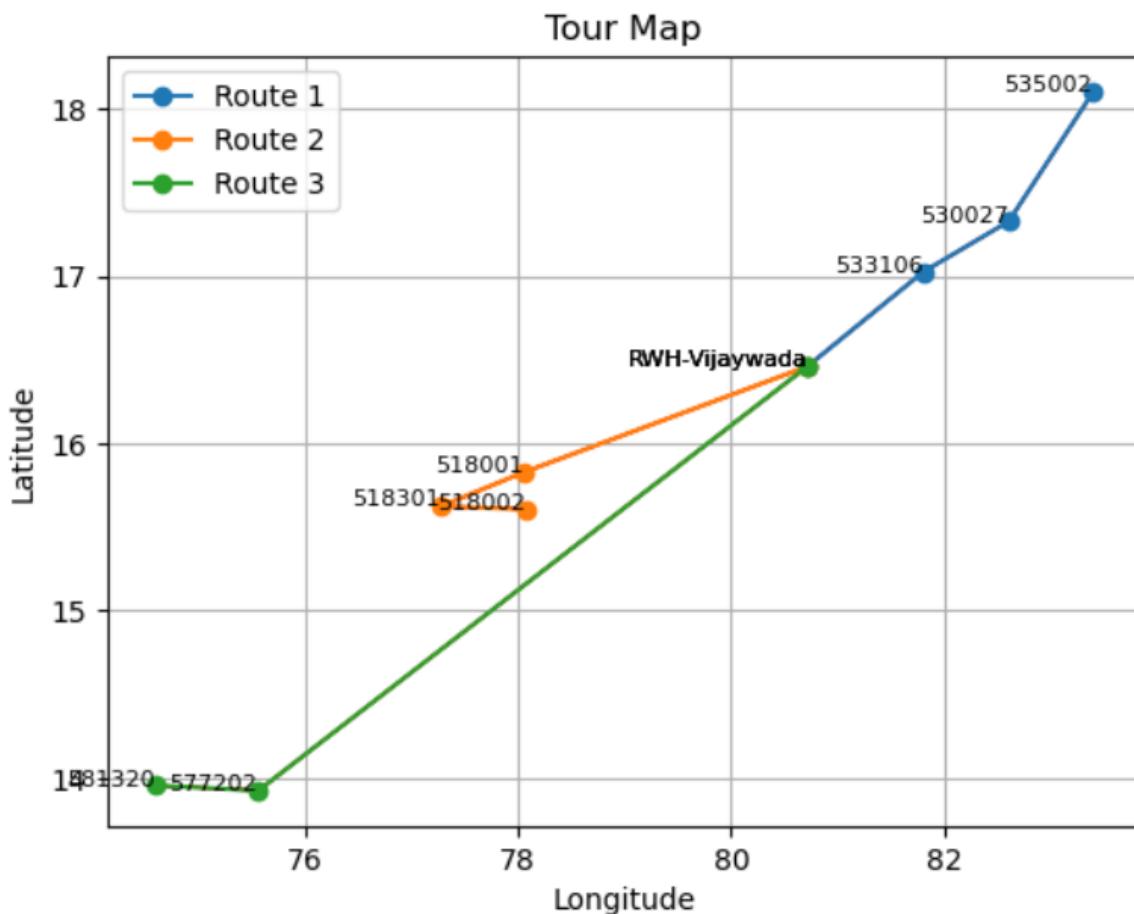
Distance covered: 585 KM



Vehicle 3: Elcher 17 Feet



Distance covered: 909 KM



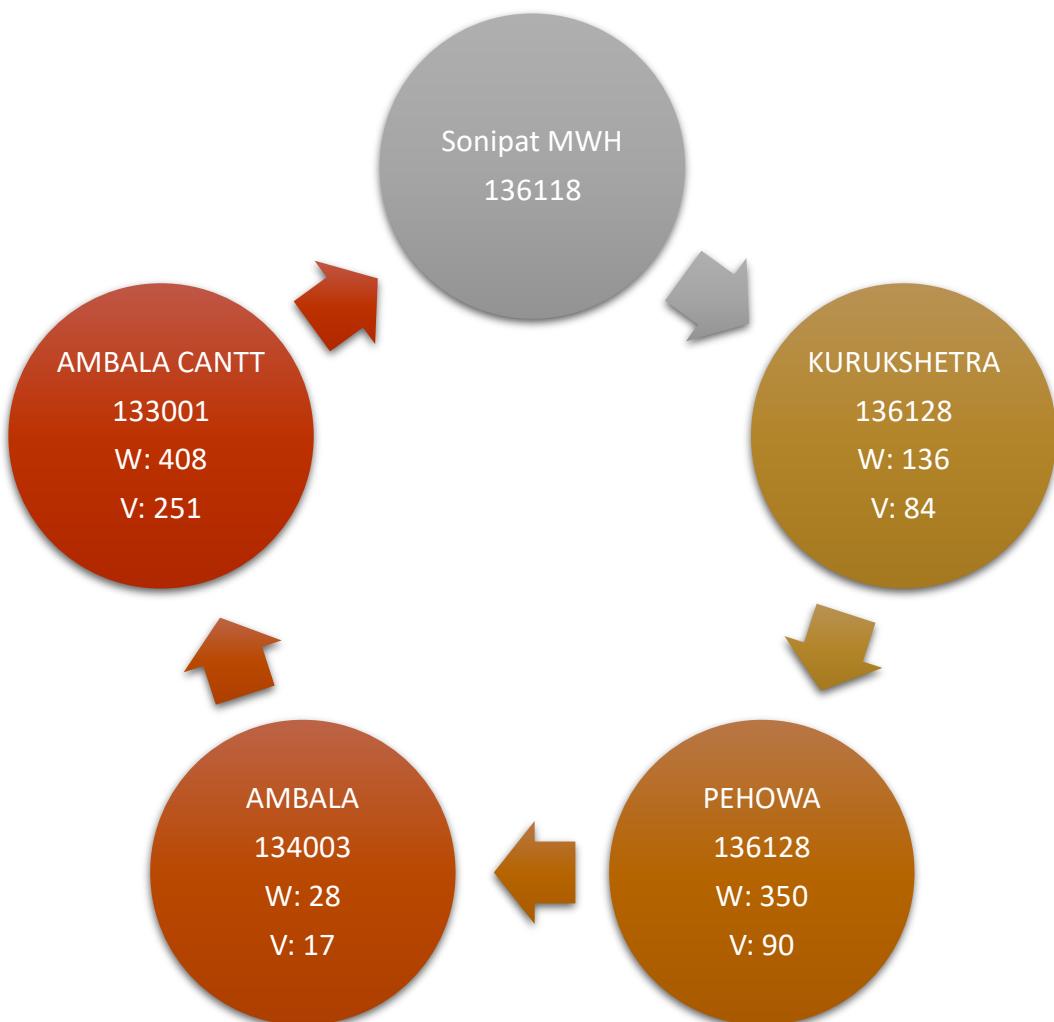
For Warehouse: Sonipat MWH

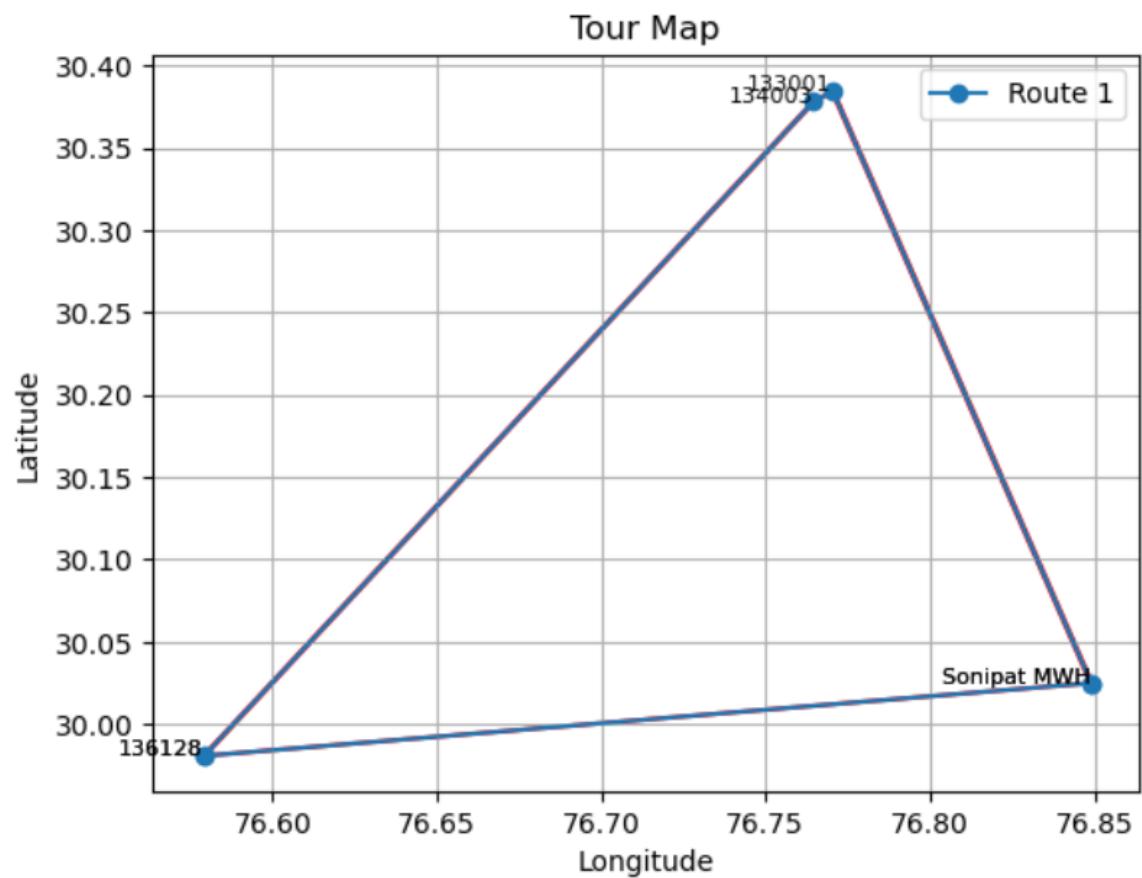
Incity Routing:

Vehicle 1: Elcher 17 Feet



Distance covered: 147 KM





TVS
Supply Chain
Solutions

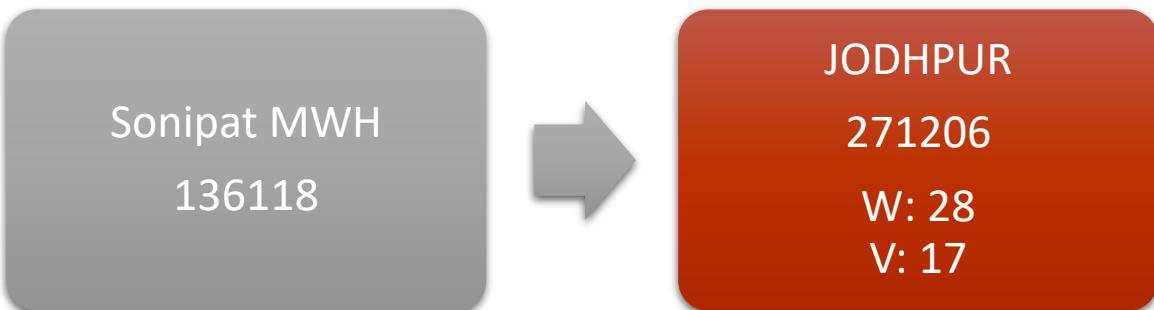
BELIEVE IN THE
POWER OF US

Upcountry Routing:

Vehicle 1: Elcher 17 Feet



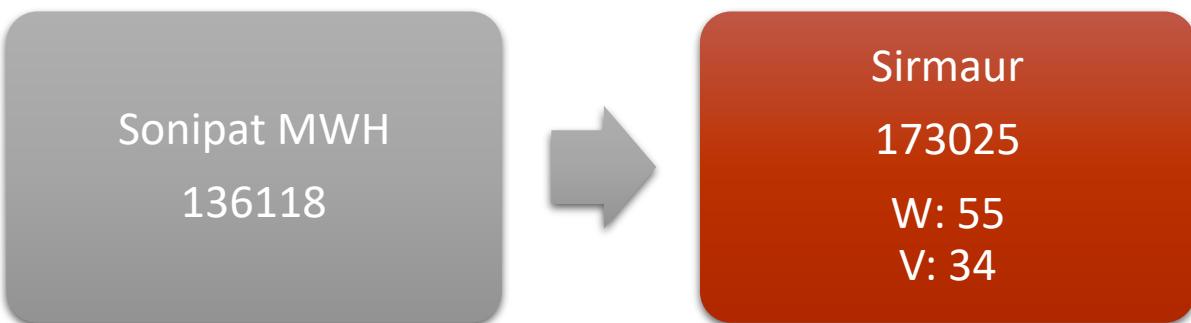
Distance covered: 788 KM



Vehicle 2: Mahindra Bolero Pickup



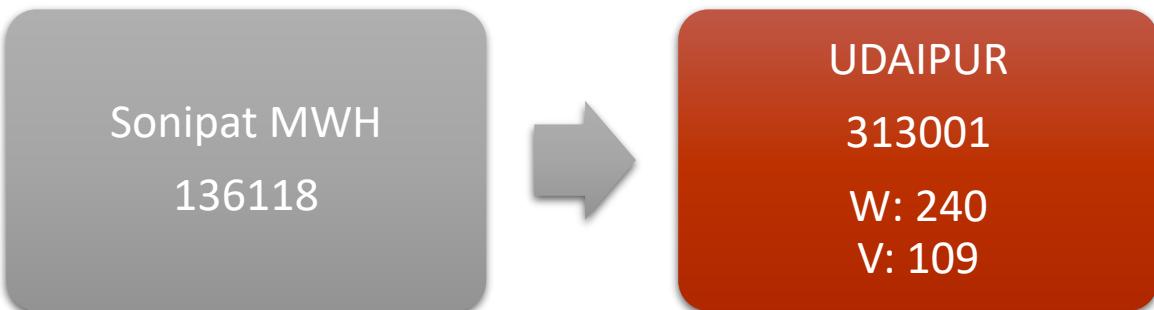
Distance covered: 108 KM



Vehicle 3: Elcher 14 Feet



Distance covered: 326 KM



Vehicle 4: Elcher 17 Feet



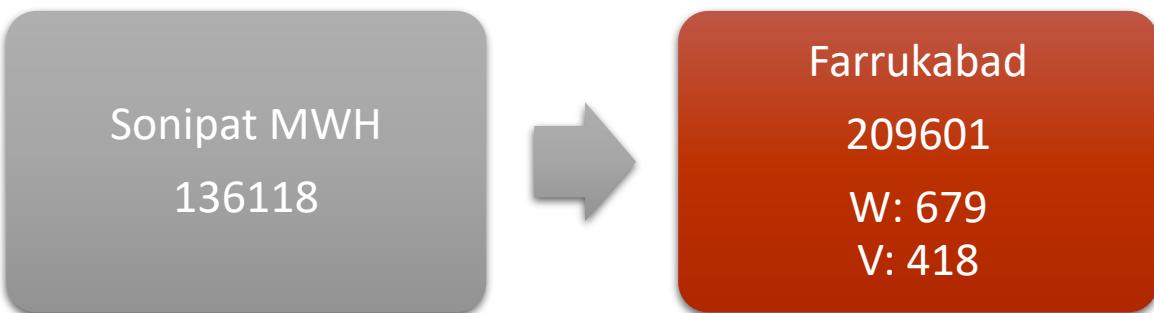
Distance covered: 1048 KM



Vehicle 5: Elcher 17 Feet



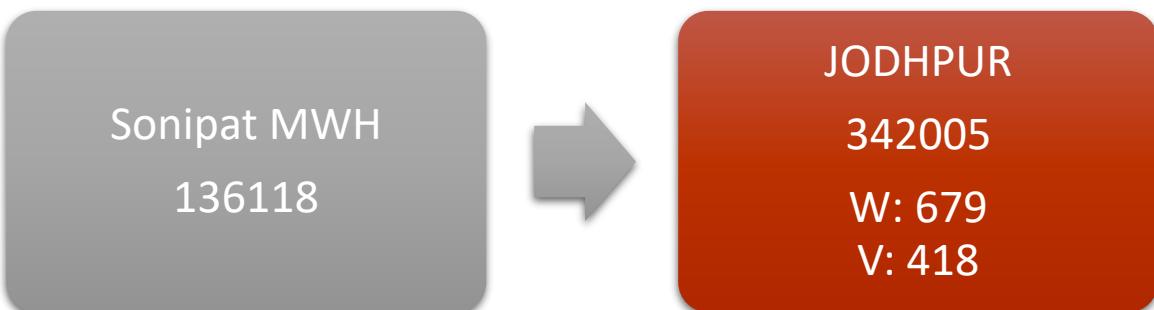
Distance covered: 502 KM



Vehicle 6: Elcher 17 Feet



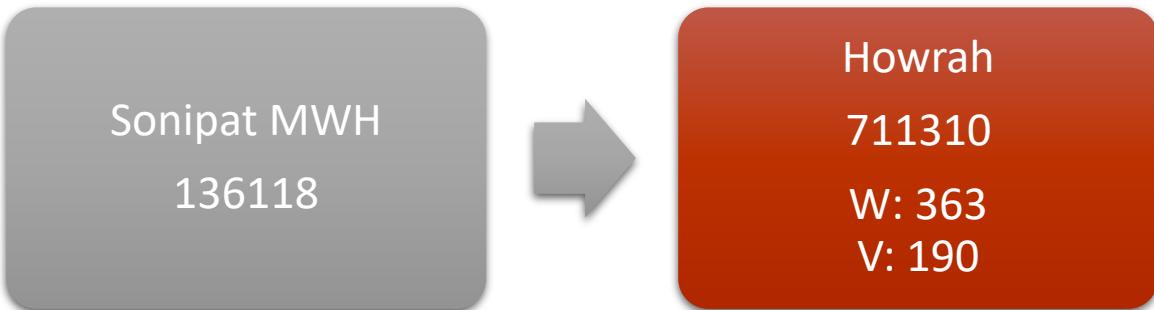
Distance covered: 704 KM



Vehicle 7: Elcher 17 Feet



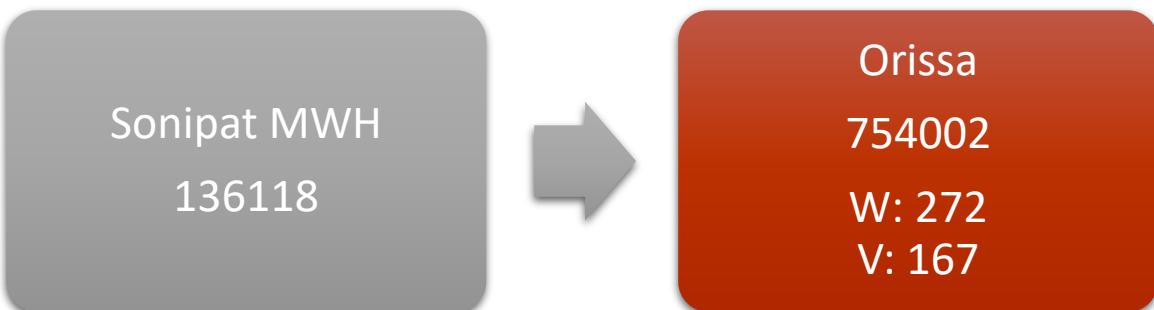
Distance covered: 1754 KM



Vehicle 8: Elcher 17 Feet



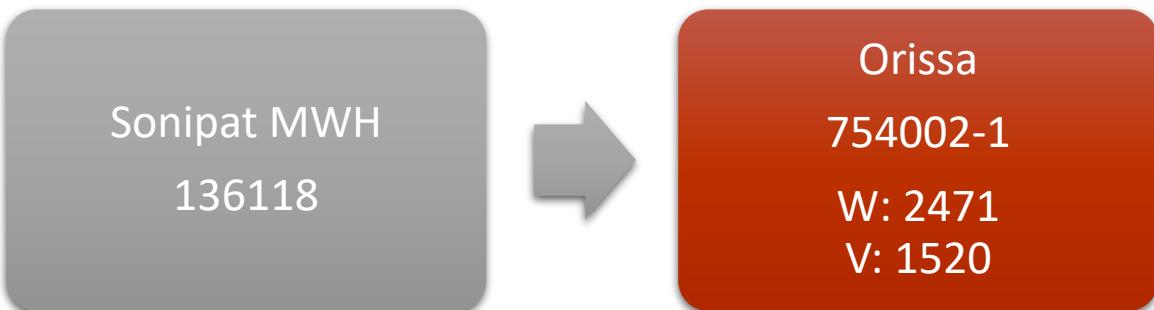
Distance covered: 1778 KM



Vehicle 9: Container 32 FT SXL



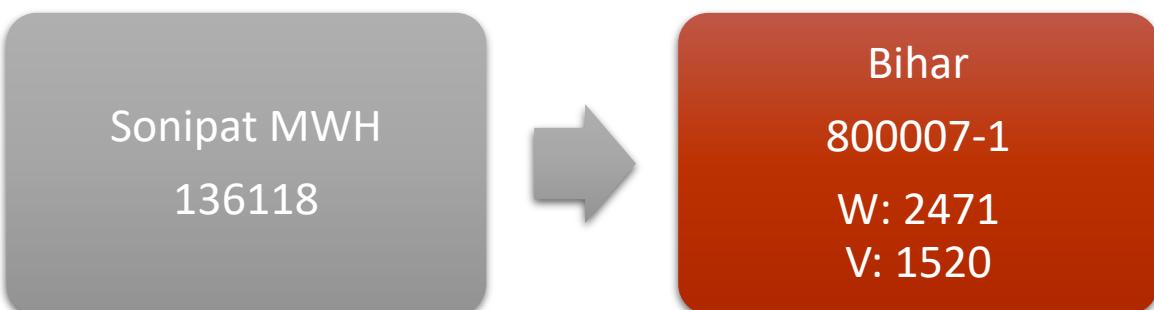
Distance covered: 1778 KM



Vehicle 10: Container 32 FT SXL



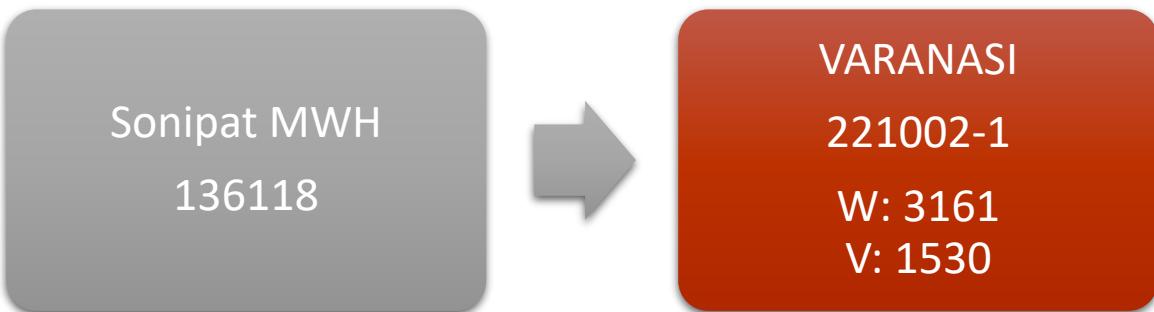
Distance covered: 1198 KM



Vehicle 11: Container 32 FT SXL



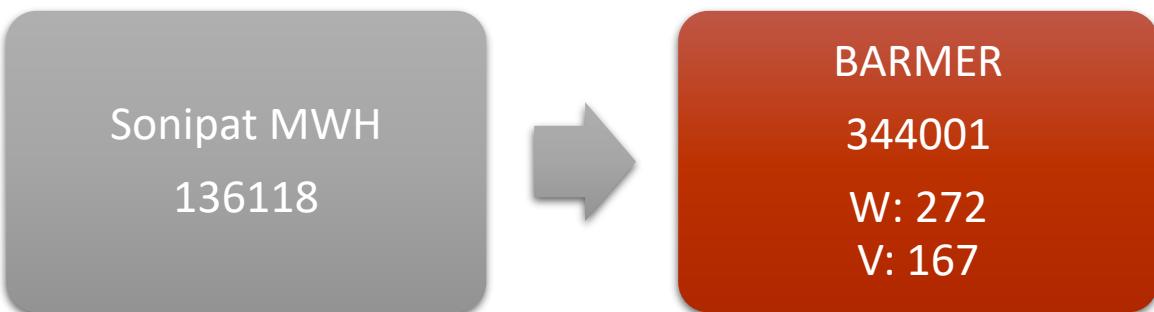
Distance covered: 997 KM



Vehicle 12: Elcher 17 Feet



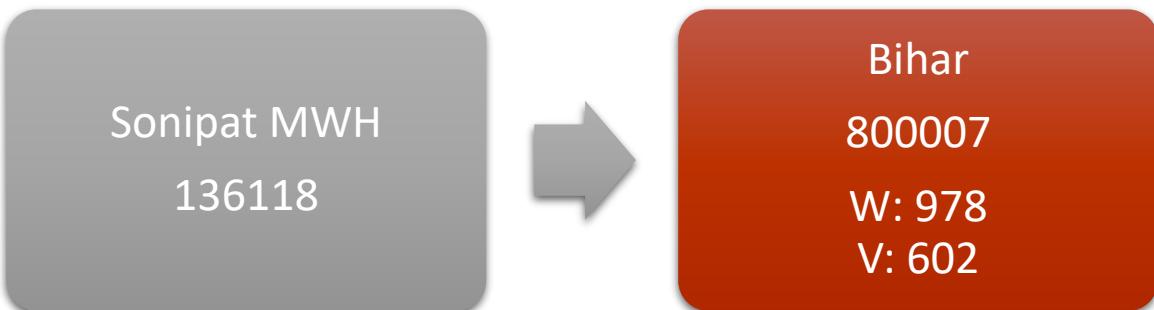
Distance covered: 895 KM



Vehicle 13: Elcher 20 Feet



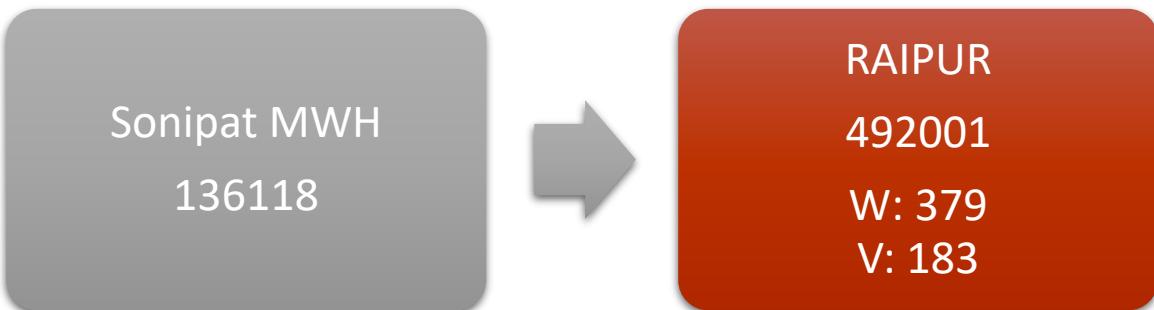
Distance covered: 1198 KM



Vehicle 14: Elcher 17 Feet



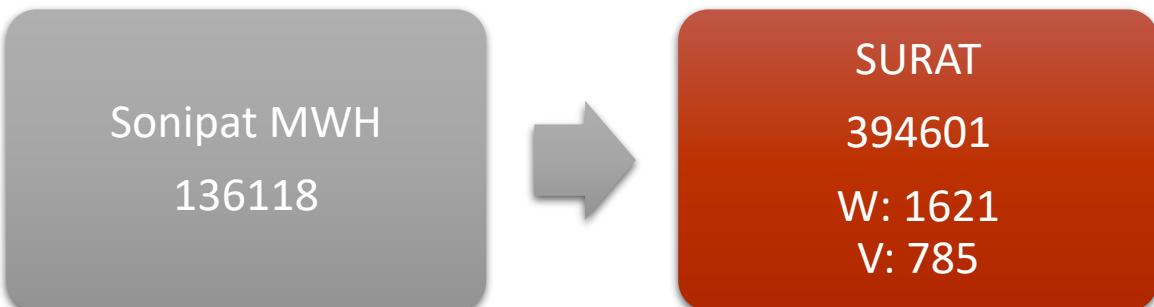
Distance covered: 1362 KM



Vehicle 15: Elcher 20 Feet



Distance covered: 1323 KM



Vehicle 16: Container 32 FT SXL



Distance covered: 450 KM



Vehicle 17: Container 32 FT SXL



Distance covered: 235 KM



Vehicle 18: Container 32 FT SXL



Distance covered: 372 KM



Vehicle 19: Container 32 FT SXL



Distance covered: 247 KM



Vehicle 20: Container 32 FT SXL



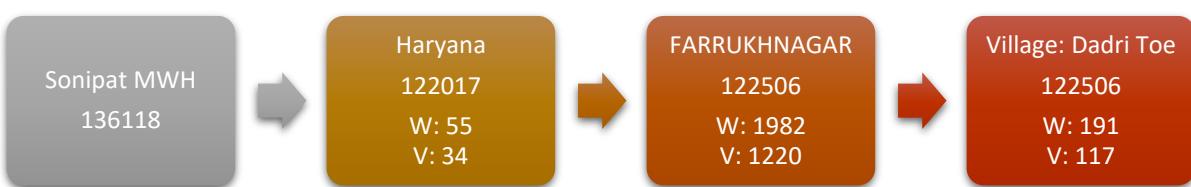
Distance covered: 222 KM



Vehicle 21: Container 32 FT SXL



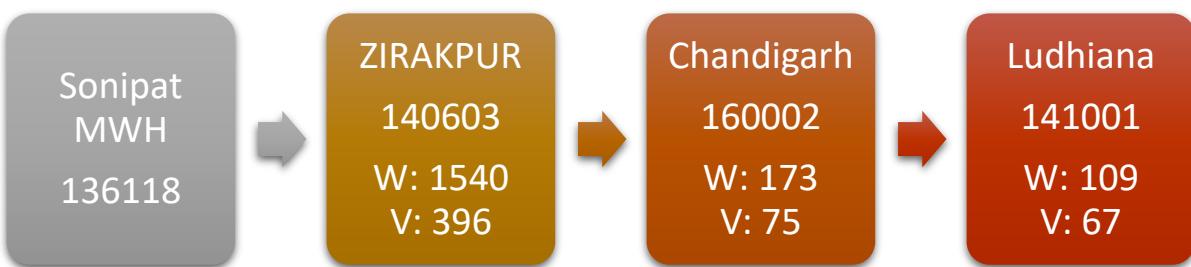
Distance covered: 241 KM

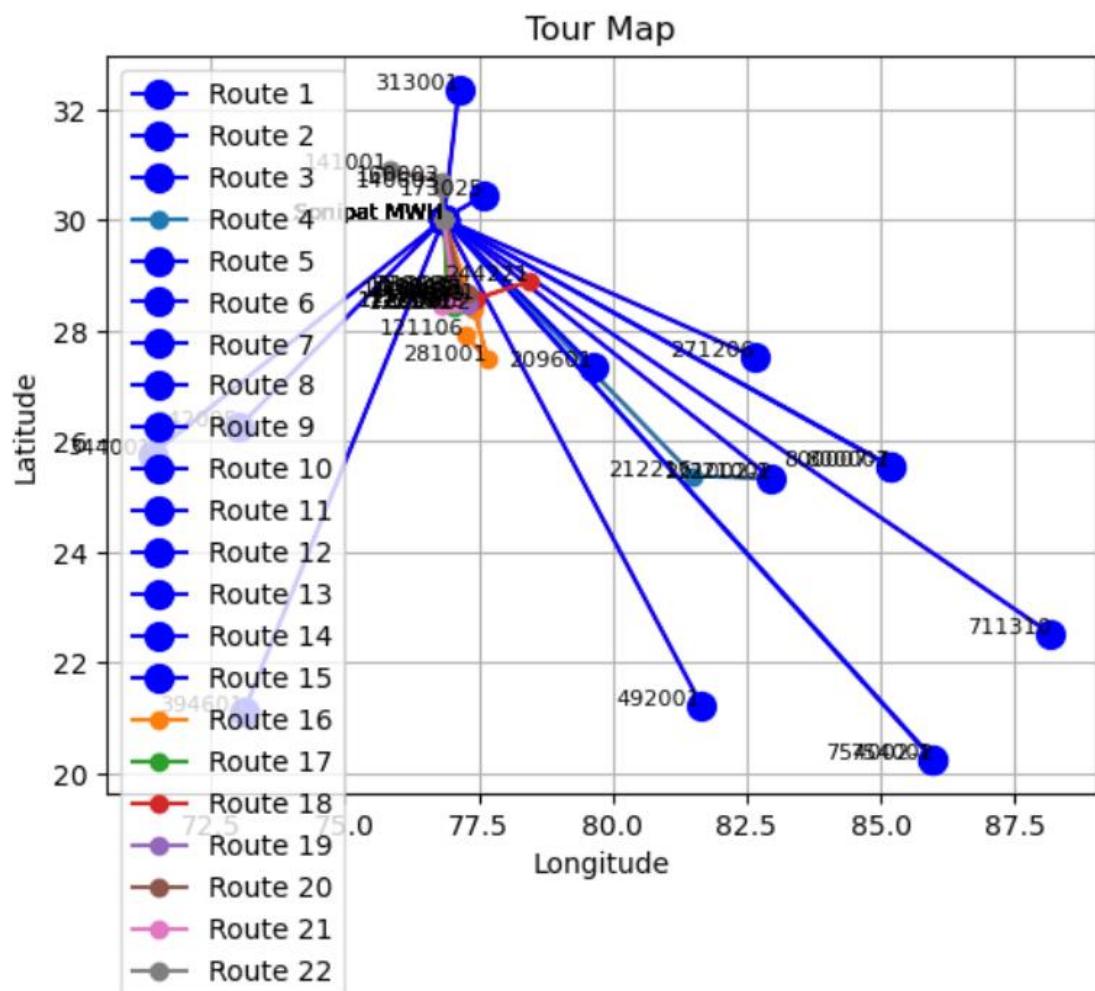


Vehicle 22: Elcher 20 Feet



Distance covered: 213 KM





Number of vehicles of each type to be rented for routing:

Truck Type	Count
Tata Ace	7
Mahindra Bolero pickup	3
Eicher 14 Feet	15
Eicher 17 Feet	42
EICHER 20 FEET	15
CONTAINER 32 FT SXL	29

Total no. of trips: 111