

## **Problem Description: Multi-Trip Capacitated Vehicle Routing Problem with Time Windows (MT-CVRPTW)**

You are working as a logistics coordinator for a delivery company that services a set of locations within India. The company needs to deliver goods from a central warehouse to various customer locations. The delivery must be planned efficiently to minimize total operational cost while adhering to several constraints.

### **Objective**

Create a delivery plan that minimizes the total travel distance and the number of trucks used while satisfying the constraints related to vehicle capacities, customer time windows, and multiple trips per vehicle.

### **Constraints**

#### **1. Vehicle Fleet:**

- The company has a fleet of trucks with different capacities. Each truck can make multiple trips in a day if necessary. The maximum working hours for a truck in a day is 16 hours.
- Trucks available:
  - 3 tonner Box: 2800 KG capacity (5 available)
  - 5 tonner Box: 4800 KG capacity (3 available)
  - 7.5 tonner Truck: 7500 KG capacity (2 available)

#### **2. Customer Orders:**

- Each customer has a specific time window during which they can receive deliveries.
- Each order has a specified weight.
- Each customer location can be serviced by the allowed truck types only.

#### **3. Time Windows:**

- Deliveries must occur within specific time windows provided by the customers.
- The time window for each customer is given as a start and end time (e.g., 08:00 - 12:00).

#### **4. Multiple Trips:**

- Trucks are allowed to return to the warehouse to reload and make multiple trips throughout the day.
- Each trip must start and end at the central warehouse.

#### **5. Travel Matrix:**

- A matrix is provided indicating the travel time and distance between each pair of locations, including the warehouse.

#### **6. Loading and Unloading:**

- Each loading/unloading operation at a customer location takes 20 minutes.
- Each loading/re-loading operation at the warehouse takes 60 minutes.

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## Data

You are provided with the following files: ([link to download the data](#))

1. trucks.csv: Information about the trucks in the fleet.
2. order\_list.xlsx: Details of customer orders including origin and destination codes, weights, and dispatch dates.
3. locations.csv: Information about each location, including allowed trucks and loading/unloading windows.
4. travel\_matrix.csv: A matrix indicating the travel distance and time between locations.

### 1. trucks.csv

- truck\_type: The type of the truck (e.g., "3 tonner Box").
- truck\_max\_weight: The maximum weight the truck can carry in KG (e.g., 2800).
- truck\_weight\_unit: The unit of weight measurement (e.g., "KG").
- truck\_id: A unique identifier for the truck (e.g., "T3\_1").

### 2. locations.csv

- location\_code: A unique code representing the location (e.g., 12854113).
- trucks\_allowed: The types of trucks allowed at the location (e.g., "['3 tonner Box']").
- location\_loading\_unloading\_window\_start: The start time for loading/unloading operations (e.g., "8:00").
- location\_loading\_unloading\_window\_end: The end time for loading/unloading operations (e.g., "22:00").

### 3. travel\_matrix.csv

- source\_location\_code: The code for the source location (e.g., 12854113).
- destination\_location\_code: The code for the destination location (e.g., 12854113).
- travel\_distance\_in\_km: The travel distance between the source and destination in kilometers
- travel\_time\_in\_min: The travel time between the source and destination in minutes

### 4. order\_list.xlsx

- Invoice No.: The invoice number (e.g., "INV\_14062024\_01").
- Origin Code: The code for the origin location (e.g., "A123").
- Destination Code: The code for the destination location (e.g., 12854121).
- Total Weight: The total weight of the order in KG (e.g., 1200.0).
- Dispatch Date: The date the order was dispatched (e.g., "2023-06-14").

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## Tasks

### 1. Data Understanding:

- Analyze the provided data files to understand the constraints and requirements for the delivery plan.

### 2. Modeling:

- Formulate a mathematical model to represent the Multi-Trip Capacitated Vehicle Routing Problem with Time Windows (MT-CVRPTW).
- Ensure the model includes all constraints related to vehicle capacities, customer time windows, multiple trips, and travel distances.

### 3. Implementation:

- Implement the model using an appropriate optimization tool or software (e.g., Python with PuLP or Gurobi).
- Generate an optimal or near-optimal delivery plan based on the given data.

### 4. Validation:

- Validate the solution by ensuring all constraints are met.
- Provide a summary of the total travel distance, number of trips made by each truck, and adherence to time windows.

### 5. Reporting:

- Prepare a report that includes:
  - A description of the problem and its constraints.
  - The mathematical formulation of the model.
  - The implementation approach and tools used.
  - The final delivery plan with detailed routes for each truck.
  - Analysis and validation of the results.

## Deliverables

1. The mathematical model formulation.
2. The code used for the implementation.
3. The final delivery plan and validation results.
4. A comprehensive report as described above.

## Notes

- Consider all given constraints to ensure feasible and practical routes.
- Use visualization tools to represent the routes on a map for better understanding and presentation.
- Discuss any assumptions or simplifications made during the modeling process.

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