## Challenge

Professional, delivery and operational fleets are a significant contributor to global greenhouse emissions. Fleet owners aspire to achieve net-zero emissions promptly; however, the transition presents a complex dilemma. Balancing the urgency of achieving net-zero emissions with business sustainability and customer satisfaction requires a decision-making framework that considers factors such as timing, location, and approach.

By harnessing the power of data and mathematical models, you will navigate the complexities of demand forecasts, dissect emission profiles, and find ways to meet ambitious emission targets. The end game is to develop ingenious solutions that strike a balance between operational effectiveness and environmental impact.

## Problem Statement

Road transport is the backbone of supply chain, playing a pivotal role in moving goods and bolstering the economy. This mode of transport's advantages are flexibility, door-to-door service, and connectivity between cities, towns, and villages. While it comes with convenience and advantage, professional, delivery and operational fleets are a significant contributor to global greenhouse emissions. Fleet owners aspire to achieve net-zero emissions promptly; however, the transition presents a complex dilemma. Balancing the urgency of achieving net-zero emissions with business sustainability and customer satisfaction requires a decision-making framework that considers factors such as timing, location, and approach.

**you will have a chance to develop mathematical models to optimize fleet decarbonization strategies, to help fleet owners make informed decisions that align with their energy transition objectives and business outcomes.**

By harnessing the power of data and mathematical models, you will navigate the complexities of demand forecasts, dissect emission profiles, and find ways to meet ambitious emission targets. The end game is to develop ingenious solutions that strike a balance between operational effectiveness and environmental impact. We will provide various yearly 'demand' data from a fleet operator that must be met. The demand data is further divided into various size and distance buckets which indicate what vehicle sizes should be used and how much distance per day they can cover. These are some additional constraints imposed on meeting the customer demand. We provide various vehicles from the following 3 drivetrains: Diesel, LNG, and BEV (Battery Electric Vehicle). For each of these vehicles, the cost, operational yearly range, distance bucket they can cover, and the vehicle ID (unique identifier which helps you reference them in your solution) is provided. We include the information on the fuel consumption by every model of the vehicle and the corresponding fuel types. Furthermore, we also include the cost for every fuel type along with the amount of carbon emissions by each of them, for every single year. Finally, you are also provided with the total carbon emission limits that must not be exceeded every year. All the data provided spans the years 2023 to 2038 (both years inclusive), for a total of 16 years.

Your solution should provide an optimal fleet composition over the years, which meets all supply-chain demand and constraints while abiding by the carbon emission limits for every year and has the lowest overall cost possible. The data provided to you and the solution expected from you has been further explained in the next section.

## Data

We are providing the following datasets:

1. **Demand.csv:** This file gives you the total yearly distance demand (in kms) that needs to be satisfied with vehicles of size Sx (size bucket) which can travel at least a minimum of Dx (distance bucket) per day. For example, row 1 indicates that there is a yearly demand of 869181 km for the S1 sized vehicles which can travel at least a minimum of D1 distance bucket per day.
2. **Vehicles.csv:** This file gives you the vehicle ID (model), type of vehicle (drivetrain), size bucket, year in which you can purchase it, purchase cost, yearly range (in kms), and the daily maximum distance bucket it can travel.
3. **Vehicles_fuels.csv:** This file gives you the fuel consumption (unit of fuel consumed/km) for every vehicle ID using a certain type of fuel.

| ID | Vehicle | Size | Year | Cost ($) | Yearly range (km) | Distance |
|---|---|---|---|---|---|---|
| BEV_S1_2023 | BEV | S1 | 2023 | 187000 | 102000 | D1 |
| : | : | : | : | : | : | : |
| Diesel_S2_2024 | Diesel | S2 | 2024 | 107120 | 106000 | D4 |
| : | : | : | : | : | : | : |
| LNG_S4_2038 | LNG | S4 | 2038 | 301395 | 118000 | D4 |

| Year | Size | Distance | Demand |
|---|---|---|---|
| 2023 | S1 | D1 | 869181 |
| 2023 | S1 | D2 | 2597094 |
| : | : | : | : |
| 2038 | S4 | D4 | 306910 |

| ID | Fuel | Consumption (unit_fuel/km) |
|---|---|---|
| BEV_S1_2023 | Electricity | 0.893043 |
| : | : | : |
| Diesel_S1_2023 | B20 | 0.223016 |
| : | : | : |
| LNG_S4_2038 | BioLNG | 0.154568 |

4. **Fuels.csv:** There are 5 fuel types, and for each, this table provides the carbon emission per unit fuel and the (median) cost per unit fuel across all the years. It also includes the uncertainty in the fuel cost.

| Fuel | Year | Emissions (CO2/unit_fuel) | Cost ($/unit_fuel) | Cost Uncertainty (±%) |
|---|---|---|---|---|
| B20 | 2023 | 3.04858 | 1.220845 | 0 |
| : | : | : | : | : |
| Electricity | 2024 | 0.0 | 0.184113 | 2 |
| : | : | : | : | : |
| LNG | 2038 | 2.486188 | 0.926499 | 30 |

5. **Carbon_emissions.csv:** Provides the total carbon emissions limits that should not be violated for every year. It is a decreasing profile over the years.

| Year | Total Carbon emission limit |
|---|---|
| 2023 | 11677957 |
| 2024 | 10510161 |
| : | : |
| 2038 | 2404387 |

## Notations:

$\mathrm{C}_{\mathrm{total}}$ ← Total cost of fleet ownership and operations across all the years.

$C_{buy}^{yr}$ ← Total cost of buying vehicles in year $yr$.

$C_{ins}^{yr}$ ← Total insurance cost incurred on the vehicles in the fleet for the year $yr$.

$C_{mnt}^{yr}$ ← Total maintenance cost incurred on the vehicles in the fleet for year $yr$.

$C_{fuel}^{yr}$ ← Total fuel cost incurred on the operating fleet in the year $yr$.

$C_{sell}^{yr}$ ← Amount received by selling some vehicles in the fleet in the year $yr$.

$V_{yr}$ ← Set of all vehicles purchased in the year $yr$.

$C_{v_{yr}}$ ← Purchase cost of a single vehicle with ID $v_{yr}$.

$N_{v_{yr}}$ ← Number of vehicles of ID $v_{yr}$ that have been purchased.

$F_{yr}$ ← Fleet of vehicles in the year $yr$.

$C_{v_{yrp}}$ ← Cost of vehicle in fleet purchased in the year $yrp$. $yrp$ is the year of purchase and $yr$ is the year of operation such that $yrp \leq yr$.

$N_{v_{yrp}}$ ← Number of vehicles currently in the fleet in the year $yrp$.

$I_{(yr-yrp)}^{v_{yrp}}$ ← Insurance cost in the year $yr$ for vehicle $v_{yrp}$ purchased in the year $yrp$.

$M_{(yr-yrp)}^{v_{yrp}}$ ← Maintenance cost in the year $yr$ for vehicle $v_{yrp}$ purchased in the year $yrp$.

$D_{(yr-yrp)}^{v_{yrp}}$ ← Depreciation cost in the year $yr$ for vehicle $v_{yrp}$ purchased in the year $yrp$.

$U_{yr}$ ← Vehicles being used (driven) in the year $yr$. This is a subset of $F_{yr}$.

$F_v$ ← All fuel types applicable for vehicle $v$.

$Ds_v^f$ ← Distance travelled by vehicle v using fuel f.

$N_v^f$ ← Number of vehicles of type $v$ driving fuel type $f$.

$m_v^f$ ← Fuel Consumption of vehicle type $v$ driving with fuel type $f$.

$C_{uf,f}^{yr}$ ← Cost of unit fuel of type $f$ in the year $yr$.

$N_{yr,v_{yrp}}^{sell}$ ← Number of vehicles $v_{yrp}$ to be sold in the year $yr$.

$Carbon_{tot}^{yr}$ ← Total carbon emission in the year $yr$.

$CE^f$ ← Carbon emission for the fuel type $f$.

## Objective:

$$C_{total} = \sum_{yr=2023}^{2038} C_{buy}^{yr} + C_{ins}^{yr} + C_{mnt}^{yr} + C_{fuel}^{yr} - C_{sell}^{yr}$$

$$C_{buy}^{yr} = \sum_{v_{yr} \epsilon V_{yr}} C_{v_{yr}} * N_{v_{yr}}$$

$$C_{ins}^{yr} = \sum_{v_{yrp} \epsilon F_{yr}} C_{v_{yrp}} * I_{(yr-yrp)}^{v_{yrp}} * N_{v_{yrp}}$$

$$C_{mnt}^{yr} = \sum_{v_{yrp} \epsilon F_{yr}} C_{v_{yrp}} * M_{(yr-yrp)}^{v_{yrp}} * N_{v_{yrp}}$$

$$C_{fuel}^{yr} = \sum_{v \epsilon U_{yr}} \sum_{f \epsilon F_v} Ds_v^f * N_v^f * m_v^f * C_{uf,f}^{yr}$$

$$C_{sell}^{yr} = \sum_{v_{yrp} \epsilon F_{yr}} C_{v_{yrp}} * D_{(yr-yrp)}^{v_{yrp}} * N_{yr,v_{yrp}}^{sell}$$ Your

## Constraints:

1. Vehicle of size Sx can only cater to the demand of size bucket Sx.
2. Vehicle belonging to distance bucket Dx can satisfy all demands for distance bucket D1 to Dx. For example, vehicle belonging to distance bucket D4 can satisfy demand of D1, D2, D3, D4buckets; similarly, D3 can satisfy D1, D2, D3 but NOT D4.
3. Total carbon emitted by fleet operations each year should be within the respective year's carbon emissions limits provided in carbon_emissions.csv. Total carbon emissions for a year is calculated using:

$$Carbon_{tot}^{yr} = \sum_{v \epsilon U_{yr}} \sum_{f \epsilon F_v} Ds_v^f * N_v^f * m_v^f * CE^f$$

4. Total yearly demand for each year must be satisfied for each distance and size buckets.
5. Vehicle model of year 20xx can only be bought in the year 20xx. For example, Diesel_S1_2026 can only be bought in 2026 and not in any subsequent or previous years.
6. Every vehicle has a 10-year life and must be sold by the end of 10th year. For example, a vehicle bought in 2025 must be sold by the end of 2034.
7. You cannot buy/sell a vehicle mid-year. All buy operations happen at the beginning of the year and all sell operations happen at the end of the year.
8. Every year at most 20% of the vehicles in the existing fleet can be sold.

## Evaluation:

You are expected to provide the solution in a .csv format file. The column names that should exist in the .csv along with "valid" entries are provided in the table below.

| Column Name | Valid entries |
|---|---|
| Year | 2023, 2024, …., 2038 |
| ID | Should be among list of IDs provided in vehicles.csv |
| Num_Vehicles | >=1 |
| Type | Should be among "Buy", "Use", "Sell". |
| Fuel | Should be among "Electricity", "B20", "LNG", "BioLNG", "HVO". |
| Distance_bucket | Should be among D1, D2, D3, D4. |
| Distance_per_vehicle(km) | Should > 0 and <= Yearly range of that model. |

Note: Distance bucket of the solution file corresponds to the distance bucket in the demand.csv file. Note that this is not the distance bucket of the vehicle itself (we get that from vehicles.csv anyways using the provided ID).

## Additional info:

1. Vehicle resale value, insurance cost and maintenance costs as a percentage of its purchase cost is given below for each year after the purchase of vehicle.

| | % of Purchase Cost | | |
|---|---|---|---|
| End of Year | Resale Value (%) | Insurance Cost (%) | Maintenance Cost (%) |
| 1 | 90% | 5% | 1% |
| 2 | 80% | 6% | 3% |
| 3 | 70% | 7% | 5% |
| 4 | 60% | 8% | 7% |
| 5 | 50% | 9% | 9% |
| 6 | 40% | 10% | 11% |
| 7 | 30% | 11% | 13% |
| 8 | 30% | 12% | 15% |
| 9 | 30% | 13% | 17% |
| 10 | 30% | 14% | 19% |

To illustrate the calculations, let us take an example of purchase cost = $100 for a vehicle bought on Jan 1st, 2025. Using the percentages in the above table, the values can be calculated as follows:

| Year of Operation | End of Year | Resale Date | Resale Value (RV) ($) | Insurance Cost (IC) ($) | Maintenance Cost (MC) ($) | Insurance & Maintenance Period |
|---|---|---|---|---|---|---|
| 2025 | 1 | 31st Dec, 2025 | 90 | 5 | 1 | 1st Jan – 31st Dec, 2025 |
| 2026 | 2 | 31st Dec, 2026 | 80 | 6 | 3 | 1st Jan – 31st Dec, 2026 |
| 2027 | 3 | 31st Dec, 2027 | 70 | 7 | 5 | 1st Jan – 31st Dec, 2027 |
| 2028 | 4 | 31st Dec, 2028 | 60 | 8 | 7 | 1st Jan – 31st Dec, 2028 |
| 2029 | 5 | 31st Dec, 2029 | 50 | 9 | 9 | 1st Jan – 31st Dec, 2029 |
| 2030 | 6 | 31st Dec, 2030 | 40 | 10 | 11 | 1st Jan – 31st Dec, 2030 |
| 2031 | 7 | 31st Dec, 2031 | 30 | 11 | 13 | 1st Jan – 31st Dec, 2031 |
| 2032 | 8 | 31st Dec, 2032 | 30 | 12 | 15 | 1st Jan – 31st Dec, 2032 |
| 2033 | 9 | 31st Dec, 2033 | 30 | 13 | 17 | 1st Jan – 31st Dec, 2033 |
| 2034 | 10 | 31st Dec, 2034 | 30 | 14 | 19 | 1st Jan – 31st Dec, 2034 |

2. Distance bucket mappings.

| Distance bucket | Name of category |
|---|---|
| Up to 300 km daily | D1 |
| Up to 400 km daily | D2 |
| Up to 500 km daily | D3 |
| Up to 600 km daily | D4 |