CARNET- Carbon Neutral Evaluation Tool

February 2021

1 Introduction

Baltimore County (BC) requires an interactive decision support tool, wherein decision makers can alter input parameters, to identify and evaluate various feasible (and ideally optimal) conversion roadmaps for the transformation of the current BC vehicle fleet to a low-carbon, renewable energy vehicle fleet in order to achieve a percentage reduction in greenhouse gas emissions from a baseline year by a target date. The current goal is to reduce emissions by 40% of 2006 levels by 2037.

2 Dataset

BC has a fleet of 1400+ vehicles which are a combination of buses, trucks and sedans. All of them are run on gas engines (ICEs).

3 Model Formulation

3.1 Variables

- **Planning horizon:** Let $T = \{0, 1, 2, 3...20\}$ indicate the total planning horizon in years and $t \in T$.
- **Vehicle:**Let V_i^t be the set of all vehicles in the portfolio at a given time t with n_t being the total number of vehicles.
- **Fuel:** Let F_i^t be the fuel/consumable cost of vehicle i in the portfolio in the time t. This is calculated based on FE_t (with a deterioration factor DF_t), the fuel economy of the vehicle measured in miles per gallon and VMT_t, the Vehicle Miles travelled- $F_i = \left[\frac{FE_t}{DF_t} \times VMT_i^t\right] \times c_t$ where c_t is the cost in \$ for fuel. We denote the first component in the above equation as f_i^t or the fuel consumed.
- **Emission Cost:** E_i^t be the emission cost of vehicle V_i^t at time t and E_t be the total emission cost of the portfolio of vehicles in year t. This is

calculated based on the fuel consumed f_i^t and the emission factor EF and the environmental damage cost of emission C_{CO2} as follows.

$$E_i = f_i^t \times EF \times C_{CO2}$$

We will assume the damage cost of emission C_{CO2} to be \$120 per ton (based on literature).

- **Purchase Costs:** Let P_i^t be the salvage adjusted purchase cost the corresponding infrastructure set up cost of the replacement vehicle i in the year t and P_t be the total cost purchase and setting up of all new vehicles and in time t. P_T is the total purchase cost over the time horizon.

$$P_T = \sum_{t=0}^{max(T)} P_t$$

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- **Maintenance Costs:** Let M_i^t be the cost of maintenance and repair of vehicle V_i^t in the portfolio in the year t. M_t be the total cost of maintenance and repair in year t and M_T is the total maintenance cost over the time horizon.

$$M_T = \sum_{t=0}^{max(T)} M_t$$

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- **Total Cost:** Let C_i^t be the total cost incurred in year t. It is computed as-

$$C_i^t = E_i^t + M_i^t + F_i^t$$

and C_T is the total cost incurred over the entire time horizon T across all the vehicles.

$$C_T = E_T + M_T + F_T$$

3.2 Decision

The decision that needs to be made is either 'Keep'(K) or 'Replace' (R) a vehicle V_i in a given year t. An optimal decision is a matrix of size $n \times T$ of Ks and Rs.

3.3 Stage

Since there is one decision per year it makes sense to keep every $t \in T$ as the stage.

3.4 Recursion equation and constraints

We write down the recursion equation of minimizing the total cost of the Replacement problem as below.

$$g(t) = \min_{x} \{C_t + g(x)\}$$

Where $g(t)$ is the minimum cost incurred from time t till time $\max(T)$ and x satisfies the inequality $t + 1 \leq x \leq \max(T)$. *This equation will have to be applied to each of the i vehicles individually.(To discuss).*

3.5 Constraints

- **Purchase Budget-** The annual purchase and set-up cost cannot exceed B_t. i.e

  $$P_t \leq B_t$$

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- **Mileage threshold-** Vehicle V_i can only be replaced if it has travelled a threshold miles A. i.e

  $$VMT_i \geq A$$

  if decision is replace(R).