Optimal Green Fleet Composition Using Machine Learning

By Name(s): Elissar Samaha, Vrushali Patil
Advisors: Dr. J. Velázquez Martínez, Dr. K. Gámez Pérez
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Summary:

This research focused on formulating an optimal fleet replacement policy that considers on costs as well as sustainability in terms of CO₂ emissions. We used machine learning algorithms to analyze vehicles’ performance and examined their CO₂ emissions for varying route and load conditions. We used these insights to build an optimization model. By running different scenarios on our test case fleet, we observed 700,000 KgCO₂ drop in emissions for approximately 37000 USD of the increase in overall fleet costs. This increase was marginal compared to the cost benefits realized by optimal fleet replacement policy over the baseline scenario.

INTRODUCTION

“From shifting weather patterns that threaten food production, to rising sea levels that increase the risk of catastrophic flooding, the impacts of climate change are global in scope and unprecedented in scale. Without drastic action today, adapting to these impacts in the future will be more difficult and costlier.” UN IPCC Fifth Climate Report, 2014. The latest UN climate report mentions that reducing environmental impact is no longer a choice.
METHODOLOGY

We used two-pronged approach in this research. In the first part, we analyzed the relationship between vehicle characteristics and average CO₂ emissions of each vehicle. We performed this analysis for all vehicles in each route cluster-load bin combination. By analyzing vehicles within the same route cluster and load bin, we isolated the effects of vehicle characteristics while assessing CO₂ emissions. We considered following vehicle characteristics in this analysis: Brand, engine type, age, mileage, maintenance costs in last year.

Using supervised machine learning technique on the historical data, we developed a vehicle classification algorithm. As CART is a greedy algorithm, first few splits in the tree are considered as the most important characteristics that influence the outcome variable (CO₂ emissions).

In the second part of the research, we developed an optimization model to minimize the costs of the overall fleet. This model proposed the number of vehicles to be replaced every year. It used the purchase price for new vehicles, depreciation rates, resale value, and operating costs (fuel consumption and maintenance costs) and was constrained by demand for total number of vehicles in the fleet, upper and lower limit on a number of vehicles that can be replaced every year. Though fuel consumption costs (which is a proxy for CO₂ emissions) was part of the above model, the model objective was not to explicitly minimize CO₂ emissions but to reduce overall fleet cost. We incorporated the additional constraint of ‘maximum total fleet CO₂ emissions’ in this model that forced the model to consider CO₂ emissions as a key focus area rather than just as one of many costs.

We ran multiple simulations of this model by varying ‘maximum total fleet CO₂ emissions’ and observed its effect on total cost as well as on the number of vehicles to be replaced every year. We plotted the relationship between total cost and total CO₂ emissions.

RESULTS

We analyzed the vehicles trips in different data subsets with same route cluster and load bin. We ran a classification tree algorithm with CO₂ emissions as a target label. As seen in figure 2 below, the first split of the tree is on the “age” feature, this implied that this is the most informative characteristic influencing CO₂ emissions. We analyzed multiple data subsets in exactly same way. In some datasets,
brand came out as the most informative characteristics. But in these datasets, brand and age were highly correlated. Hence, we concluded that age and brand are the most informative characteristics influencing CO₂ emissions of vehicle irrespective of route it operates on and load it carries.

We ran the optimization model with a relaxed CO₂ constraint over a period of 3 years, the model proposed to sell 213 vehicles from fleet of 402. Refer to the table 1 for sample of results:

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>YEAR 1</th>
<th>YEAR 2</th>
<th>YEAR 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>386</td>
<td>SELL</td>
<td>KEEP</td>
<td>KEEP</td>
</tr>
<tr>
<td>387</td>
<td>KEEP</td>
<td>SELL</td>
<td>KEEP</td>
</tr>
<tr>
<td>388</td>
<td>SELL</td>
<td>KEEP</td>
<td>KEEP</td>
</tr>
</tbody>
</table>

We changed the overall CO₂ emissions constraint. The tighter the emission the higher the costs, but an initial drop of 3.5% in CO₂ emissions was gained by 0.04% increase in overall fleet costs for the test case fleet. Even though optimal cost increased with tighter CO₂ constraints, the increase was not significant and overall fleet cost was still significantly lower than it would have been in absence of any fleet replacement policy.

Our capstone partner is one of the largest retailers in Mexico and one of their main goals is to reduce CO₂ emissions for their fleet of 1200 last-mile delivery trucks and 590 inbound trailers. To address Coppel’s concerns, we analyzed their data to determine what vehicle characteristics influence CO₂ emissions the most. We found that age and brand are the most important characteristics influencing CO₂ emissions performance of vehicles. When Coppel buys new vehicles, they can select the brands that have proven high performance in terms of CO₂ emissions.

We developed a fleet replacement model that proposes a vehicle replacement timeline for optimal overall fleet costs and is constrained by the desired CO₂ emission level. We ran this model for varying degrees of CO₂ emissions constraint and observed that reducing CO₂ emissions means an increase in the overall fleet costs (as expected) but this increase can be quantified for the given fleet and was not significant for Coppel fleet. For a fleet of 402 vehicles, an initial gain of 700,000 KgCO₂ drop in emissions was observed for approximately 37000 USD of the cost increase. Optimal overall fleet cost in all scenarios was significantly lower that costs Coppel would incur in absence of fleet replacement policy.

Coppel’s transport managers can use the fleet replacement model every year for the strategic composition of their fleet considering vehicle demands. The fleet replacement model has a number of budget-based levers that allow managers the flexibility to incorporate changing budget constraints and financial priorities of the company year-on-year.

As more and more countries impose CO₂ emissions regulations and policies (like emissions tax and credits), our mathematical and fact-backed fleet replacement approach will help companies to align their fleet operations with their strategic sustainability agenda.