Optimal Green Fleet Composition through Machine Learning

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http://sustainablelogistics.mit.edu
1. What is our project all about?
2. Why this is relevant?
3. What others have done?
4. What is our approach?
5. Results
6. Managerial Implications
What is our project all about?

Formulating a fleet composition strategy not just based on costs and service but also based on CO2 emissions
Why this is relevant?
Why this is relevant?

**CO₂ makes 76% of Green House Gas Emissions**

- **Methane, 16**
- **Others, 8**
- **CO₂, 76**

Globally, 14% of CO₂ emission comes from transport sector and this may double by 2050.

**Electricity/Heat, 31**

- **Transportation, 15**
- **Manufacturing, 12.4**
- **Others, 41.6**

**CO₂ makes 76% of Green House Gas Emissions**
Our Sponsor Company

- One of the largest retailers in Mexico
- Furniture, Appliances, Apparel
- ~$6 Billion USD of Revenue
- 1300 Stores
- 19 Regional DCs
- 1200 Last Mile Vehicles
- 590 Inbound Vehicles
What others have done?

**Individual Vehicle Base**
- Ahmed, 1973
- Chisholm, 1974
- Evans, 1989

**Overall fleet Approach**
- Redmer, 2016
- Ahani, Arantes, & Melo, 2016

**Green Fleet Approach**
- Gong & Wu, 2011
- Stasko & Gao, 2012
Our approach

Formulate an optimization model that proposes vehicle replacement timeline

Identify vehicle characteristics that have the biggest impact on CO$_2$ emissions using Machine Learning

Coppel Inbound Fleet Composition Decision
Our approach-Part 1: Create optimization model

Optimization model will make retirement decisions for each vehicle over a period of 5 years.

- Running Costs (Fuel, Maintenance etc)
- Purchase Price
- Resale Price
- Fleet Demand (Min-Max vehicles that can be replaced every year)
- Fleet CO2 Emissions Budget

Minimize Total Cost

- Retirement Decision per Vehicle per Year (Sell or Keep)
Our approach - Part 2: Identify vehicle characteristics

Isolate vehicle characteristics by analyzing vehicles in same route cluster and load bin.
Results-Part 1: Create Optimization Model

We run the optimization model with a relaxed CO$_2$ constraint, the model proposed to sell 213 vehicles from fleet of 402 vehicles.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>YEAR 1</th>
<th>YEAR 2</th>
<th>YEAR 3</th>
<th>YEAR 4</th>
<th>YEAR 5</th>
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<tbody>
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</table>
Results - Part 1: Create Optimization Model

We changed the overall CO$_2$ emissions constraint, the tighter the emissions the higher the costs, but an initial gain of 700,000 KgCO$_2$ drop in emissions is achieved for 37,000 USD of cost increase.
We isolated the vehicle trips data based on cluster and load bin. We ran the algorithm on the sets that contain the most rows of data.

<table>
<thead>
<tr>
<th></th>
<th>Low Load</th>
<th>Medium Load</th>
<th>High Load</th>
<th>Overload</th>
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<tbody>
<tr>
<td><strong>Route cluster 1</strong></td>
<td></td>
<td><strong>145</strong></td>
<td>33</td>
<td>23</td>
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<tr>
<td><strong>Route cluster 2</strong></td>
<td>57</td>
<td><strong>299</strong></td>
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</tbody>
</table>

*Table: Number of Vehicle trips in each cluster and load bin*
## Sample Data Structure

<table>
<thead>
<tr>
<th>Vehicle ID</th>
<th>Brand</th>
<th>Engine Type</th>
<th>Age</th>
<th>Mileage (km)</th>
<th>Load bin</th>
<th>Cluster</th>
<th>Maintenance factor ($/km)</th>
<th>Fuel Factor (l/km)</th>
<th>CO2 emissions (KgCO2/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1825</td>
<td>KENWORTH</td>
<td>260 HP</td>
<td>15</td>
<td>266864</td>
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<td>3.45</td>
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<td>2509</td>
<td>FREIGHTLINER</td>
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<td>13</td>
<td>410681</td>
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<td>Cluster 1</td>
<td>0.89</td>
<td>3.47</td>
<td>9.07405</td>
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<td>477792</td>
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<td>9</td>
<td>1005888</td>
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<td>3.39</td>
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<td>554411</td>
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<td>2.3</td>
<td>3.5</td>
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<td>318235</td>
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<td>Cluster 1</td>
<td>8.05</td>
<td>3.4</td>
<td>8.891</td>
</tr>
</tbody>
</table>
Cluster 1 - Medium Load: The first split of the tree is on the “brand” feature.

Results - Part 2: Identify vehicle characteristics
Cluster 2 - Medium Load: The first split of the tree is on the “age” feature.
Results-Part 2: Identify vehicle characteristics

Cluster 1 - Medium Load:

- **Age**
- **CO2 Emissions**
Results-Part 2: Identify vehicle characteristics

Cluster 2 - Medium Load:

Cluster 1 - Low Load:

Cluster 3 - High Load:
When making decision on new vehicles, detailed evaluation of brands should be done to ensure that new vehicles have better performance.
Managerial Implications

**Operations**
- Use the model for strategic replacement
- Centralize fleet decision
- Evaluation of procurement contracts for brand replacement

**Financial**
- Manage fleet investment capital
- Reduce operational costs

**Environment**
- Prepare for regulation compliance
- Run scenarios for CO2 emissions
“Be the change you want to see in the world”--Gandhi