Transportation Vehicle Modelling for Policy Analysis

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Transportation Contributions the **Majority** of GHG Emissions

**Baseline Emissions (2007)**

- **Transportation**: 59%
- **Buildings**: 37%
- **Waste**: 4%

*Source: City of Surrey, Community & Emissions Plan, 2013:34*
Our Planned Deliverables

Vehicle Stock Insights

How has vehicle ownership changed between 2006 and 2016?

What other factors correlate with different vehicle stock composition?

Policy Analysis Tools

If we meet particular targets for vehicle stock composition, how will that affect GHG emissions?

What areas of Surrey provide the best opportunity for reducing GHG emissions?
Our Project

Data

- ICBC vehicle registration\(^1\)
- Transportation demand model output\(^1\)
- Building and population projections\(^1\)
- Census / StatCan data

\(^1\) Thank you to the City of Surrey for providing these non-open data.

Process

1. Data Collections and Cleaning
   - Spatial Rebasing
2. Exploratory Data Analysis
3. Vehicle Stock Regression Modelling
   - Demographic, Transportation, Spatial/Temporal elements
4. Transportation Demand Classification by vehicle class
5. Emissions Modelling
Geographical Rebasing

ICBC Registration: Postal Codes

Transportation Models: Traffic Analysis Zones

Census: Dissemination Area

Sources:
City of Surrey, StatCan, Canada Post
Geographical Rebasing—Postal Codes

Approximate Postal Code catchment areas with their centroid.

Sources:
Canada Post, Google Maps API, geocoder.ca
Geographical Rebasing—Census Data

Goals of rebasing census data:
- Develop a TAZ-level table or database of all census variables relevant to transportation models (e.g.: vehicle stock models)
- Standardize all selected census variables across different years to a common set of variables

Issues with rebasing census data:
- No readily available interpolation / distribution algorithms
- Census population and housing stock may be under-estimated
- Census specification and vector names varies across the years.
- Standardization requires extensive “manual” adjustments

Resultant: 3 Census data table of 369 standardized variables for 374 TAZs
Vehicle Stock—Distribution of Vehicle Stock

Green Vehicles early in its adoption, Further analysis focused on Passenger vehicle stock

Source: ICBC Registration
Vehicle Stock—Visualizing Vehicles Per Capita

Percent Change of Passenger Vehicles Per Capita Between 2006 and 2016

Source: ICBC Registration
Vehicle Stock—Visualizing Vehicle Net Weight


Source: ICBC Registration
## Vehicle Stock—Changes in Vehicle Attributes

<table>
<thead>
<tr>
<th>Vehicle per Capita</th>
<th>Vehicle Weight</th>
<th>Vehicle Age</th>
<th>TAZ Count</th>
<th>% of TAZ Count</th>
<th>% of TAZ by Pop. (in 2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑ Weight</td>
<td>Older</td>
<td>195</td>
<td>52.14%</td>
<td>69.43%</td>
<td></td>
</tr>
<tr>
<td>↓ Weight</td>
<td>Younger</td>
<td>43</td>
<td>11.50%</td>
<td>11.92%</td>
<td></td>
</tr>
<tr>
<td>↑ Weight</td>
<td>Older</td>
<td>5</td>
<td>1.34%</td>
<td>0.28%</td>
<td></td>
</tr>
<tr>
<td>↓ Weight</td>
<td>Younger</td>
<td>3</td>
<td>0.80%</td>
<td>0.99%</td>
<td></td>
</tr>
<tr>
<td>↑ Weight</td>
<td>Older</td>
<td>45</td>
<td>12.03%</td>
<td>9.25%</td>
<td></td>
</tr>
<tr>
<td>↓ Weight</td>
<td>Younger</td>
<td>11</td>
<td>2.94%</td>
<td>2.97%</td>
<td></td>
</tr>
<tr>
<td>↑ Weight</td>
<td>Older</td>
<td>4</td>
<td>1.07%</td>
<td>0.23%</td>
<td></td>
</tr>
<tr>
<td>↓ Weight</td>
<td>Younger</td>
<td>2</td>
<td>0.53%</td>
<td>0.34%</td>
<td></td>
</tr>
</tbody>
</table>

Source: ICBC Registration
Vehicle Stock—Next Steps and Data Gaps

1. Contextualize Findings: Variable Exploration with Demographic Variables
   ○ Understanding how vehicle ownership has changed in relation with other key demographic variables

2. Hypothesis Testing & Modelling: Obtain Unique Vehicle ID Between Years
   ○ Apply statistical testing for rigorous inference
   ○ Develop vehicle aging model to better understand vehicle ownership dynamics
Vehicle Classification

Purpose

Needed **Vehicle Classification Scheme** to various Make and Models that is not provided by ICBC dataset

And **Fuel Consumption Ratios** for passenger vehicles based on make, model, and year

Method

Adopted classification scheme from **FuelEconomy**, a collaboration between U.S. Department of Energy and the Environmental Protection Agency (EPA)
Vehicle Classification

- We decided to adopt a classification scheme from FuelEconomy which is a collaboration between U.S. Department of Energy and the Environmental Protection Agency (EPA)
- This classification offered us not only sufficient detail (with regards to different types of vehicles), it also provided us fuel consumption ratios for passenger vehicles based on make, model and year
Vehicle Classification—Result

5,152 Different Veh Models

12 Vehicle Classes

Cars
- Two-Seater
- Mini-Compact
- Subcompact
- Compact
- Midsize
- Large
- Station Wagons

Trucks
- Pick-up Trucks
- Vans
- Minivans
- SUVs
- Special Purpose Vehicles
Vehicle Classification

Cars
- Two-Seaters
- Mini-Compact
- Subcompact
- Compact
- Midsize
- Large
- Station wagons

Defined by Interior Volume

Trucks
- Pick-up Trucks
- Vans
- Minivans
- SUVs
- Special Purpose Vehicles

Defined by Gross Vehicle Weight Rating (GVWR)
Vehicle Classification—Distribution in ICBC Registry

![Distribution of Vehicle Classes over Time](image-url)
Vehicle Stock Forecasting

Goal
- Provide Business-As-Usual (BAU) vehicle stock size forecasts for City of Surrey beyond the year of 2016

Challenges
- Need to account for geographic effects w/o necessarily interpreting them
- Need to account for effects of vehicle class
- Limited dataset size (only 3 time points)
  - Time series methods unfeasible
- Omitted variables may affect accuracy of the forecast
- For regression models, need future values of independent variables
Vehicle Stock Forecasting

Approach
- Fit models at three geographic levels: city, community and TAZ
- Community models are the most sensible considering the data size
- Independent variables available: Year, Surrey Population & Housing
- **WARNING**: These prediction models do not yield valid and useable coefficients
  - Models are continuously modified to improve fit and diagnostics

Final community-level model
- Vehicle counts per community and vehicle class as a function of the community and community total units
- Variance of the model follows a log-normal distribution
- $R^2 = 92\%$, Deviance Explained = 92.3\%, with a sample size of 273
- Reasonable model diagnostics
Vehicle Stock Forecasting

Surrey Vehicle Count BAU Log-Normal Model, with VClass

Surrey Vehicle BAU per cap Log-Normal Model, with VClass

- Surrey Vehicle Counts: 250000, 500000, 750000, 1000000
- Surrey Vehicle Counts per Person / Unit: 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2

Legend:
- Red: Vehicle per Person
- Blue: Vehicle per Unit
Vehicle Stock Forecasting

Surrey Vehicle Count BAU, best IgNormal fit, Compact Cars

Surrey Vehicle Count BAU, best IgNormal fit, Minivan
Vehicle Stock Forecasting

Surrey Vehicle Count BAU, best IgNormal fit, Sport Utility Vehicles

Surrey Vehicle Count BAU, best IgNormal fit, Pickup Trucks
Vehicle Stock Forecasting

Surrey Vehicle Count BAU, best IgNormal fit, Sport Utility Vehicles

Surrey Vehicle Count BAU, best IgNormal fit, Subcompact Cars
GHG Emission Inventories Methodology

Vehicle Stock \( \times \) Distance Travelled \( \times \) Fuel Consumption \( \rightarrow \) Total Fuel Volume \( \times \) Emission Factors = Approximate CO\(_2\) emissions

\( \text{Total Fuel Volume} = \text{Vehicle Stock} \times (\text{Distance Travelled} \times \text{Fuel Consumption}) \times \text{Emission Factors} \)

Source:
IPCC (2006)
Next Steps

1. Regression Modelling of Vehicle Stock with Demographic Variables
2. More Advanced Modelling of Vehicle Stock (Markov Chain, Stock-Flow)
3. Validate and Redevelop Vehicle Stock Model with More Data
4. Compute GHG Emissions based on Vehicle Stock Forecasts once Transportation Demand Data is Made Available
Policy Analysis Tool

We’ve developed an interactive tool for planning and testing the outcomes of different policies in the City of Surrey.
### Policy: Policy #1: All SUVs

<table>
<thead>
<tr>
<th>Stock at date:</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cars [n]</td>
<td>287985</td>
<td>337985</td>
<td>387985</td>
<td>437985</td>
</tr>
</tbody>
</table>

### Stock inflow at date:

<table>
<thead>
<tr>
<th>Category</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Vehicles [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minicompact Cars [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Subcompact Cars [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Compact Cars [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Two Seaters [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Midsize Cars [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Large Cars [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minivans [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SUVs [%]</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Station Wagons [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Small Pickup Trucks [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Standard Pickup Trucks [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vans [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Special Purpose [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Sum:** 100% 100% 100% 100%

**Notes:**
Questions?