Performance Evaluation of Freight Truck Trip Generation Models

Ehsan Doustmohammadi
Mehrnaz Doustmohammadi
Michael Anderson

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Introduction

- 2012 Commodity Flow Survey
  - 11 billion tons of commodities
  - worth over $13 trillion shipped
  - Trucking was dominant mode
  - handling almost 74% of the nation’s freight
- Impact on Urban Communities
  - Roadway Use – mix with cars
  - Planning for the future
Study Objective

Compare two truck modeling techniques.

(a) Traditional truck modeling methodology published in the Quick Response Freight Manual (QRFM) and

(b) Truck tour-based approach

Use depends on data availability

Using a single city
### Background: QRFM Model

#### Truck Trip Generation Rate (QRFM Manual)

<table>
<thead>
<tr>
<th>Model Category No.</th>
<th>Generation Variable (Number of Employments/Households)</th>
<th>NAICS Code</th>
<th>Four-Tire Trucks</th>
<th>Single Unit Trucks (6+ Tires)</th>
<th>Combination Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agriculture, Mining, and Construction</td>
<td>11, 21, 23</td>
<td>1.110</td>
<td>0.289</td>
<td>0.174</td>
</tr>
<tr>
<td>2</td>
<td>Manufacturing, Transportation/Communications/Utilities, and Wholesale</td>
<td>22, 31-33, 42, 48, 49</td>
<td>0.938</td>
<td>0.242</td>
<td>0.104</td>
</tr>
<tr>
<td>3</td>
<td>Retail</td>
<td>44</td>
<td>0.888</td>
<td>0.253</td>
<td>0.065</td>
</tr>
<tr>
<td>4</td>
<td>Office and Services</td>
<td>51-56, 92</td>
<td>0.437</td>
<td>0.068</td>
<td>0.009</td>
</tr>
<tr>
<td>5</td>
<td>Households</td>
<td>-</td>
<td>0.251</td>
<td>0.099</td>
<td>0.038</td>
</tr>
</tbody>
</table>
Background: QRFM Model; Cont’d

Friction Factor (QRFM Manual)

- Four-tired commercial vehicles:
  \[ F_{ij} = e^{-0.08^{*}t_{ij}} \]

- Single unit trucks (6+ tires):
  \[ F_{ij} = e^{-0.10^{*}t_{ij}} \]

- Combinations:
  \[ F_{ij} = e^{-0.03^{*}t_{ij}} \]

Gravity Model of Trip Distribution

\[ T_{ij} = P_{i} \left[ \frac{A_{j} F_{ij} K_{ij}}{\sum_{j} A_{j} F_{ij} K_{ij}} \right] \]

Where:
- \( T_{ij} \) = Trips produced at \( i \) and attracted at \( j \)
- \( P_{i} \) = Total trip production at \( i \)
- \( A_{j} \) = Total trip attraction at \( j \)
- \( F_{ij} \) = Friction factor or travel time factor
- \( K_{ij} \) = Socioeconomic adjustment factor
Truck Tour-based Model; Birmingham Case Study Data

- GPS Data Source: American Transportation Research Institute (ATRI)
- ALDOT and RPCGB Data

<table>
<thead>
<tr>
<th>Month</th>
<th>Records</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>February</td>
<td></td>
<td>1,068,591</td>
</tr>
<tr>
<td>May</td>
<td></td>
<td>1,154,229</td>
</tr>
<tr>
<td>July</td>
<td></td>
<td>1,109,508</td>
</tr>
<tr>
<td>October</td>
<td></td>
<td>1,156,712</td>
</tr>
</tbody>
</table>
The tour-based model requires also:

- **Socio-economic (SE) data**
  - population, households, land area.

- **Employment data**
  - industrial, retail, office, and other.

- **Truck Zone Information**
  - industrial parks, warehousing areas, truck stops, quarries, intermodal terminals, etc.
## Proposed Tour-based Model: Pros and Cons

### Benefits

- Can give detailed truck movement models.
- Captures true nature of vehicle (truck) movement.
- Useful for vehicle related policies and impact assessment.

### Difficulties

- Very data intensive – usually requiring detailed ‘travel diary’- like data.
- High complexity and thus also very time intensive.
- Can not relate to directly to flow of commodities.
Model Validation Results

QRFM Model Validation

%RMSE = \left( \frac{\sum_j (Model_j - Count_j)^2}{(\text{Number of Counts} - 1)} \right)^{0.5} \times 100

\left( \frac{\sum_j Count_j}{\text{Number of Counts}} \right)

QRFM approach:
%RMSE value of 47.9%
Model Validation Results

**Truck Tour Based Model Validation**

\[ \%RMSE = \left( \frac{\sum_j (Model_j - Count_j)^2}{(Number \ of \ Counts - 1)} \right)^{0.5} \times 100 \]

\[ \left( \frac{\sum_j Count_j}{Number \ of \ Counts} \right) \]

**Links Characteristics in Validation**

<table>
<thead>
<tr>
<th>Interstate</th>
<th>Facility Type</th>
<th>Number of Links</th>
<th>Number of Lanes</th>
<th>Speed limit (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-65</td>
<td>1</td>
<td>24</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>I-20</td>
<td>1</td>
<td>10</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>I-20/I-59</td>
<td>1</td>
<td>14</td>
<td>4</td>
<td>60</td>
</tr>
<tr>
<td>I-459</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>60</td>
</tr>
</tbody>
</table>

Source: ALDOT

Tour-based approach: %RMSE value of **31.8%**
## Results: Models Performance by Time of Day; Cont’d

### Truck VMT by Time Period; Tour-based Approach and QRFM Approach

<table>
<thead>
<tr>
<th>Vehicle Miles Traveled by Time Period</th>
<th>Percent Difference Between Two Approaches</th>
<th>Nash-Sutcliffe (NS) Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM Truck VMT</td>
<td>42.7%</td>
<td>0.73</td>
</tr>
<tr>
<td>MD Truck VMT</td>
<td>2.8%</td>
<td>0.97</td>
</tr>
<tr>
<td>PM Truck VMT</td>
<td>-29.8%</td>
<td>0.56</td>
</tr>
<tr>
<td>NT Truck VMT</td>
<td>84.5%</td>
<td>-0.85</td>
</tr>
</tbody>
</table>

**Nash-Sutcliffe (NS) Efficiency Coefficient**

\[
E(NS) = 1 - \frac{\sum (y_2 - y_1)^2}{\sum (y_2 - \bar{y}_2)^2}
\]

- \(y_2\): Link-based VMT of tour-based approach
- \(\bar{y}_2\): Average of all VMT of tour-based approach
- \(y_1\): Link-based VMT of QRFM approach.
Conclusions

- Both used socio-economic data
  - tour-based approach used truck GPS data.

- Tour-based approach provides **better results**

- Tour-based larger data collection, processing and development effort

- QRFM approach uses publicly available data

- Accuracy depends on investment
  - Time of day requirements