Mobility interventions to protect supply chain workers during pandemics

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Co-authors: Elanakayon Annalingam, Erik Nevland, Peter Park

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Objectives

**Truck Parking (rest stop) supply**
- Identify long-haul HCV rest stop parking locations
- Classify HCV parking locations
- Estimate total (legal) parking supply

**Connect rest stops with distribution centers**
- Identify major distribution centers (DCs)
- Link observed trips between rest stops and DCs
- Prioritize rest stops for resources during a pandemic
From closed rest areas to drive-thru testing limitations, truck drivers face rough road during coronavirus pandemic

By Mary Wisniewski
Chicago Tribune • Jun 24, 2020 at 2:10 pm
Background

- **Fatigue** is cited as a contributing factor to freight collisions.

- **Hours of Service (HOS) Laws** have been enacted with the intent of reducing driver fatigue.

- **Electronic Logging Device** mandates:
  - The United States began mandating **ELDs** in 2017
  - Canada implemented a similar **ELD** mandate in 2021; enforcement expected in June 2022

Caledon illegal trucking operator hit with $1M fine

By Ryan Rumbolt
Published December 10, 2021 at 5:09 pm
Identify Parking Locations

• **Truck GPS data** for 2014 was used to identify long-haul HCV stop locations:
  • ~27 million stop events
  • ~3.3 million trips in North America

• Rest stops are identified when a vehicle is stopped for 2 hours or longer in the middle of a trip
Parking Activities: Region of Peel
Classification Scheme

Notable Truck Parking Characteristics:

1. **Legality** – is a parking space legal or unauthorized?
2. **Accessibility** – is a parking space open or limited access?
3. **Ownership** – is a parking space publicly or privately owned?
4. **Dedication** – is parking the dedicated function of the location?
5. **Roadside** – is the parking space a roadside?
Classification Scheme

**Authorized Parking Locations**

1. Public Rest Areas and Gas Stations
2. Weigh Stations
3. Open Access HCV Parking
4. Limited Access HCV Parking
5. Authorized Roadside Parking

**Unauthorized Parking Locations**

6. Unauthorized Roadside Parking
7. Unauthorized Highway Ramp Parking
8. Unauthorized Parking on Public Property
9. Unauthorized Parking on Private Property
Locations where trucks park:
- Parcel contains SIC '5541' firm:
  - TRUE: Public Rest Areas and Gas Stations
  - FALSE: Parcel contains weigh station:
    - TRUE: Weigh Stations
    - FALSE:
      - Parcel area (m²) / parcel road length (m):
        - ≤50: Area is zoned to allow truck parking
        - ≥50:
          - Parcel area (m²) / total building footprint area (m²):
            - ≤10: Area is zoned as 'Airport'
            - ≥10:
              - Parcel contains >100m of highway ramp:
                - TRUE: Unauthorized Highway Ramp Parking
                - FALSE:
                  - Parcel contains SIC '42' firm:
                    - TRUE: Open Access HCV Parking
                    - FALSE: Limited Access HCV Parking
                  - FALSE:
                    - Truck parking tickets have been issued in parcel:
                      - TRUE: Unauthorized Parking on Public Property
                      - FALSE:
                        - Unauthorized Parking on Private Property
                        - Legal Roadside Parking
    - FALSE:
      - Parcel area (m²) / parcel road length (m):
        - ≤50:
          - Area is zoned to allow truck parking:
            - TRUE:
              - Land use indicates public ownership:
                - TRUE:
                  - Unauthorized Parking on Public Property
                - FALSE:
                  - Unauthorized Parking on Private Property
              - FALSE:
                - Truck parking tickets have been issued in parcel:
                  - TRUE: Unauthorized Roadside Parking
                  - FALSE:
                    - Unauthorized Roadside Parking
## HCV Parking Supply

![Image Source: Modified from Google (2019)]
Parking Supply – Manual Counting

- Public Rest Areas and Gas Stations
- Open Access HCV Parking
- Limited Access HCV Parking

Number of HCV Parking Spaces Counted

Frequency
# Parking Supply – Model Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Negative Binomial</th>
<th>Zero-Inflated Negative Binomial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td>Intercept</td>
<td>1.49</td>
<td>2.27</td>
</tr>
<tr>
<td>Perimeter&lt;sub&gt;i&lt;/sub&gt;</td>
<td>1.96</td>
<td>2.19</td>
</tr>
<tr>
<td>Rural&lt;sub&gt;i&lt;/sub&gt;</td>
<td>1.48</td>
<td>-0.35</td>
</tr>
<tr>
<td>Perimeter&lt;sub&gt;i&lt;/sub&gt; × Rural&lt;sub&gt;i&lt;/sub&gt;</td>
<td>-2.63</td>
<td>-1.91</td>
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<tr>
<td>Area&lt;sub&gt;paved,i&lt;/sub&gt;</td>
<td>53.04</td>
<td>82.90</td>
</tr>
<tr>
<td>Perimeter&lt;sub&gt;i&lt;/sub&gt; × Area&lt;sub&gt;paved,i&lt;/sub&gt;</td>
<td>-49.46</td>
<td>-49.46</td>
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<tr>
<td>Class&lt;sub&gt;open,i&lt;/sub&gt;</td>
<td>1.02</td>
<td>0.60</td>
</tr>
<tr>
<td>Class&lt;sub&gt;rest,i&lt;/sub&gt;</td>
<td>-0.12</td>
<td>-0.44</td>
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<tr>
<td>IND&lt;sub&gt;59,i&lt;/sub&gt;</td>
<td>-2.13</td>
<td>-2.04</td>
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</table>

### Zero-Inflated Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
<th>Model 6</th>
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</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.14</td>
<td>0.32</td>
<td>0.923</td>
<td>0.11</td>
<td>0.744</td>
<td>0.744</td>
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<tr>
<td>Area&lt;sub&gt;paved,i&lt;/sub&gt;</td>
<td>-163.07</td>
<td>-124.72</td>
<td>0.005</td>
<td>-156.99</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>Perimeter&lt;sub&gt;i&lt;/sub&gt; × Area&lt;sub&gt;paved,i&lt;/sub&gt;</td>
<td>68.40</td>
<td>69.31</td>
<td>37.76</td>
<td>37.76</td>
<td>37.76</td>
<td>37.76</td>
</tr>
</tbody>
</table>

### Data

<table>
<thead>
<tr>
<th>Removed Outliers</th>
<th>3</th>
<th>1</th>
<th>2</th>
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</thead>
<tbody>
<tr>
<td>n</td>
<td>127</td>
<td>129</td>
<td>128</td>
</tr>
<tr>
<td>k</td>
<td>5</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>df</td>
<td>121</td>
<td>123</td>
<td>121</td>
</tr>
</tbody>
</table>

(***), (**), (*) represent statistical significance to 99%, 95%, or 90% respectively
Parking Supply – Model Estimates

<table>
<thead>
<tr>
<th>TAZ</th>
<th>City of Mississauga Estimated Supply</th>
<th>TAZ</th>
<th>City of Brampton Estimated Supply</th>
<th>TAZ</th>
<th>Town of Caledon Estimated Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>736</td>
<td>1</td>
<td>16</td>
<td>1</td>
<td>523</td>
</tr>
<tr>
<td>2</td>
<td>1,242</td>
<td>2</td>
<td>792</td>
<td>2</td>
<td>216</td>
</tr>
<tr>
<td>3</td>
<td>187</td>
<td>3</td>
<td>3,931</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>165</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>7,423</td>
</tr>
<tr>
<td>5</td>
<td>19,588</td>
<td>5</td>
<td>195</td>
<td>5</td>
<td>886</td>
</tr>
<tr>
<td>6</td>
<td>259</td>
<td>6</td>
<td>939</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>90</td>
<td>7</td>
<td>973</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>136</td>
<td>8</td>
<td>10,067</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>449</td>
<td>9</td>
<td>37</td>
<td></td>
<td></td>
</tr>
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<td>10</td>
<td>0</td>
<td>10</td>
<td>645</td>
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</tr>
<tr>
<td>11</td>
<td>1,206</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Total Estimated Supply:
- City of Mississauga: 24,058
- City of Brampton: 17,594
- Town of Caledon: 9,049

Region of Peel Total: 50,701
Prioritization of Rest Stops

• GPS data is used next to identify trips between overnight rest stops and distribution centers (DCs)
GPS Data Statistics

• GPS Data in the Region of Peel
  ➢ obtained from Transport Canada and the Smart Freight Centre

<table>
<thead>
<tr>
<th>Description</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; dataset received</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; dataset received</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Frame</td>
<td>February 1, 2020 to July 31, 2020</td>
<td>January 1, 2019 to Dec 31, 2019</td>
</tr>
<tr>
<td>Raw data file size</td>
<td>109,372,246 data records</td>
<td>50,415,327</td>
</tr>
<tr>
<td>Data fields</td>
<td>Truck ID, date/time, latitude, longitude</td>
<td>Truck ID, date/time, latitude, longitude</td>
</tr>
<tr>
<td>Study Area</td>
<td>Region of Peel</td>
<td>Region of Peel</td>
</tr>
<tr>
<td>Number of unique trucks</td>
<td>117,537</td>
<td>43,736</td>
</tr>
<tr>
<td>(based on power ID)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• Trips identified for trucks:
  ➢ resting overnight for at least 2 hours: 9 pm to 6 am period
  ➢ Traveling to a distribution center (DC) in the morning
## Identifying Distribution Centres (DCs)

<table>
<thead>
<tr>
<th>Source</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>McMaster Institute of Transportation &amp; Logistics report</td>
<td>A list of firms that attract or generated significant freight activity in the Greater Toronto-Hamilton Area.</td>
</tr>
<tr>
<td></td>
<td>(MITL, 2014)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>DMTI Enhanced Points of Interest</td>
<td>Businesses filtered by Standard Industrial Classification (SIC) codes using SIC4225 (i.e., warehouses).</td>
</tr>
<tr>
<td>3</td>
<td>ATRI GPS data</td>
<td>Locations with a high concentration of parking were individually verified.</td>
</tr>
</tbody>
</table>
DC Locations
Optimization

• P-Median used to determine impact of available open/closed rest stops

• Assign closest open rest stop to the DC for each trip

• Travel cost based on AM morning travel times

• Demand based on observed trips to DCs

Minimize $\sum_i \sum_j D_j c_{ij} x_{ij}$

Subject to:

• $\sum_i x_{ij} = 1 \quad \forall j$

• $\sum_i Y_i = p$

• $x_{ij} \leq Y_i \quad \forall i, j$

• $x_{ij} \in \{0,1\} \quad \forall i, j$

• $Y_i \in \{0,1\} \quad \forall i, j$
Trip Rest Stops to DCs

• How does opening more rest areas help change travel time between major freight facilities?

P = 2; Two available rest stops for parking

P = 10; Ten available rest stops for parking
Travel Time Results

<table>
<thead>
<tr>
<th>Cumulative Percentage of trips</th>
<th>Travel Time in Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00%</td>
<td>Travel Time Results</td>
</tr>
<tr>
<td>10.00%</td>
<td></td>
</tr>
<tr>
<td>20.00%</td>
<td></td>
</tr>
<tr>
<td>30.00%</td>
<td></td>
</tr>
<tr>
<td>40.00%</td>
<td></td>
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<td>50.00%</td>
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</tr>
<tr>
<td>90.00%</td>
<td></td>
</tr>
<tr>
<td>100.00%</td>
<td></td>
</tr>
</tbody>
</table>

- 2 Open Rest Areas
- 6 Open Rest Areas
- 10 Open Rest Areas
Conclusions – Next Steps

• Optimization testing is still in progress

• Optimization can benefit from:
  ➢ Expanded data beyond sample values
  ➢ Capacity constraints based on parking supply
  ➢ Substitution patterns with other potential parking locations

• Further research expected on illegal truck parking
Acknowledgements

• NSERC
• Region of Peel
• Transport Canada
• Additional data providers