Quantification of Transit Train Activity Data for Energy Consumption Estimation

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Objective
- For a given rail system, develop an approach to quantify trip-based transit train data for energy consumption estimation.

Introduction
- Fossil fuel energy consumption leads to emissions of criteria pollutants, hazardous air pollutants, greenhouse gases (GHG).
- Energy consumption characteristics for each rail system, route, and passenger trip need to be quantified to identify ways to improve energy efficiency.
- The General Transit Feed Specification is an open source format that allows public transit agencies to provide transportation schedules and geographic information to developers.

Methods
- The method is based on GTFS data and real-time transit tracking.
- Case study for the Washington Metropolitan Area Transit Authority (WMATA) Metrorail system.
- GTFS-Static feed: ✓ Data on stops, routes, trips, and schedules.
- GTFS-Realtime feed: ✓ Real-time train positions were reported every 7 to 10 seconds by WMATA.

- GTFS-Realtime dwell time derived dwell time
  ✓ GTFS-Realtime data were downloaded on randomly selected 17 days in 2016 and 2017.
  ✓ Rush hour: 8:00 a.m. – 10:00 a.m.
  ✓ By extracting occupancy time of the track circuits that represent station stops, dwell times were derived for multiple routes and station stops.
- Bias-corrected based on comparison to field measurements.
- Field measurement:
  ✓ A field trip was made to Washington D.C. during 12/13/2016 to 12/17/2016.
- Multiple rides of each route were taken with GPS receivers.
- One Hz speed trajectory data were collected for above ground segments of the six routes.
- Dwell time data were collected for multiple stops of the six routes for validation purpose.
- Speed trajectory processing

Results
- Example daily number of one-way trips of the blue line on October 12th, 2015: 174

<table>
<thead>
<tr>
<th>Route</th>
<th>One-way travel time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>63</td>
</tr>
<tr>
<td>Blue</td>
<td>64</td>
</tr>
<tr>
<td>Green</td>
<td>47</td>
</tr>
<tr>
<td>Orange</td>
<td>57</td>
</tr>
<tr>
<td>Yellow</td>
<td>36 (non-rush)</td>
</tr>
<tr>
<td>Silver</td>
<td>48 (Huntington - Greenbelt)</td>
</tr>
</tbody>
</table>

Legend
- GTFS stops
- Reference stops
- Green
- Orange
- Red
- Silver
- Yellow

Table 1. Comparison of measured dwell time and GTFS-Realtime derived dwell time.

<table>
<thead>
<tr>
<th>Average (s)</th>
<th>Standard Deviation (s)</th>
<th>Sample size</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>6</td>
<td>120</td>
<td>27 29</td>
</tr>
<tr>
<td>28</td>
<td>9</td>
<td>120</td>
<td>40 49</td>
</tr>
</tbody>
</table>

Table 2. Examples of average speeds. Dwell times were derived from GTFS-Realtime and bias-corrected.

Trip | Distance (mile) | Average speed (mph) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without dwell time</td>
<td>With dwell time</td>
</tr>
<tr>
<td>Federal Triangle – Metro Center</td>
<td>0.31</td>
<td>18.82</td>
</tr>
<tr>
<td>Rosslyn – Arlington Cemetery</td>
<td>0.90</td>
<td>27.10</td>
</tr>
<tr>
<td>Van Dorn St. – Franconia-Springfield</td>
<td>3.10</td>
<td>31.04</td>
</tr>
</tbody>
</table>

Conclusion
- A method combining GTFS data and transit tracking using GPS receivers can be used to collect transit train data for energy estimation on trip basis.
- Validation and adjustment are recommended for GTFS-Realtime data.
- Accurate dwell time is needed to accurately estimate mean speed between stations.
- Speed trajectory collected using GPS receivers needs post-processing.
- The trains typically accelerate to cruising speed, maintain a typical cruising speed, and decelerate in a similar manner for a given segment from one stop to the next.
- Acceleration is related to speed in the WMATA Metrorail system.

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