Building a Framework for Evaluating Reasonableness of CTPP Travel Time Estimates and Margins of Error

presented to
Chicago Area Travel Model User Group

presented by
Cemal Ayvalik
(cayvalik@camsys.com)

April 4, 2018
Outline

• Background
• Motivation
• Study Design
• Data and Analysis
• Preliminary Results
• Conclusions
• Recommendations
Background

- **Census Transportation Planning Products (CTPP)** – Special tabulations of Census data, now ACS
  - Pioneered by AASHTO in partnership with all states to support transportation policy and planning efforts

- **Transportation Tables**
  - Demographic characteristics of home locations
  - Characteristics of work locations
  - Commuting patterns and modal/temporal distributions

- **2006-2010 CTPP features**
  - First CTPP based on 5-year ACS data for small geographic units such as Census Tracts and Traffic Analysis Zones
  - 343 tables for over 200,000 geographies.
2006-2010 CTPP

- Released October 31, 2013
- Reduced sample size
- Spaning over five years
- Data quality for small geographies
  - Need to incorporate uncertainty in the estimates
  - New disclosure proofed data
- Updated data dissemination software
- Extensive training materials and workshops
- Technical support

Person 1 (continued)

- a. LAST WEEK, did this person work for pay at a job or business?
  - Yes » SKIP to question 39
  - No » Did not work or retired
- b. LAST WEEK, did this person do ANY work for pay, even for as little as one hour?
  - Yes
  - No » SKIP to question 35c
- c. Is the work location inside the limits of that city or town?
  - Yes
  - No, outside the city/town limits
- d. Name of county
- e. Name of U.S. state or foreign country
- f. ZIP Code

Answer question 35c » If this person did NOT work last week, otherwise, SKIP to question 35a.

- a. LAST WEEK, was this person on layoff from a job?
  - Yes » SKIP to question 35c
  - No
- b. LAST WEEK, was this person TEMPORARILY absent from a job or business?
  - Yes, on vacation, temporary illness, leaving work early, or other factors » SKIP to question 35c
  - No » SKIP to question 35b
- c. Has this person been informed that he or she will be recalled to work within the next 6 months OR been given a date to return to work?
  - Yes » SKIP to question 37
  - No

During the LAST 4 WEEKS, has this person been ACTIVELY looking for work?

- Yes
- No » SKIP to question 39

...
Assessing the Utility of 2006-2010 CTPP Data

- Develop a list of common and unique applications of CTPP data
- Assess common issues encountered and remedies implemented
- Suggest solutions, including future research and/or resource development
- Inform decision-making for future products
The key considerations included

- Data content
- Geographic delineation
- Multiyear data accumulation
- Margins of error
- Data perturbation
- Data dissemination and training
- Future planning of CTPP data products
Data Content

- Different delineation of workplace data (multiple job holders, more relevant definition of part and full-time)
- More three-way residence and workplace tabulations
- Added-value tabulations such as commute distances
- Concerns with the data quality and timely release
- Unforeseen consequences of scope reduction
  - Smaller CTPP
  - No TAZ or TAD level tabulations
  - Less flexible than before
Margins of Error

• 90 percent – understand the concept, but roughly half use the CTPP data without accounting for those

• Experts use margins of error
  » To evaluate the reasonableness of the estimates qualitatively
  » To decide which geographic level of detail to use

• Guidance on communicating data with margins of error
## Recommendations

### Long-Term Census ACS Improvements
- Second Jobs
- Better Information on cellphone availability
- New modes (ridersourcing) and sub travel modes (access/egress to transit)

### More Multiway SE Tables and Flow Tabulations
- Age, gender
- Employment, occupation, earnings
- School enrollment
- Internet access/use

### Value-Added Enhancements to CTPP
- Supplement with travel distance data,
- Help users access multiple datasets,
- Facilitate data fusion with other sources (such as LODES, NHTS)
Motivation

- Desire to add value to CTPP
- CTPP adds value to standard tabulations
- Understand and deal with MOEs
- MOE is a measure of sampling error not of accuracy
- Users wanted more data and more tables
- Any practical options?
- Can we test this?
Study Design

• Compare part of the CTPP flow data to an external data source
  » Auto travel times (shortest path) via Google Maps

• Synthesize ACS sampling
  » Two-step probability-proportional-to-size sampling (PPS)
  » Collect data at a higher rate for a sample of tract pairs
Study Design

Develop and Test Sample Hypotheses

1. CTPP Mean Travel Times are Equivalent to Google Estimates by Strata
2. Accuracy of Mean Travel Times is Independent of MOE (Sampling Error)
3. Accuracy of Mean Travel Times is Independent of the Strata
4. CTPP and Google MOE are Equivalent across the Strata
Data Development and Analysis
Data Development

- Study Area: Part of the Detroit Metropolitan Area
  - Population\(^1\): 4.23 M
  - Employment\(^2\): 1.95 M
  - 2006 – 2010 CTPP: 1.75 M
  - Flows among 82,452 tract pairs

1. 2016 Census Bureau Population Estimates
2. 2016 Quarterly Census of Employment and Wages
Data Development

CTPP Sample – Stratified selection of a set of tract pairs

Synthesize Commutes – A set of probable O-D pairs for each of the selected tract pairs
Data Development – CTPP Sample

- Download CTPP Tables
  - A112100; A110106; A202100; B306201; B302106

- Stratified sample to allow testing effects of select characteristics
  - **TRACT SIZE** – Place of Residence
  - **WORKER DENSITY** – Workplace
  - **AERIAL DISTANCE**

- 10% MOE with 90% confidence (n=70)
Data Development – CTPP Sample

- Probability-Proportional-to-Size Sampling
  » \( P(\text{selection}) = f(\text{size}) \)
  » 45 strata with 70 pairs w/o replacement
  » Used worker flows as the size variable
  » 3,150 O-D pairs were selected
Data Development – Test Sample

• Build point level O-D locations
  » SEMCOG’s Building Footprints
  » Establishment locations (Info USA)

• PPS with replacement to select
  » HHs from sampled residence (RES) tracts
  » Establishments from sampled Place of Work (POW) tracts

• For each sampled tract pair, randomly match RES and POW points.

• 137,100 O-Ds in the test sample pool.
Data Development – Test Sample

- A custom built Google Maps API
  - Lat/Lon pairs to highway travel times
  - Collects “Directions” data at desired times and frequency

- Data collected
  - One-month period (Late August and early October) Mondays thru Thursdays
  - 7:00 AM to 8:30 AM @30-min intervals

- Test sample of 11,235 O-D pairs to scale to CTPP sample
Analysis Approach

Differences in Mean Travel Time Estimates and Sampling Errors
- Analysis of Variance (ANOVA)

Differences in Travel Time Bin Distributions
- Cochran-Mantel-Haenszel (CMH) Statistics

CTPP Sampling Error and Accuracy Relationship
- Correlation Analysis
Preliminary Results
H1A: Mean Travel Times

- CTPP vs. Google Maps (Main Effect)
  » 26.3 vs. 23.7 Minutes
  » Small but significant (N>3,000)

- Differences Across the Strata (Interactions)
  » Minor differences in Tract Size and Worker Density
  » Greater variance across Distance categories
Minor variations across **Tract Size** and **Worker Density** categories, greater variations in **Distance** factor.
H1B: Travel Time Distributions

- CTPP & Google times statistically different by Distance
- CTPP data show “more noise” in reported travel times
- Google has higher share of shorter trips
Impact of noise in CTPP data on travel time estimates for long distance commutes.
H2: Accuracy vs. Sampling Error

**Relative Error**

\[
\frac{\text{ABS}(\text{EST}_{CTPP} - \text{EST}_{GOOGLE})}{\text{EST}_{GOOGLE}} \times 100
\]

**Sampling Error (Relative SE)**

\[
\frac{\text{SE}_{CTPP}}{\text{EST}_{CTPP}} \times 100
\]
# H2: Accuracy vs. Sampling Error

## Relative Error

\[
\frac{\text{ABS}(EST_{CTPP} - EST_{GOOGLE})}{EST_{GOOGLE}} \times 100
\]

## Sampling Error (Relative SE)

\[
\frac{SE_{CTPP}}{EST_{CTPP}} \times 100
\]

<table>
<thead>
<tr>
<th>Relative Error</th>
<th>Less than 10 Percent</th>
<th>10 to 15 Percent</th>
<th>15 to 25 Percent</th>
<th>25 to 50 Percent</th>
<th>50 to 75 Percent</th>
<th>75 to 100 Percent</th>
<th>1 to 1.5 Times</th>
<th>1.5 to 2 Times</th>
<th>2 Times or More</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 10 Percent</td>
<td>23</td>
<td>50</td>
<td>94</td>
<td>323</td>
<td>101</td>
<td>44</td>
<td>23</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>10 to 15 Percent</td>
<td>13</td>
<td>25</td>
<td>39</td>
<td>146</td>
<td>58</td>
<td>22</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 to 25 Percent</td>
<td>22</td>
<td>33</td>
<td>66</td>
<td>288</td>
<td>82</td>
<td>40</td>
<td>31</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>25 to 50 Percent</td>
<td>14</td>
<td>36</td>
<td>87</td>
<td>359</td>
<td>129</td>
<td>90</td>
<td>42</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>50 to 75 Percent</td>
<td>5</td>
<td>14</td>
<td>41</td>
<td>166</td>
<td>61</td>
<td>42</td>
<td>22</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>75 to 100 Percent</td>
<td>2</td>
<td>4</td>
<td>12</td>
<td>72</td>
<td>26</td>
<td>31</td>
<td>14</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1 to 1.5 Times</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>14</td>
<td>56</td>
</tr>
<tr>
<td>1.5 to 2 Times</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>31</td>
<td>12</td>
<td>14</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 to 3 Times</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>26</td>
<td>11</td>
<td>10</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>3 to 5 Times</td>
<td>2</td>
<td>5</td>
<td>24</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Times or More</td>
<td>1</td>
<td>5</td>
<td>23</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
H2: Accuracy vs. Sampling Error

Correlation = 0.133

95% CI = (0.096 – 0.169)

<table>
<thead>
<tr>
<th>FACTOR LEVELS</th>
<th>SIZE</th>
<th>WORKER DENSITY</th>
<th>AERIAL DISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
<td>0.127</td>
<td>0.108</td>
<td>0.070</td>
</tr>
<tr>
<td>LOW MID</td>
<td></td>
<td></td>
<td>0.255</td>
</tr>
<tr>
<td>MID</td>
<td>0.128</td>
<td>0.136</td>
<td>0.199</td>
</tr>
<tr>
<td>MID HIGH</td>
<td></td>
<td></td>
<td>0.167</td>
</tr>
<tr>
<td>HIGH</td>
<td>0.148</td>
<td>0.178</td>
<td>0.141</td>
</tr>
</tbody>
</table>
H3: Relative Errors by Strata (Accuracy)

- Test differences in mean travel time by strata
- Flows with higher levels of error:
  - Smaller residential tracts
  - Mid level worker density tracts
  - Shorter distance commutes
H4: MOE by Strata (Sampling Errors)

• Compared sampling errors in CTPP vs. Google
  » Google SEs are much lower

• CTPP errors are similar across strata

• Google errors did not vary across Tract Size and Worker Density categories

• Google errors were inversely related to distance
  » 10 percent for “6 Miles or Less”
  » 2 Percent for “25 Miles or More”
Conclusions

• A first step: Comparing CTPP to an external source
  » Synthetic approach to pair point-level O-D
  » Examine differences across market segments

• CTPP and Google mean travel times similar at the regional level
  » Differences for short and long distance commutes
  » CTPP showed greater noise in travel time distributions

• Little correlations between sampling error and accuracy

• Early comparisons of sampling errors between CTPP & Google

• Promise of data fusion with traditional data sources
Recommendations

Procedural Improvements
- Better ACS process synthesis in sample building
- Access/egress consideration
- Test new factors

Added Value
- Quality Control
- Additional data for users
- Validation of published SEs

Research
- Impute demographics to add more dimensions to CTPP
- Add travel time and demographics to LEHD
New CTPP is Coming

2012 - 2016 CTPP in early 2019

Web: http://ctpp.transportation.org

Listserv: http://www.chrispy.net/mailman/listinfo/ctpp-news

Technical Support: CTPPSupport@camsys.com

Small Geography Policy Change: http://ctpp.transportation.org/Pages/Policy-Change-on-Small-Geography.aspx
Q: Accuracy vs. Sampling Error

Low correlations between accuracy and MOEs imply presence of both good estimates with large MOEs and poor estimates with low MOEs.

A cursory analysis on the right shows a relatively favorable picture for the good estimates with large MOEs (805 vs. 517 tract pairs) for the data used in the study.

Relative Error

$$\frac{ABS(EST_{CTPP} - EST_{GOOGLE})}{EST_{GOOGLE}} \times 100$$

<table>
<thead>
<tr>
<th>Relative Error</th>
<th>Less than 10 Percent</th>
<th>10 to 15 Percent</th>
<th>15 to 25 Percent</th>
<th>25 to 50 Percent</th>
<th>50 to 75 Percent</th>
<th>75 to 100 Percent</th>
<th>1 to 1.5 Times</th>
<th>1.5 to 2 Times</th>
<th>2 Times or More</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 10 Percent</td>
<td>23</td>
<td>50</td>
<td>94</td>
<td>323</td>
<td>101</td>
<td>44</td>
<td>23</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>10 to 15 Percent</td>
<td>13</td>
<td>25</td>
<td>39</td>
<td>146</td>
<td>58</td>
<td>22</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 to 25 Percent</td>
<td>22</td>
<td>33</td>
<td>66</td>
<td>288</td>
<td>82</td>
<td>40</td>
<td>31</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>25 to 50 Percent</td>
<td>14</td>
<td>36</td>
<td>87</td>
<td>359</td>
<td>129</td>
<td>90</td>
<td>42</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>50 to 75 Percent</td>
<td>5</td>
<td>14</td>
<td>41</td>
<td>166</td>
<td>61</td>
<td>42</td>
<td>22</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>75 to 100 Percent</td>
<td>2</td>
<td>4</td>
<td>12</td>
<td>72</td>
<td>26</td>
<td>31</td>
<td>14</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1 to 1.5 Times</td>
<td>3</td>
<td>14</td>
<td>56</td>
<td>10</td>
<td>29</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5 to 2 Times</td>
<td>2</td>
<td>5</td>
<td>14</td>
<td>31</td>
<td>12</td>
<td>14</td>
<td></td>
<td>338</td>
<td></td>
</tr>
<tr>
<td>2 to 3 Times</td>
<td></td>
<td>4</td>
<td>26</td>
<td>11</td>
<td>10</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 to 5 Times</td>
<td></td>
<td></td>
<td>4</td>
<td>26</td>
<td>11</td>
<td>10</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Times or More</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>5</td>
<td>23</td>
</tr>
</tbody>
</table>

Sampling Error (Relative SE)

$$\frac{SE_{CTPP}}{EST_{CTPP}} \times 100$$