Presentation Overview

- Objective
- Research Design
- Data Filtering
- Travel Time Reliability Results
- Multimodal Comparison
- Conclusions & Further Research
Objective
Why analyze travel times?

- MAP-21, FAST Act – nationwide push for efficiency and reliability
- Previous travel time collection methods are costly per datum
  Ex. License plate match, probe vehicles, remote sensor & radar
- Bluetooth provides continuous data at a low cost-per-datum rate
Objectives

- Evaluate the travel time performance of Los Osos Valley Road as a case study of Bluetooth-collected data
- Establish a reliable framework for processing of automated travel time data collection on arterials
- Compare multimodal reliability
Research Design
Study Overview

Los Osos Valley Road
- Arterial
- 2-6 lanes
- STAA Truck Route
- Pedestrian Facilities
- Class II Bike Lanes
- SLO Transit Routes 4 & 5

Construction
- Higuera-Calle Joaquin
- 2 Lanes
- Entirety of Study
Study Area

Land Uses
- Los Osos to North
- Residential
- Public Facilities
- Commercial
  - Retail
  - Community
  - Service

Future Development
- San Luis Ranch
- Froom Ranch
- Avila Ranch
- Prado Road Interchange

Source: City of San Luis Obispo
Data Collection

Bluetooth Data
- BlueMAC Devices
- January – February 2016
- Detection strength of personal devices at BlueMAC, trip start and end times between two BlueMAC’s

SLO Transit
- Bishop’s Peak Technology
- 2/22/16 – 3/8/16
- Vehicle ID, Route ID, latitude, longitude, speed, minutes late, time
Bluetooth Sensitivity

- Strength produces probable detection range
- Can take up to 10 seconds for a Bluetooth device to pair

Source: Libelium
Bluetooth Detection

- Match Media Access Control (MAC)
- Calculate travel time from device to device
BlueMAC Data

January – February 2016
- 60 total days
- 3.22 miles

5 BlueMAC Devices
- At Foothill, Laguna, Madonna, Calle Joaquin, and Higuera
- Over 153,000 raw matches
- ~5.7% of all trips

22% of days had missing data
- Low battery
- Weak signal
- Unknown causes
Bluetooth Sensitivity Check

- Do vehicles stay within the detection range for 10 seconds?
- Do vehicles stop at the gas station before continuing on the road?
- What if there are multiple devices in one car?
- What if a bicycle or pedestrian is detected?

Class I Device
300’ Minimum Radius
Data Filtering
Raw Data

### Observed Travel Times (s) from CP05 to CP02

<table>
<thead>
<tr>
<th>Total Trips</th>
<th>Mean (Min:Sec)</th>
<th>Median (Min:Sec)</th>
<th>Std. Deviation</th>
<th>15th Percentile (Min:Sec)</th>
<th>85th Percentile (Min:Sec)</th>
<th>95th Percentile (Min:Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1828</td>
<td>505.4 (8:25)</td>
<td>157 (2:37)</td>
<td>698.3</td>
<td>85 (1:25)</td>
<td>1240 (20:40)</td>
<td>2247 (37:27)</td>
</tr>
</tbody>
</table>

![Graph showing travel times from CP05 to CP02 for specific days and times.](image)
Raw Data
Raw Data

Raw Data Travel Time Distributions - Northbound
Raw Data

![Graph showing travel time distributions for different routes.](image-url)
Raw Data

Maximum Error Check

- 95% Confidence
- Standard Deviation and Sample Size by:
  - Segment
  - Direction
  - Peak Period

\[ E = Z_{\alpha/2} \times \frac{\sigma}{\sqrt{n}} \]
\[ \pm 2 \text{ to } 4 \text{ mph} \]

<table>
<thead>
<tr>
<th>Segment</th>
<th>Direction</th>
<th>Error (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AM</td>
</tr>
<tr>
<td>Calle Joaquin-Higuera</td>
<td>Northbound</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Southbound</td>
<td>0.26</td>
</tr>
<tr>
<td>Madonna-Calle Joaquin</td>
<td>Northbound</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>Southbound</td>
<td>0.62</td>
</tr>
<tr>
<td>Laguna-Madonna</td>
<td>Northbound</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>Southbound</td>
<td>0.37</td>
</tr>
<tr>
<td>Foothill-Laguna</td>
<td>Northbound</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>Southbound</td>
<td>0.43</td>
</tr>
<tr>
<td>Weighted Error</td>
<td></td>
<td><strong>0.48 mph</strong></td>
</tr>
</tbody>
</table>
Raw Data

- 0.85 mile
- 51 min trip?
- Pass-by or pedestrian?
- Need for data processing
Median Method

Median Filter
- Basis in Q1 and Q3 cut-offs in prior studies
- Some value at or above Q3 may still be valid
- Below Q1 should not be eliminated for arterials
- Instead, eliminate data points above 2*(Median)

Inner Fence Outliers

Sorted by:
- Segment
- Direction
- Peak Period [AM, MID, PM]

Source: Li, Chai, & Tang, 2013. Removal of speeds below the first quartile and above the third quartile.
Median Method
Median Method

Error Check
- Down from 0.48 mph for Raw to 0.36 mph
- All individual errors are lower than Raw

\[ E = Z_{\alpha/2} \times \frac{\sigma}{\sqrt{n}} \]

\[ \pm 2 \text{ to } 4 \text{ mph} \]

<table>
<thead>
<tr>
<th>Segment</th>
<th>Direction</th>
<th>AM</th>
<th>MID</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calle Joaquin-Higuera</td>
<td>Northbound</td>
<td>0.40</td>
<td>0.29</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>Southbound</td>
<td>0.24</td>
<td>0.28</td>
<td>0.32</td>
</tr>
<tr>
<td>Madonna-Calle Joaquin</td>
<td>Northbound</td>
<td>0.49</td>
<td>0.48</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>Southbound</td>
<td>0.52</td>
<td>0.60</td>
<td>0.65</td>
</tr>
<tr>
<td>Laguna-Madonna</td>
<td>Northbound</td>
<td>0.47</td>
<td>0.41</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>Southbound</td>
<td>0.34</td>
<td>0.39</td>
<td>0.37</td>
</tr>
<tr>
<td>Foothill-Laguna</td>
<td>Northbound</td>
<td>0.32</td>
<td>0.25</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>Southbound</td>
<td>0.31</td>
<td>0.30</td>
<td>0.33</td>
</tr>
<tr>
<td>Weighted Error</td>
<td></td>
<td>0.36</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Median Method

- Unrealistic data removed
- Realistic data appears to be maintained
Results
Travel Time Reliability

For each segment and direction:

- Free flow travel time
  City of San Luis Obispo’s Speed Surveys
- Average travel time
- 95th percentile travel time

\[
Planning Time Index = \frac{95th\ Percentile\ Travel\ Time\ (min)}{Free\ Flow\ Travel\ Time\ (min)}
\]

\[
Buffer\ Time\ (min) = 95th\ Percentile\ Travel\ Time\ (min) - Average\ Travel\ Time\ (min)
\]

\[
Buffer\ Index = \frac{95th\ Percentile\ Travel\ Time\ (min) - Average\ Travel\ Time\ (min)}{Average\ Travel\ Time\ (min)}
\]

\[
Coefficient\ of\ Variation = \frac{Standard\ Deviation\ of\ Travel\ Time\ (min)}{Average\ Travel\ Time\ (min)}
\]

Northbound

Higuera – Calle Joaquin

- 0.52 miles
- 2 Lanes
- Construction
- 1.25-1.49 minute most often
- 7.93 minute maximum
Northbound

Calle Joaquin – Madonna

- 0.85 miles
- 4-6 Lanes
- 1.25-1.49 minute most often
- 3.97 minute maximum
Northbound

Madonna – Laguna
- 0.50 miles
- 4 Lanes
- 0.75-0.99 minute most often
- 2.93 minute maximum
Northbound

Laguna – Foothill
- 1.35 miles
- 2-4 Lanes
- 1.50-1.74 minute most often
- 2.80 minute maximum
Los Osos Valley Road

Coefficient of Variation Comparison

Peak Period and Direction

- AM NB
- AM SB
- MID NB
- MID SB
- PM NB
- PM SB

- Higuera-Calle Joaquin
- Calle Joaquin-Madonna
- Madonna-Laguna
- Laguna-Foothill
Multimodal
Transit Reliability Comparison

Routes 4 & 5

- ½ hour headways
- Enter and exit on Foothill and Madonna
- Loop at Auto Park Way and Prefumo/Descanso
- Route 4: 46% late in PM
- Route 5: 66% late in PM

Comparison of Madonna – Laguna
Transit Reliability Comparison

Routes 4 & 5

- ½ hour headways
- Enter and exit on Foothill and Madonna
- Loop at Auto Park Way and Prefumo/Descanso
- Route 4: 46% late in PM
- Route 5: 66% late in PM

Comparison of Madonna – Laguna:

Transit trips deviate by 2-3 minutes more than auto trips
Transit Reliability Comparison

Coefficient of Variation

- Compared to average trip time for segment?
- Higher variation, less reliable
- Transit performs slightly worse, but comparably to automobile reliability
Conclusions
Research Limitations

Bluetooth
- Multiple devices in a vehicle
- Is filtering too aggressive or not aggressive enough?
- Poor origin-destination data

Collisions, Incidents, and Special Events
- January-February 2016 not available at time of analysis
- Would these have explained longer travel times?

Transit GPS Data
- Would be more useful with ridership
- Post-construction transit reliability and more of the route
- What’s the value of time for riding transit v. driving?
Further Research

*Bluetooth Data Collection in San Luis Obispo*
- Post-construction travel time reliability
- Network-wide analysis for prioritization of corridor improvements
- Reliability as a performance measure or development impact

*Data Filtering*
- Methods should be tested on other roadways

*Transit Comparison*
- Transit priority based on ridership, more people’s time?
Acknowledgments

Guidance & Sanity Checks
Dr. Robert Bertini
Dr. Anurag Pande
Dr. Kimberley Mastako

Data Providers
BlueMACs: Digiwest & Cal Poly College of Engineering
Installation: City of San Luis Obispo
Transit Data: Bishop’s Peak Technology

Support & Encouragement
Transportation Cohort
Friends & Family
Thank You
Questions?