Examining Bluetooth Travel Time Data: Multimodal Implications in San Luis Obispo

2016 Western District Annual Meeting

Albuquerque, New Mexico

July 11, 2016

Krista Purser

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

Source: Chris Evans, Chronicle

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

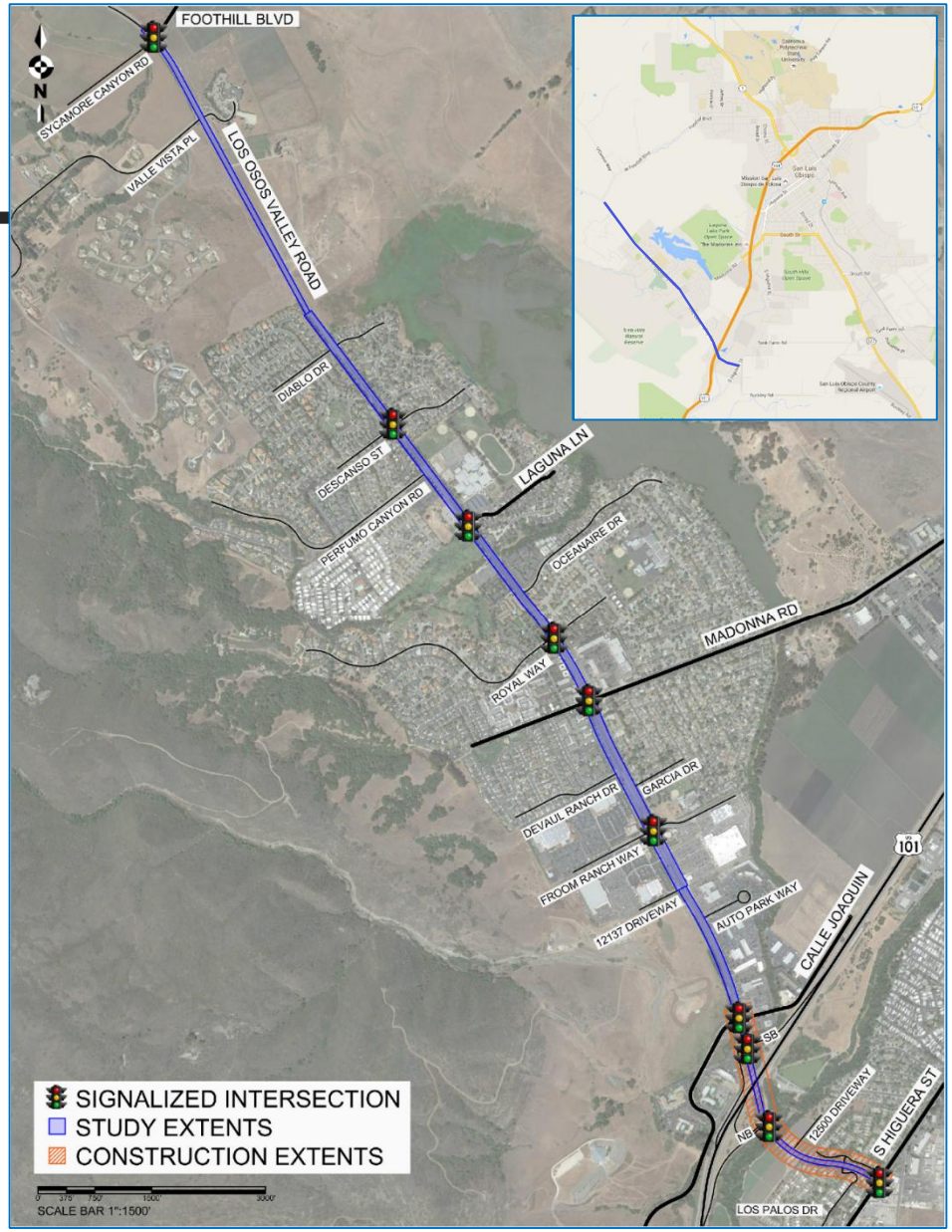
Study Overview

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



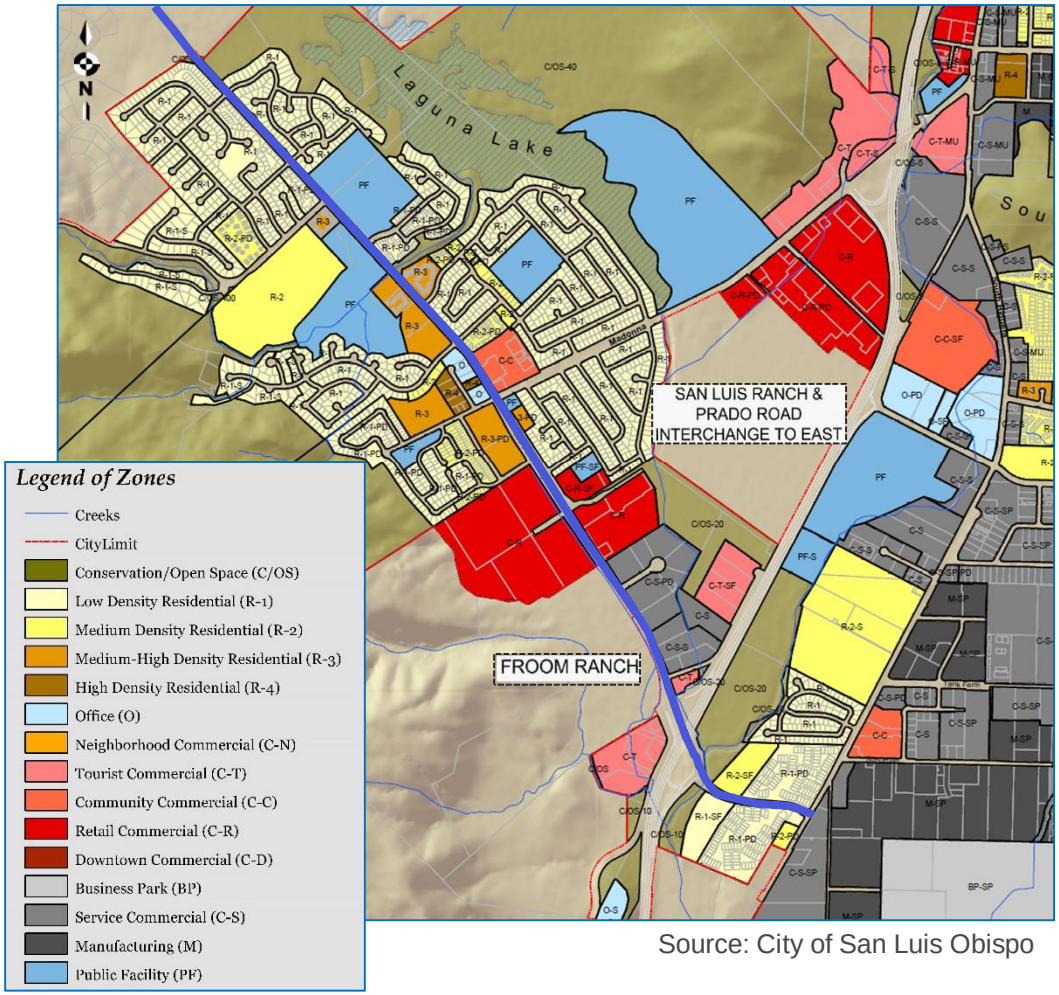
Study Area

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

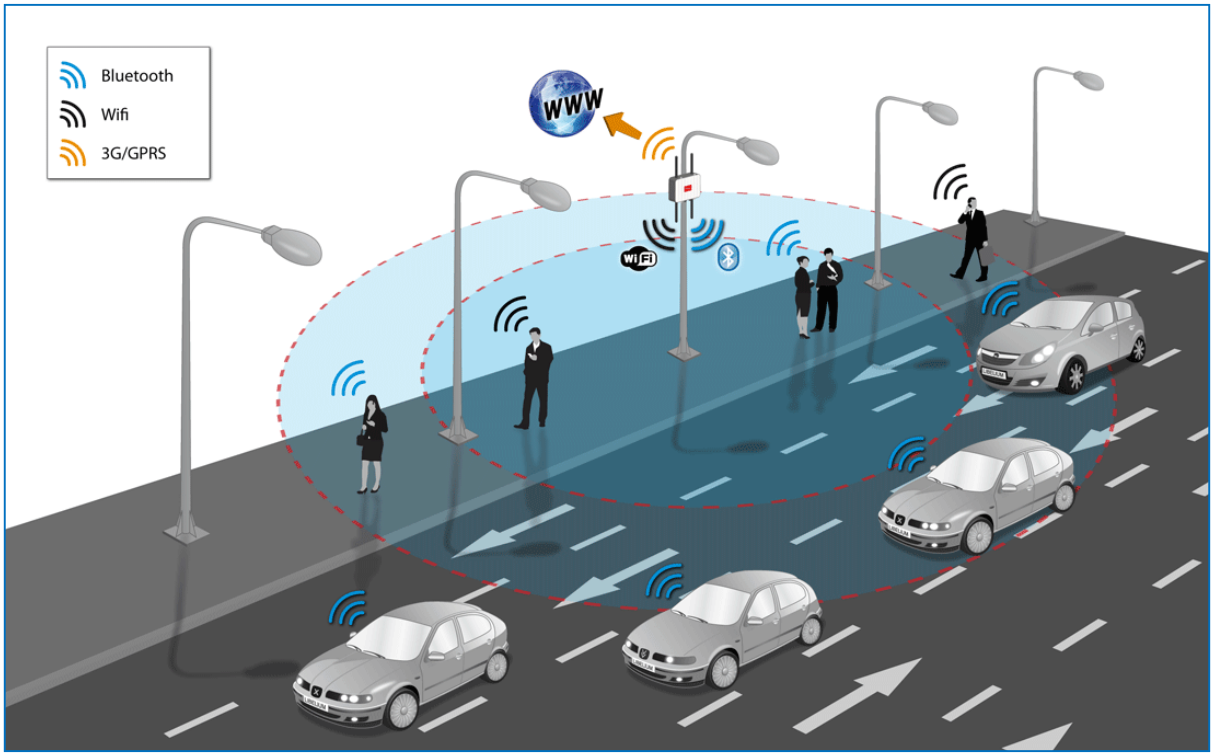
- BlueMAC Devices
- January – February 2016
- Detection strength of personal devices at BlueMAC, trip start and end times between two BlueMAC's

SLO Transit

- Bishop's Peak Technology
- 2/22/16 – 3/8/16
- Vehicle ID, Route ID, latitude, longitude, speed, minutes late, time

Bluetooth Sensitivity

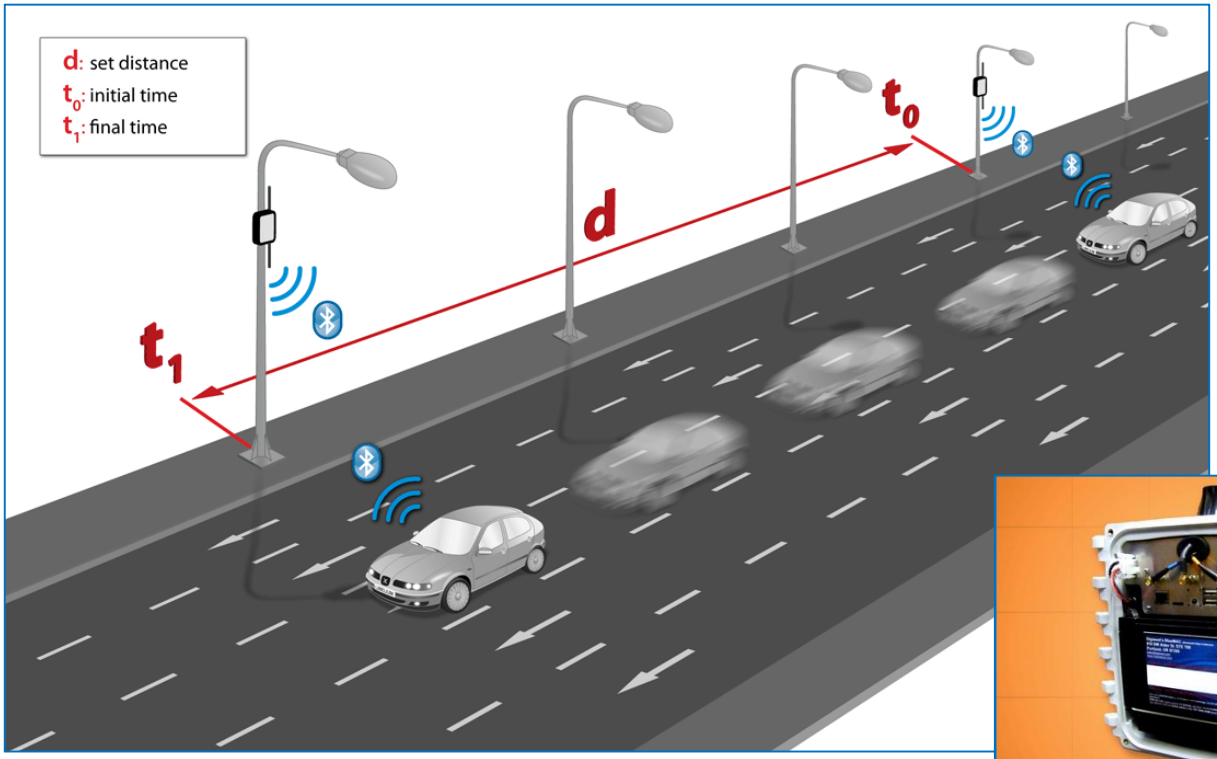
- Strength produces probable detection range
- Can take up to 10 seconds for a Bluetooth device to pair



Source: Libelium

Bluetooth Detection

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



Source: Libelium

Source: Digiwest

BlueMAC Data

January – February 2016

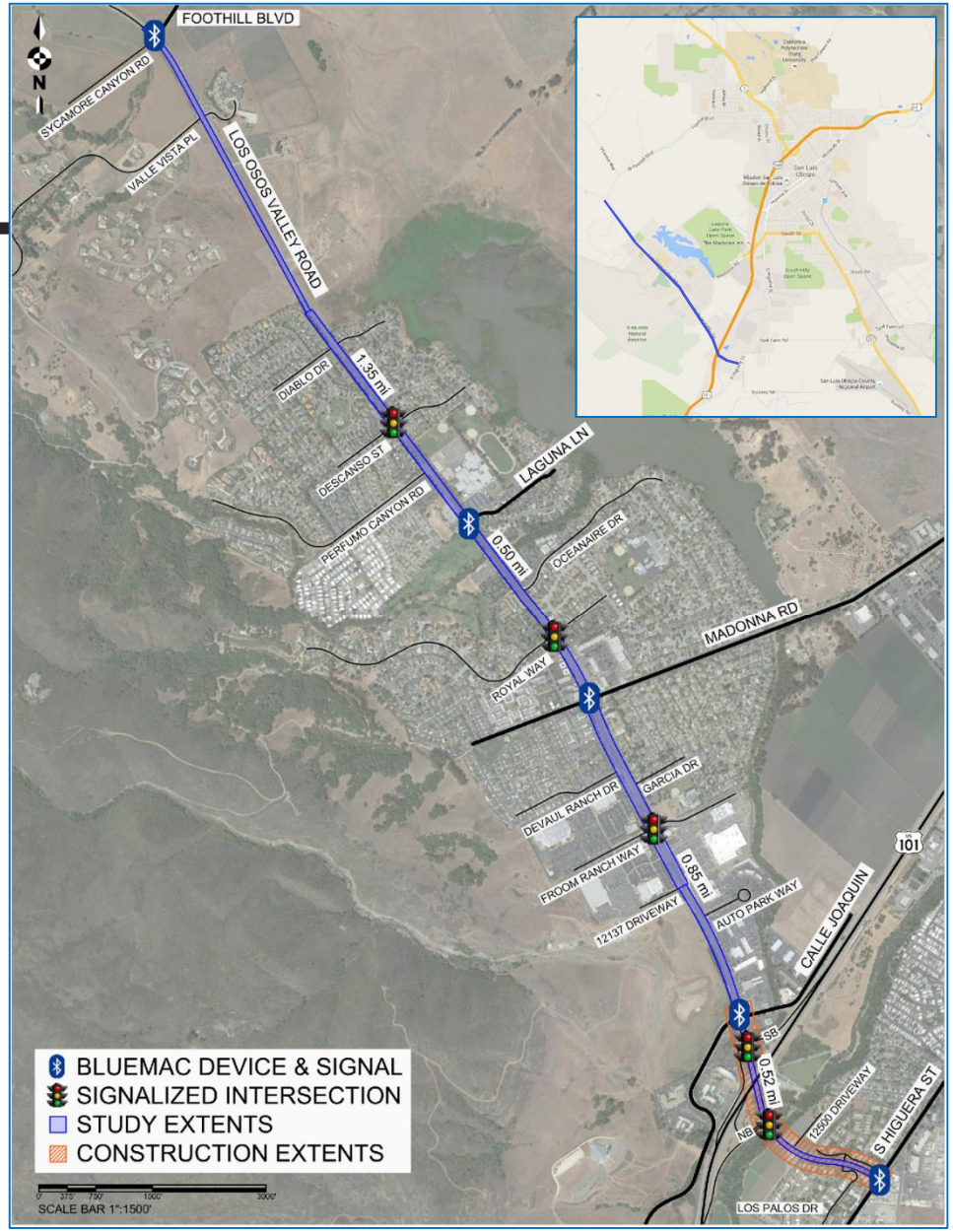
- 60 total days
- 3.22 miles

5 BlueMAC Devices

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

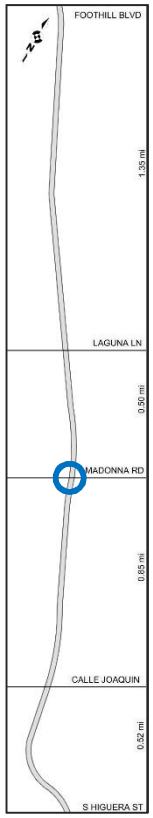
22% of days had missing data

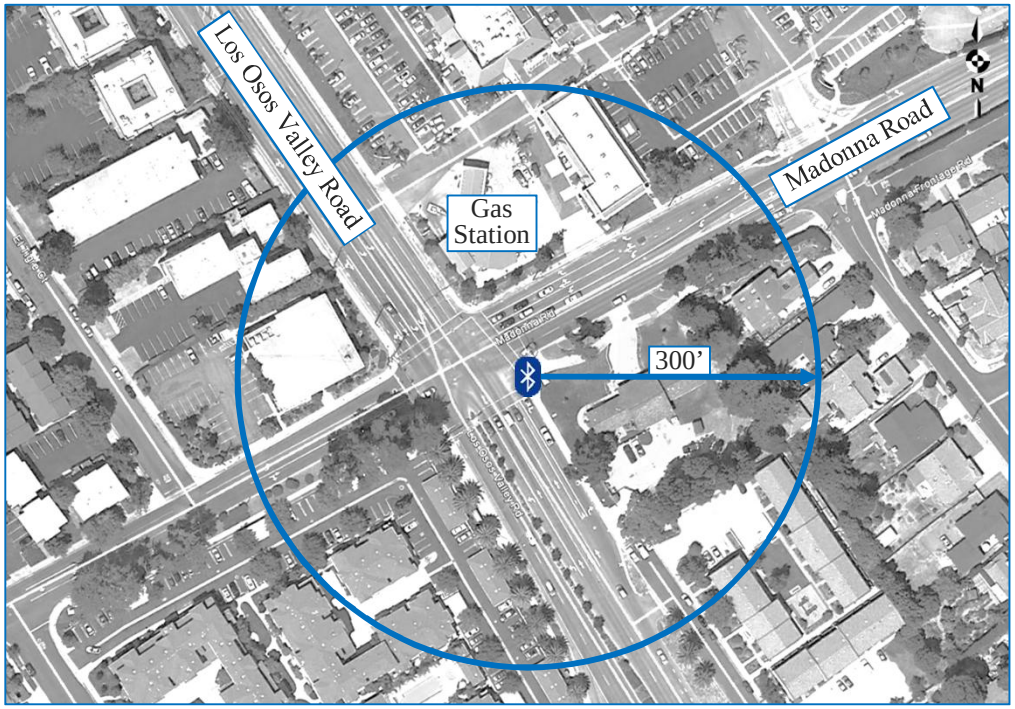
- *Low battery*
- *Weak signal*
- *Unknown causes*



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?

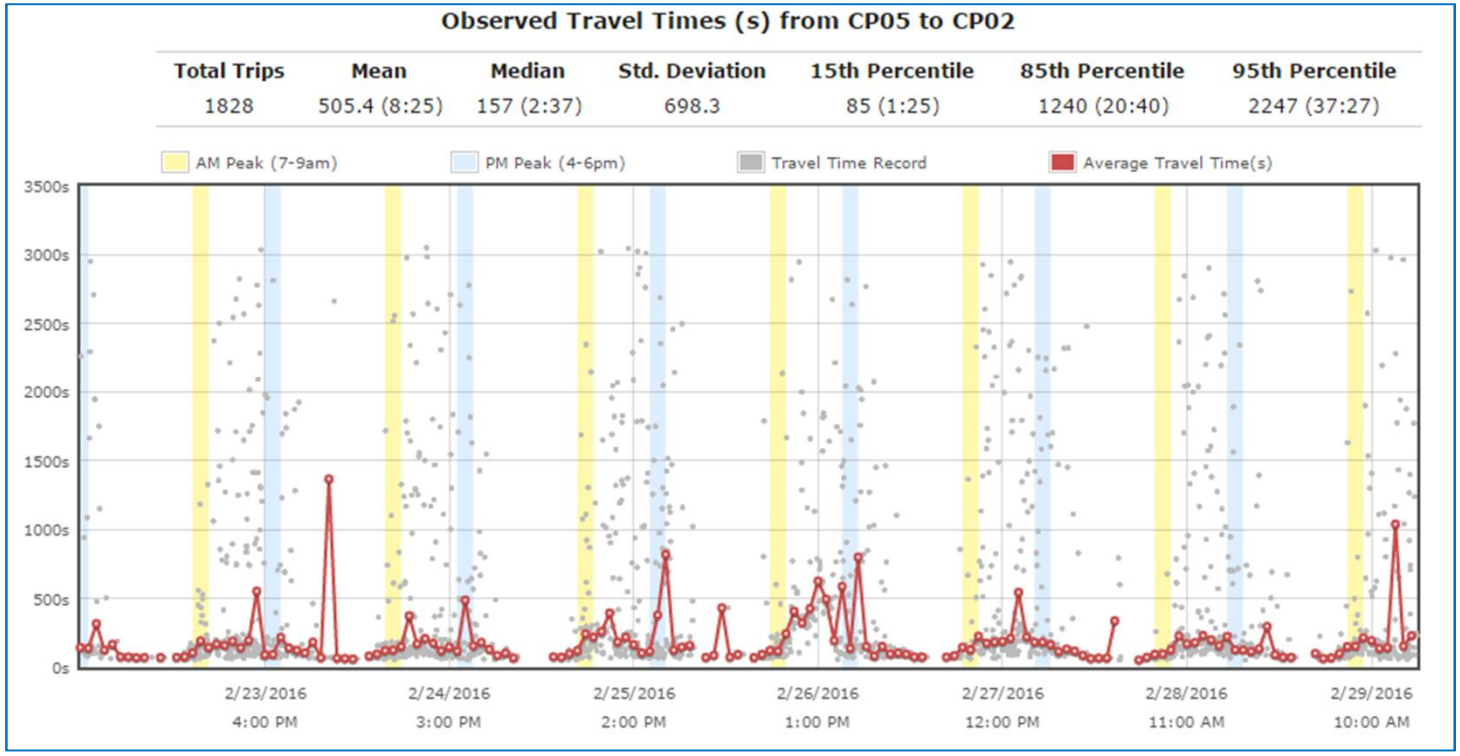




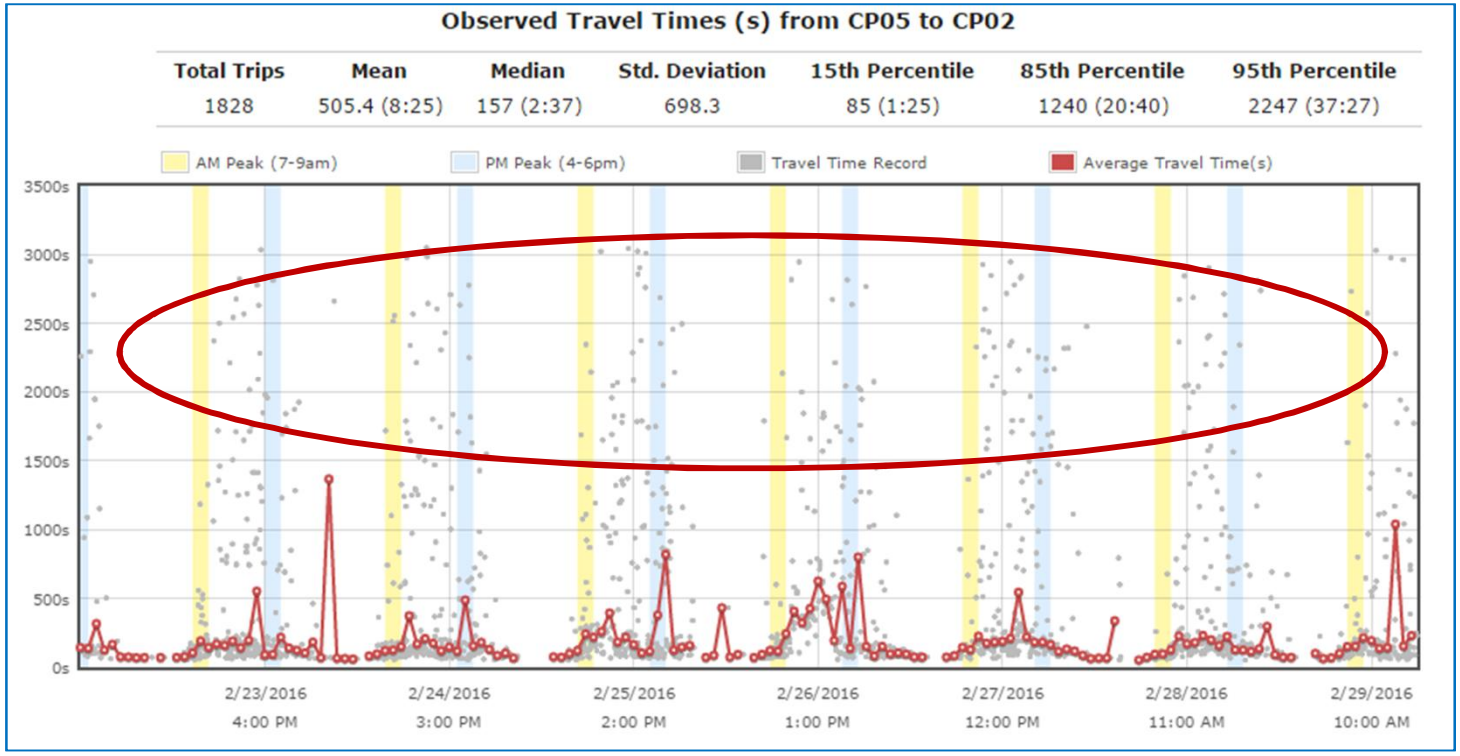
Class I Device
300' Minimum Radius

Data Filtering

Raw Data


Observed Travel Times (s) from CP05 to CP02
Total Trips
1828
Mean
505.4 (8:25)
Median
157 (2:37)
Std. Deviation
698.3
15th Percentile
85 (1:25)
85th Percentile
1240 (20:40)
95th Percentile
2247 (37:27)
AM Peak (7-9am)
PM Peak (4-6pm)
Travel Time Record
Average Travel Time(s)
3500s
3000s
2500s
2000s
1500s
1000s
500s
0s
2/23/2016 4:00 PM
2/24/2016 3:00 PM
2/25/2016 2:00 PM
2/26/2016 1:00 PM
2/27/2016 12:00 PM
2/28/2016 11:00 AM
2/29/2016 10:00 AM

Raw Data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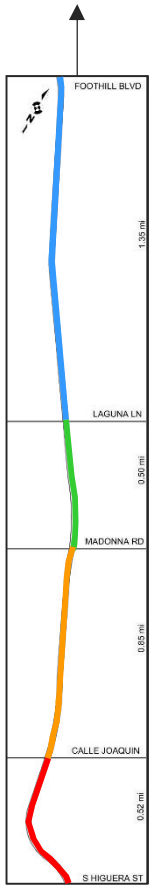
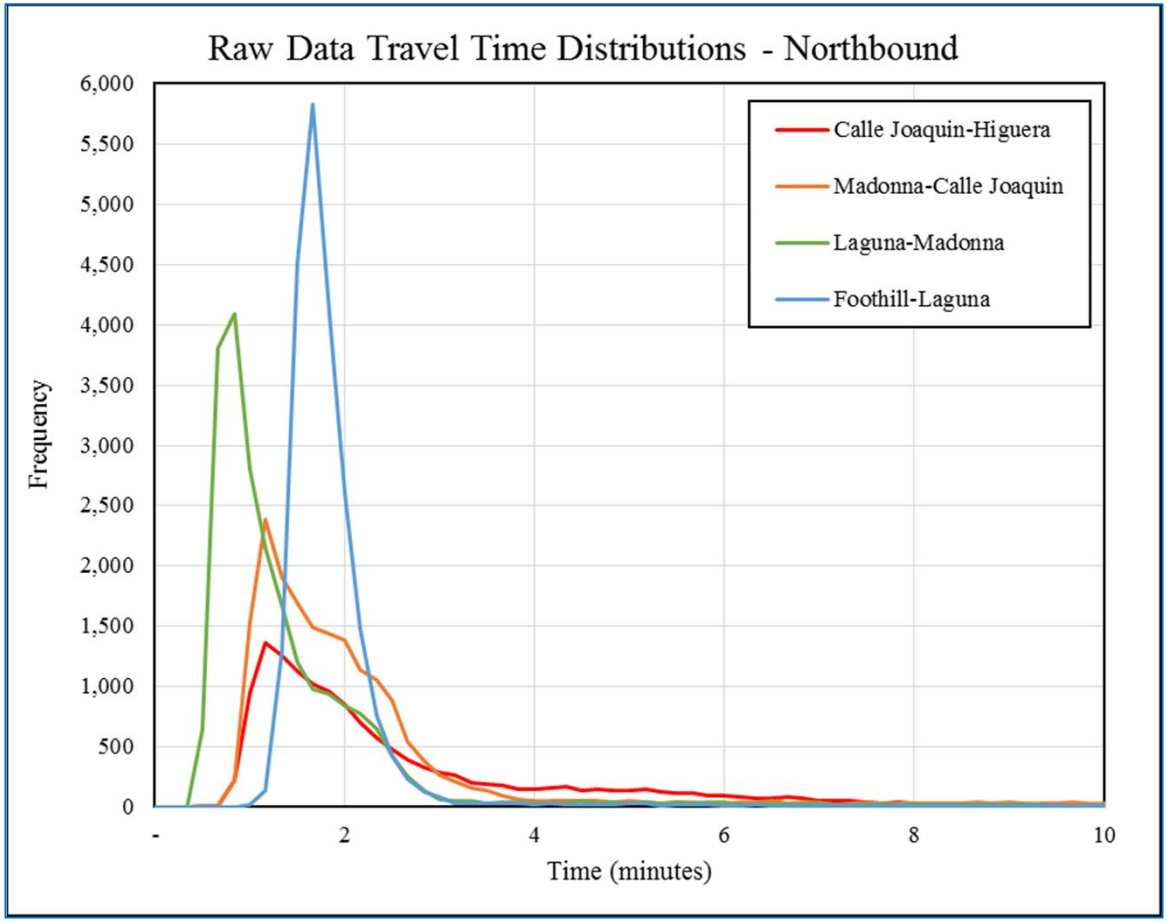
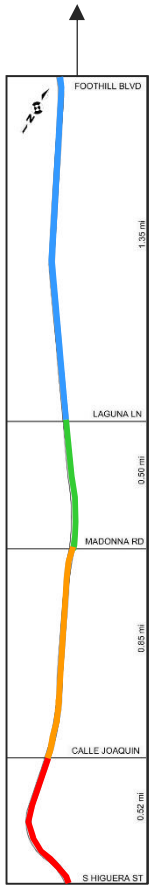

FOOTHILL BLVD
1.35 mi
LAGUNA LN
0.50 mi
MADONNA RD
0.65 mi
CALLE JOAQUIN
0.52 mi
S HIGUERA ST


Raw Data Travel Time Distributions - Northbound
Frequency
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
-
2
4
6
8
10
Time (minutes)
Calle Joaquin-Higuera
Madonna-Calle Joaquin
Laguna-Madonna
Foothill-Laguna

Raw Data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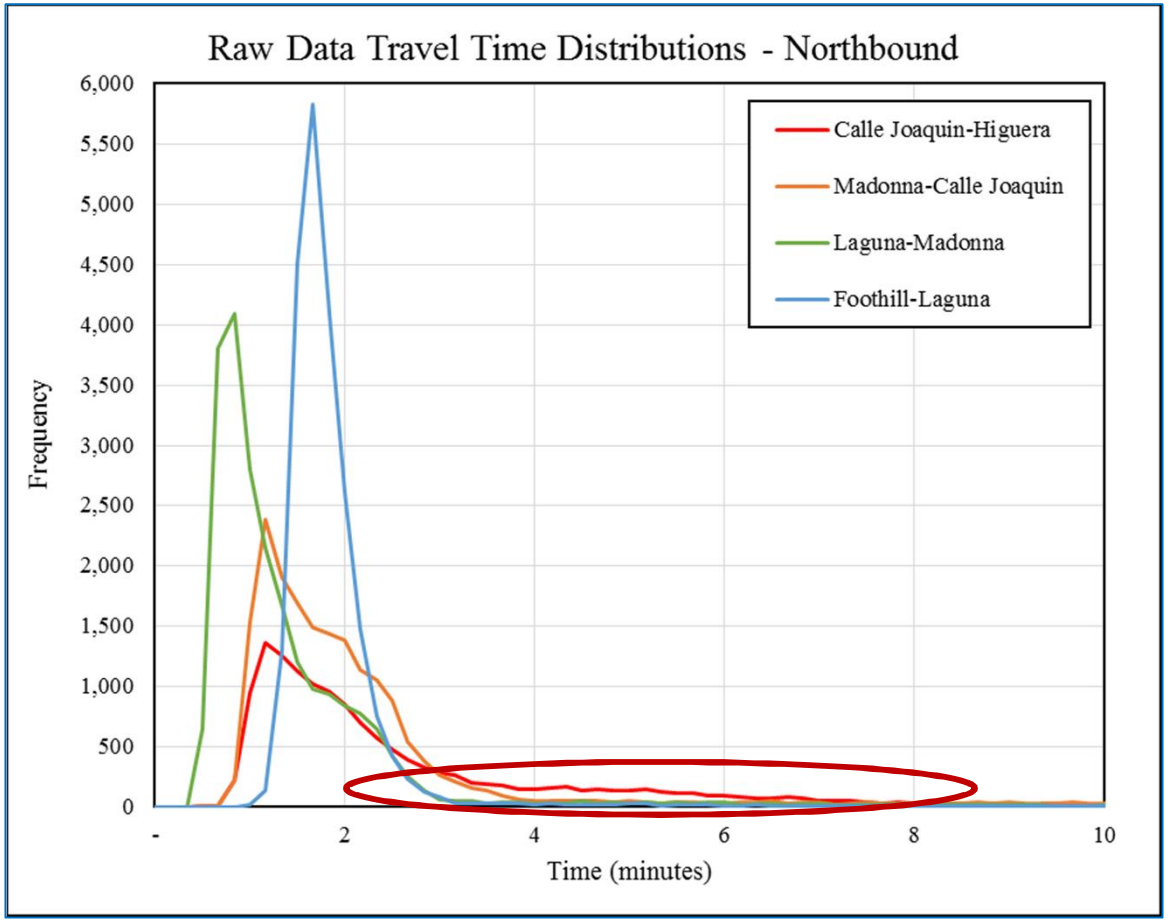
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4,000
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3,000
2,500
2,000
1,500
1,000
500
0
-
2
4
6
8
10
Time (minutes)
Calle Joaquin-Higuera
Madonna-Calle Joaquin
Laguna-Madonna
Foothill-Laguna

Raw Data

Maximum Error Check

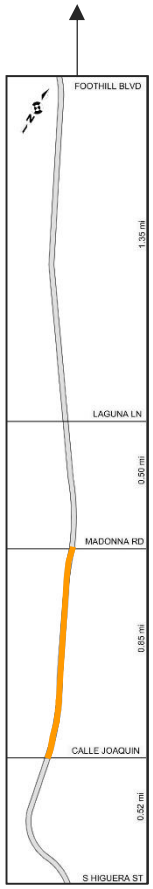
- 95% Confidence
- Standard Deviation and Sample Size by:
- *Segment*
- *Direction*
- *Peak Period*

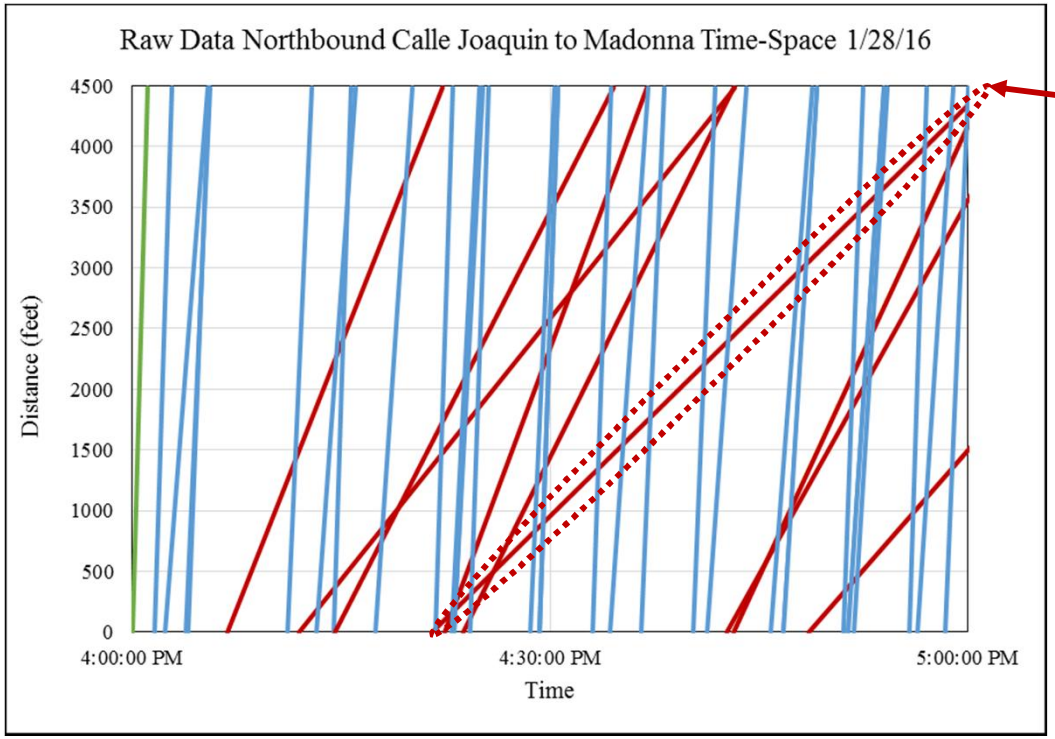
$$E = Z_{\alpha/2} \times \frac{\sigma}{\sqrt{n}}$$

±2 to 4 mph

Segment	Direction	Error (mph)		
		AM	MID	PM
Calle Joaquin-Higuera	Northbound	0.46	0.31	0.26
	Southbound	0.26	0.31	0.35
Madonna-Calle Joaquin	Northbound	0.79	0.69	0.61
	Southbound	0.62	0.67	0.76
Laguna-Madonna	Northbound	0.50	0.58	0.42
	Southbound	0.37	0.44	0.42
Foothill-Laguna	Northbound	0.50	0.49	0.40
	Southbound	0.43	0.52	0.49
Weighted Error		0.48 mph		

Raw Data





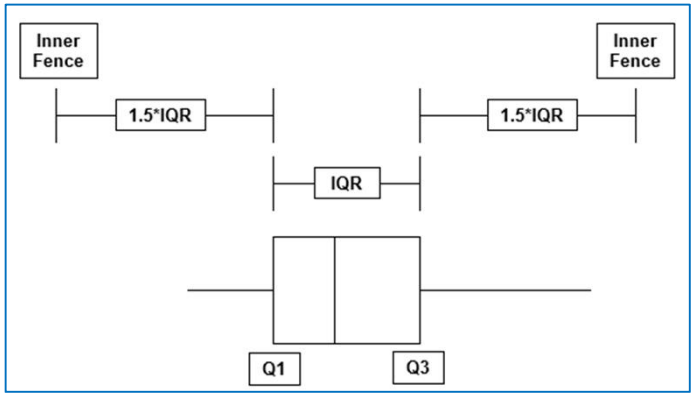
- 0.85 mile
- 51 min trip?
- Pass-by or pedestrian?
- Need for data processing

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

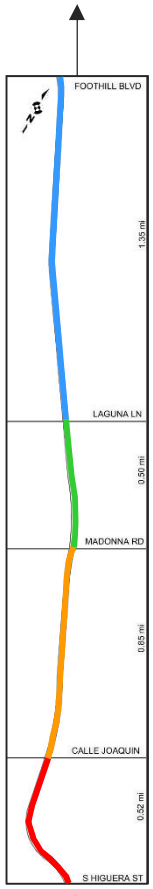


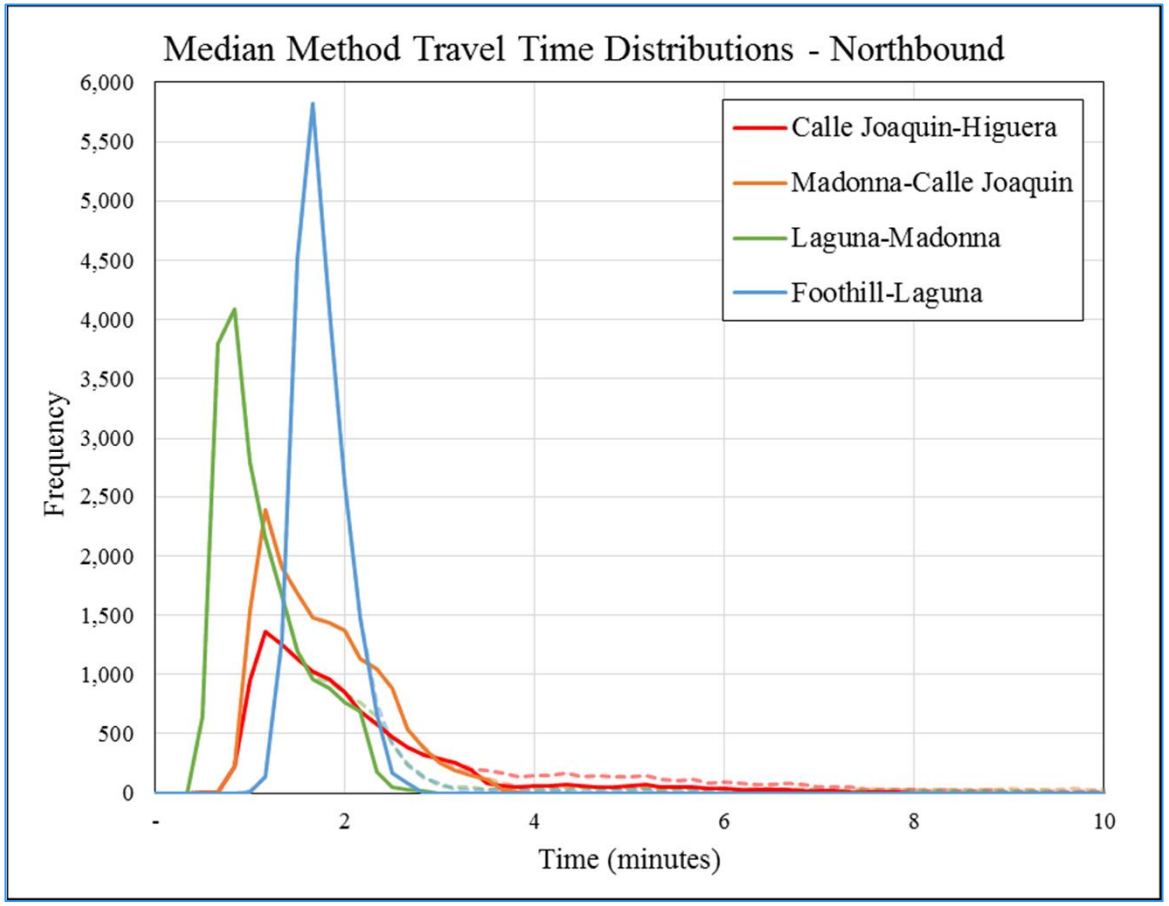
Sorted by:

- 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

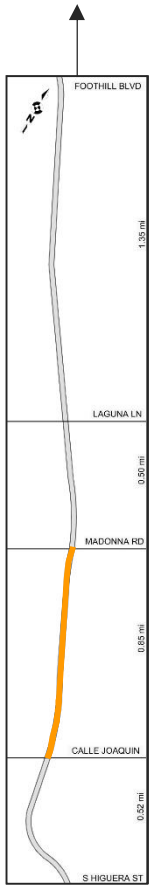
- Down from 0.48 mph for Raw to 0.36 mph
- All individual errors are lower than Raw

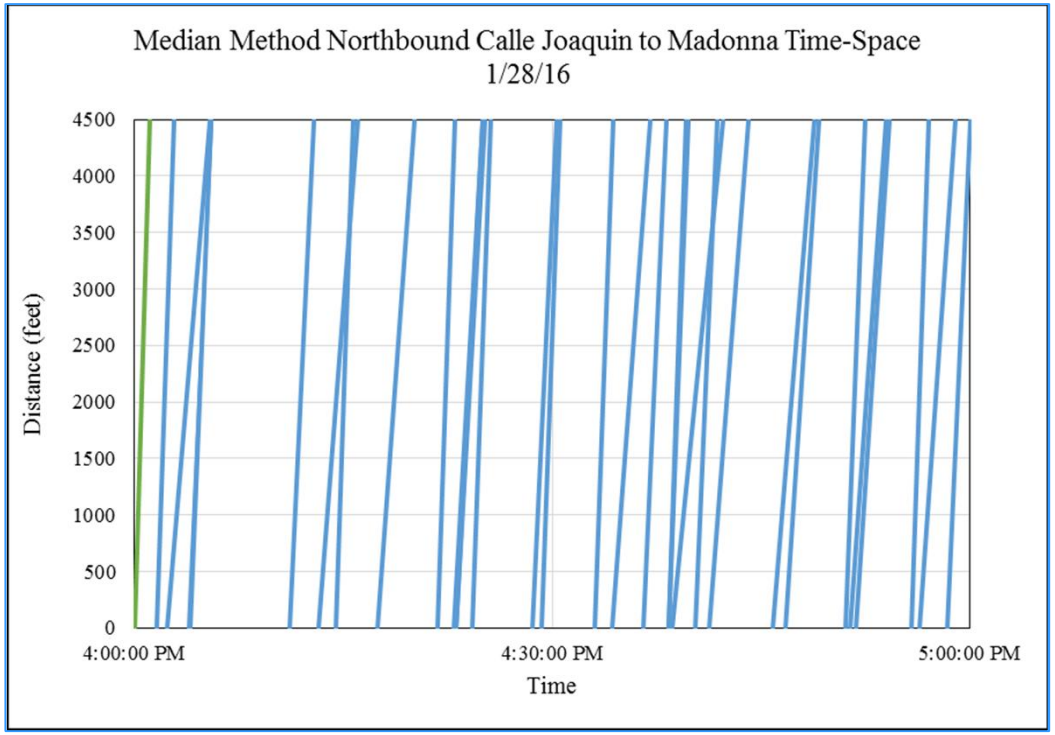
$$E = Z_{\alpha/2} \times \frac{\sigma}{\sqrt{n}}$$

±2 to 4 mph

Segment	Direction	Error (mph)		
		AM	MID	PM
Calle Joaquin-Higuera	Northbound	0.40	0.29	0.26
	Southbound	0.24	0.28	0.32
Madonna-Calle Joaquin	Northbound	0.49	0.48	0.40
	Southbound	0.52	0.60	0.65
Laguna-Madonna	Northbound	0.47	0.41	0.33
	Southbound	0.34	0.39	0.37
Foothill-Laguna	Northbound	0.32	0.25	0.21
	Southbound	0.31	0.30	0.33
Weighted Error		0.36 mph		

Median Method





- ü Unrealistic data removed
- ü 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

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

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

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

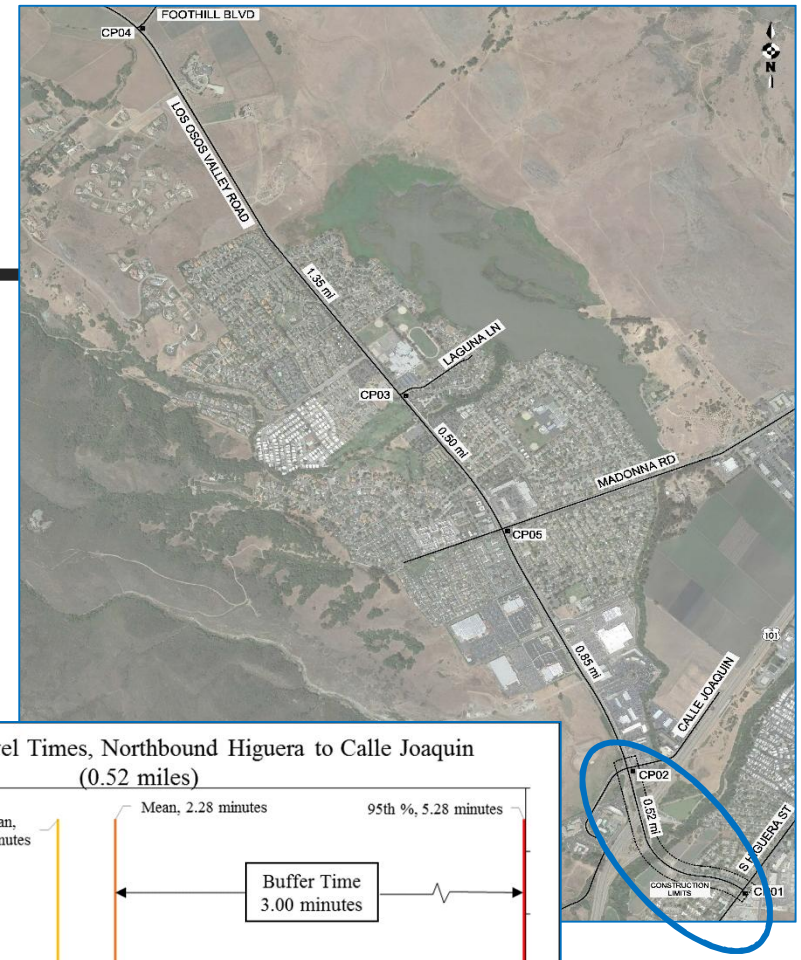
$$Coefficient\ of\ Variation = \frac{Standard\ Deviation\ of\ Travel\ Time\ (min)}{Average\ Travel\ Time\ (min)}$$

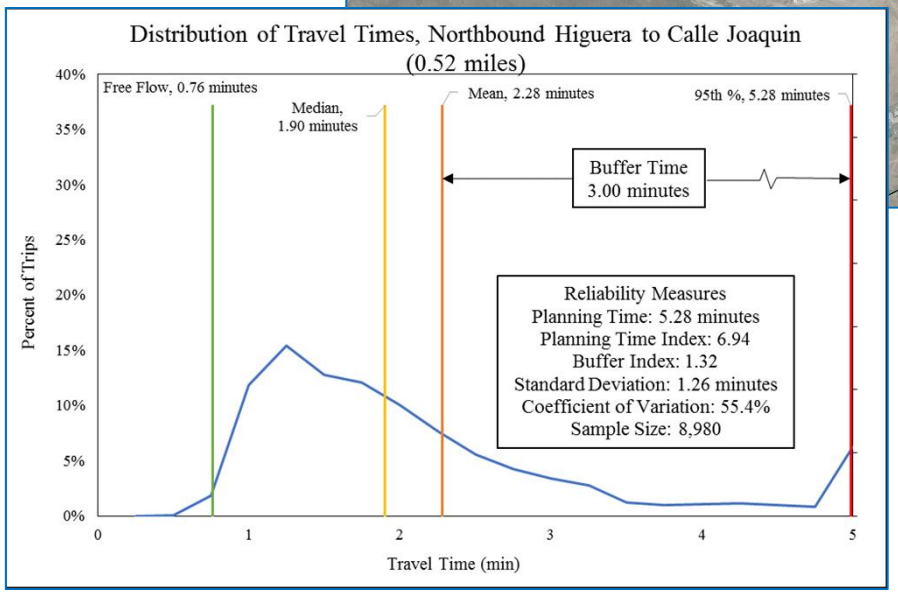
Source: Neudorff, Randall, Reiss, & Gordon, 2006.

Northbound

Higuera – Calle Joaquin

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

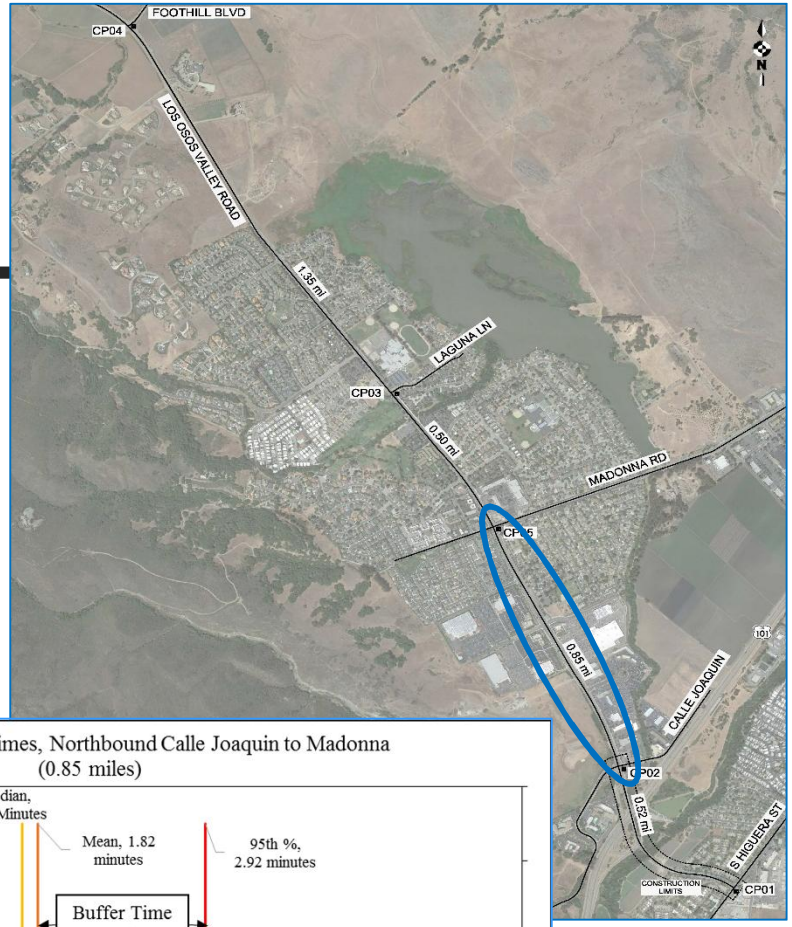


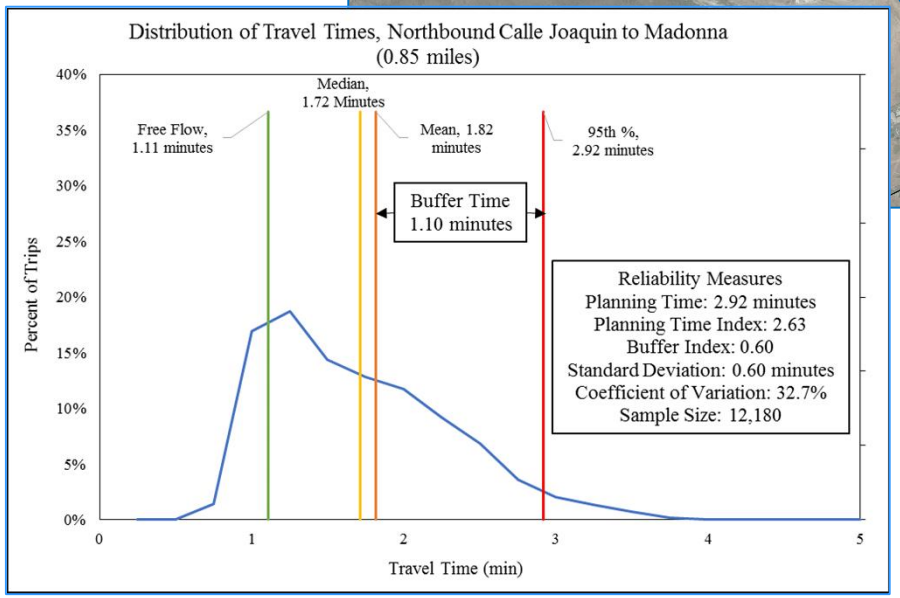


Northbound

Calle Joaquin – Madonna

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

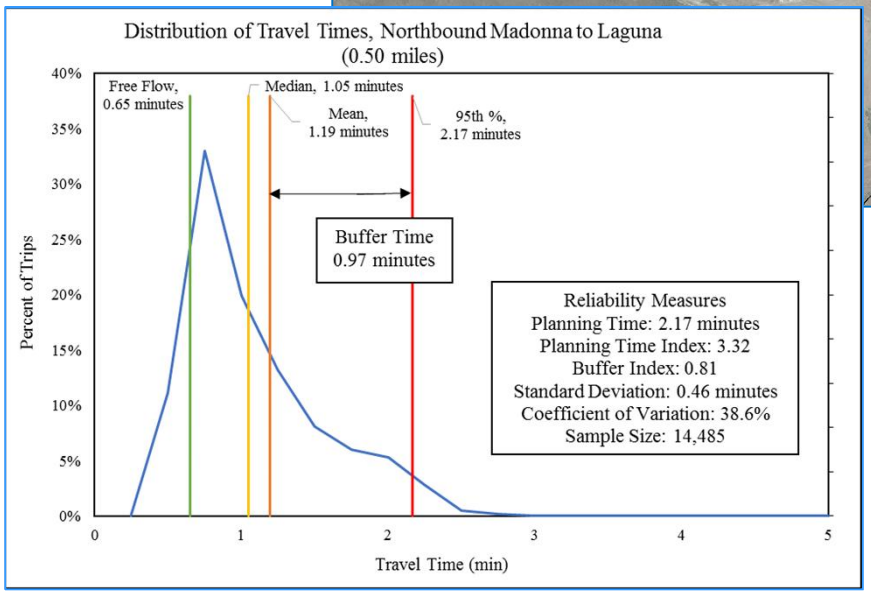




Northbound

Madonna – Laguna

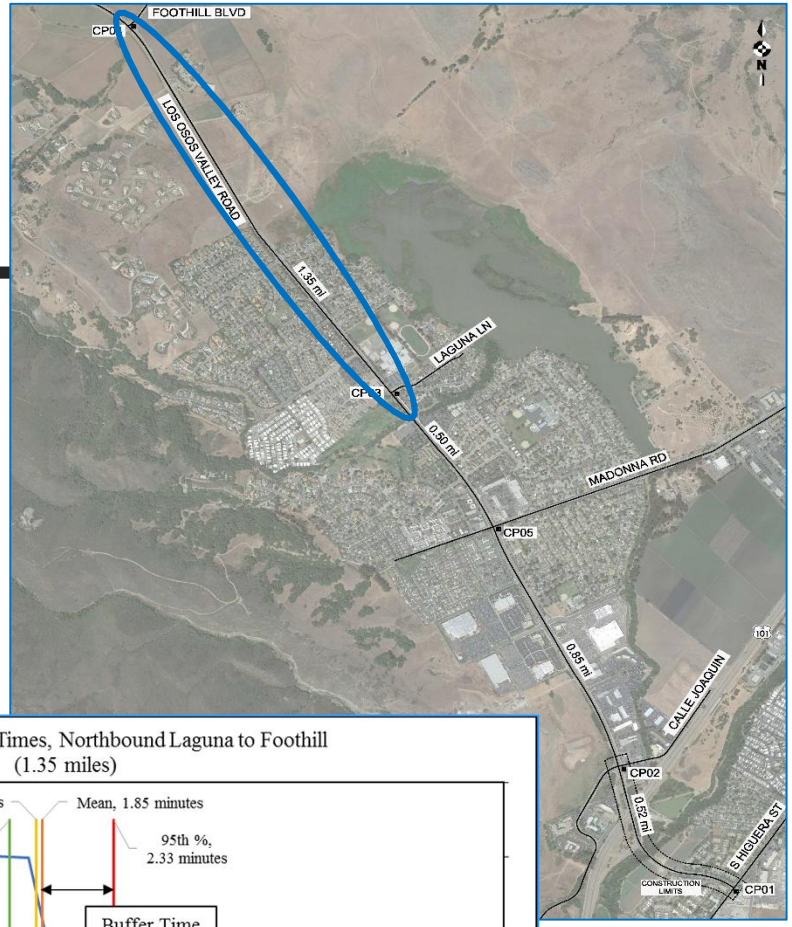
- 0.50 miles
- 4 Lanes
- 0.75-0.99 minute most often
- 2.93 minute maximum

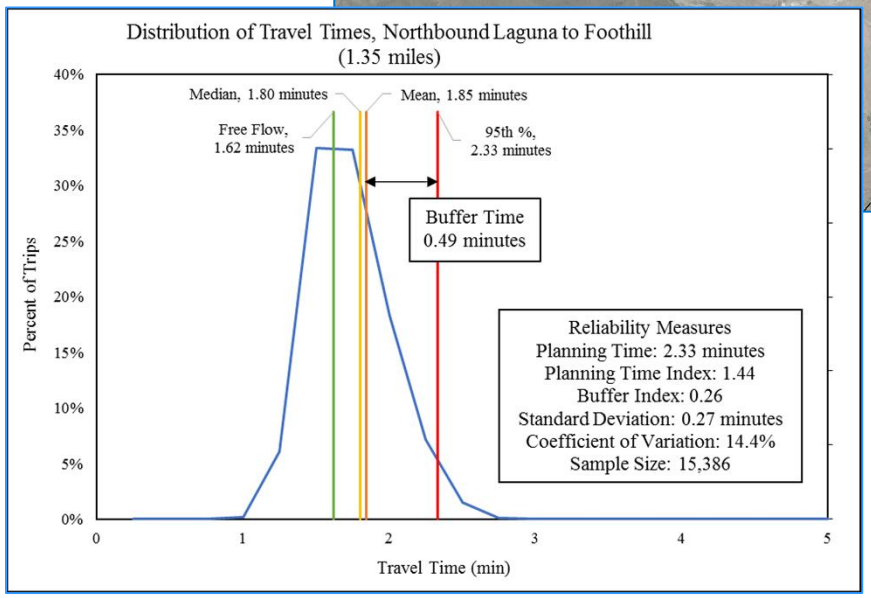


Northbound

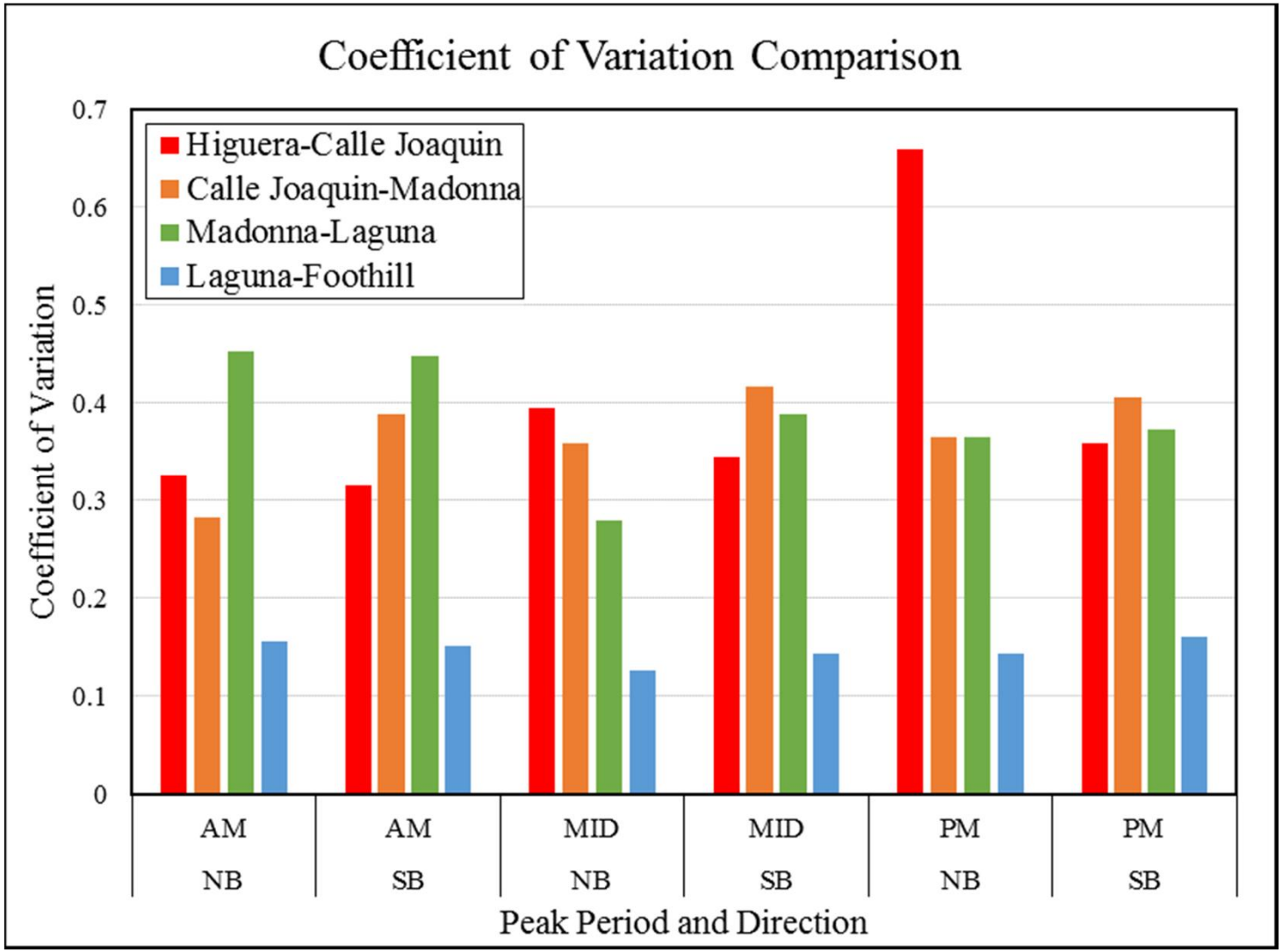
Laguna – Foothill

- 1.35 miles
- 2-4 Lanes
- 1.50-1.74 minute most often
- 2.80 minute maximum





Los Osos Valley Road



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

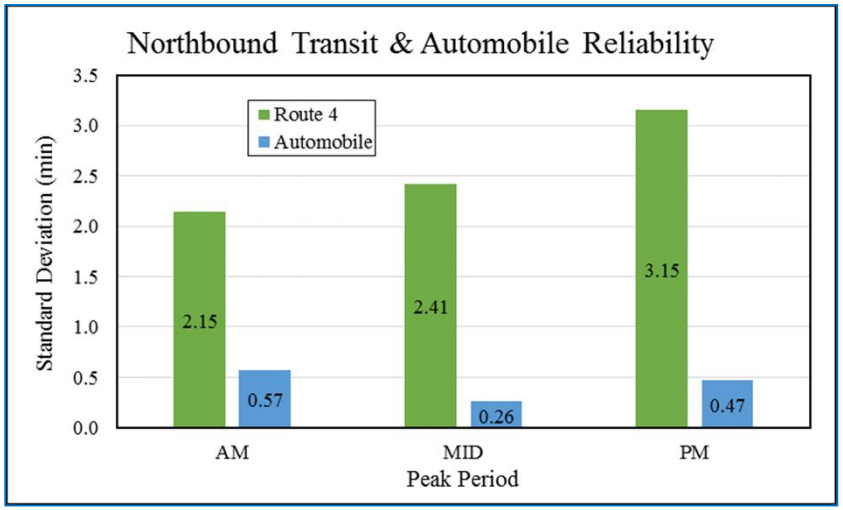
Transit Reliability Comparison

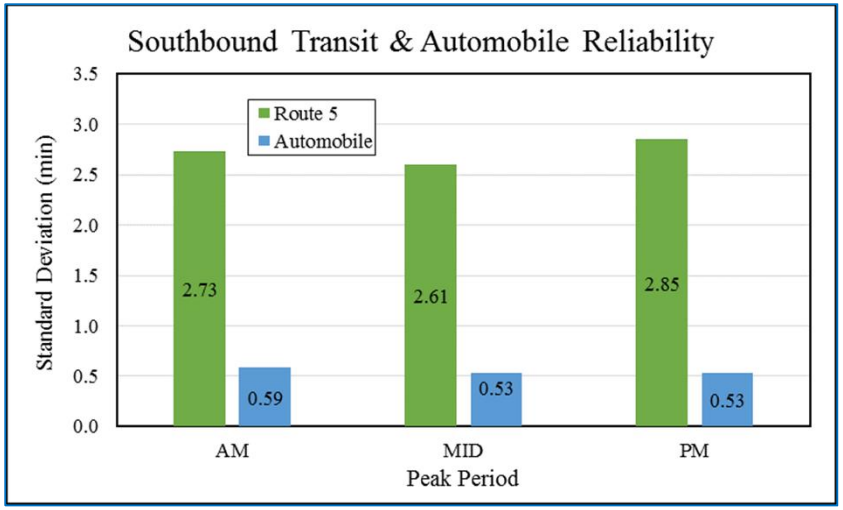
Routes 4 & 5

- 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

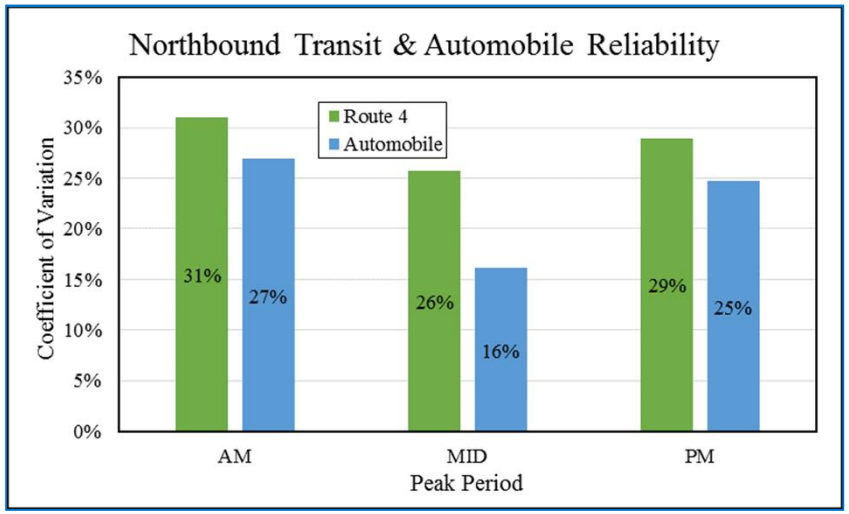


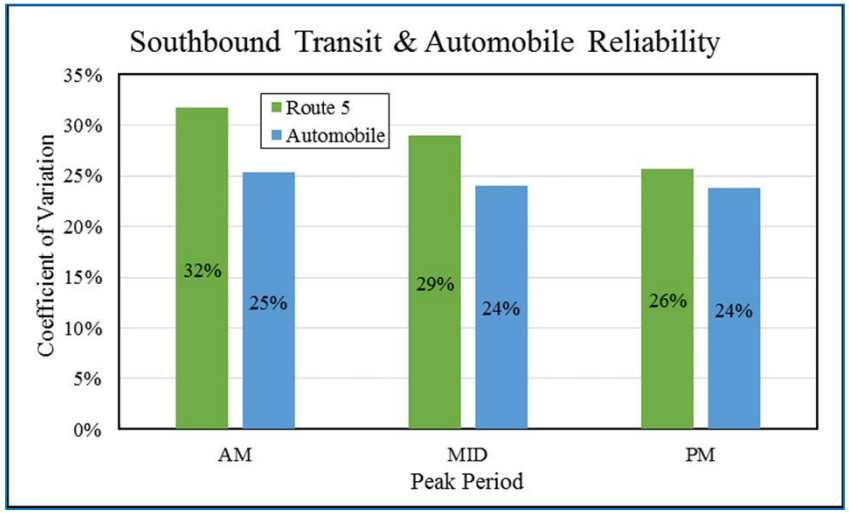


Transit Reliability Comparison

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

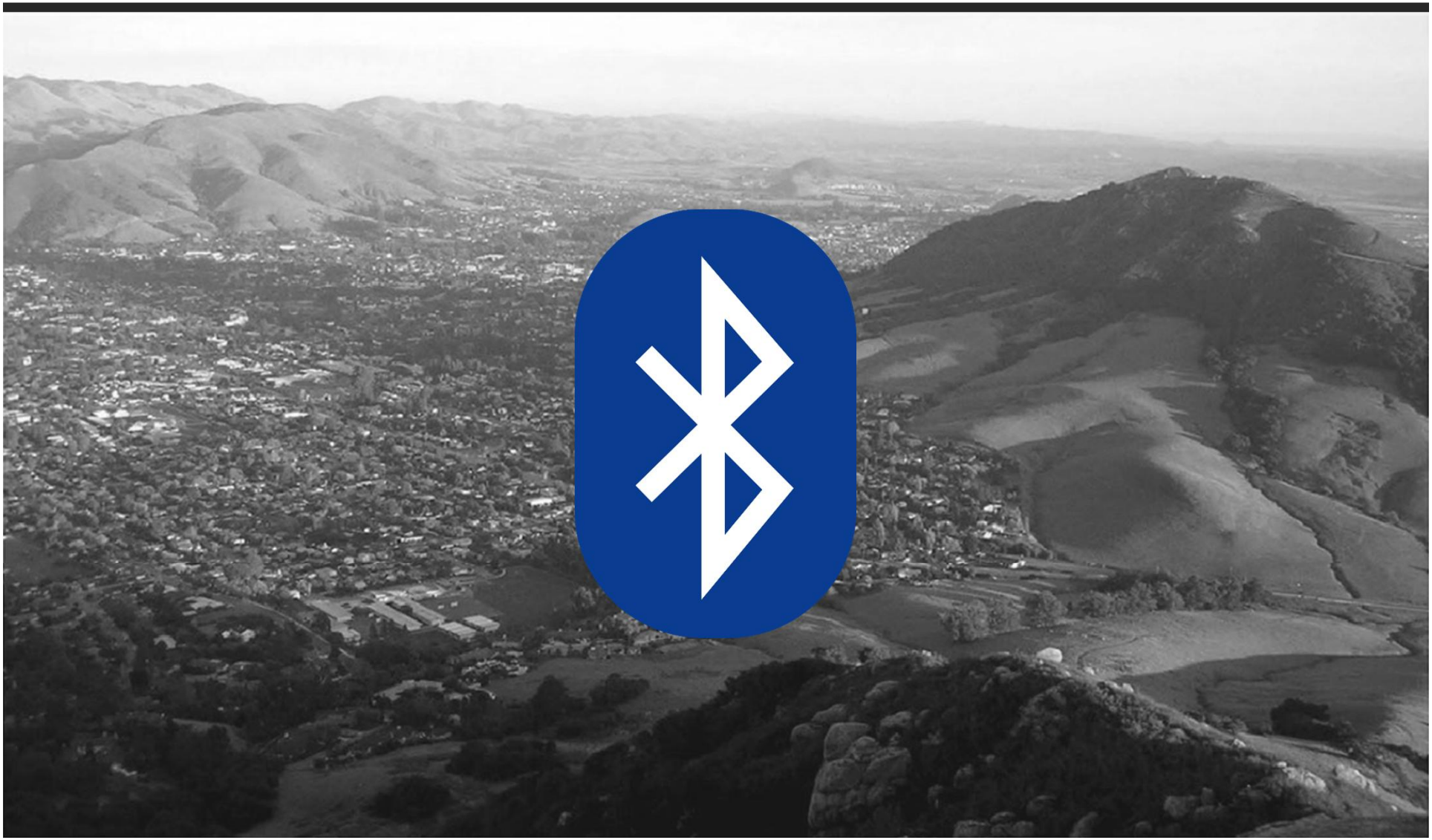
Guidance & Sanity Checks
Dr. Robert Bertini
Dr. Anurag Pande
Dr. Kimberley Mastako

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?