9-15-2021

Webinar: Data-Driven Mobility Strategies for Multimodal Transportation

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Data-Driven Mobility Strategies for Multimodal Transportation

NITC Research Seminar

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NITC
NATIONAL INSTITUTE for TRANSPORTATION and COMMUNITIES

9/15/2021

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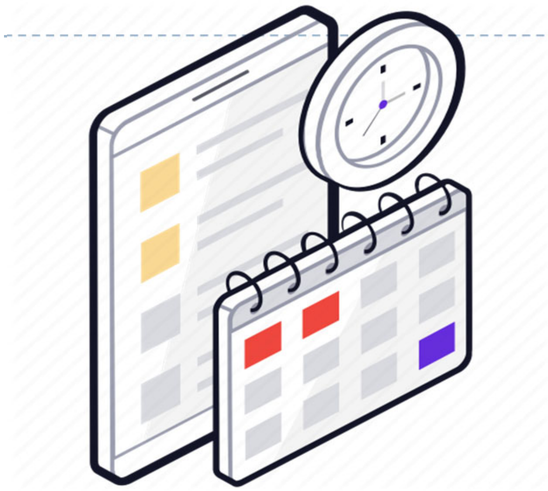
Center for Applied Transportation Sciences (CATS)
College of Engineering

Agenda

- Introduction
  - Vision
  - Objectives
- Conventional Corridors
- Connected Corridors
- Multimodal Transportation
- Project Takeaways
  - Key Learnings
  - Broader Impacts



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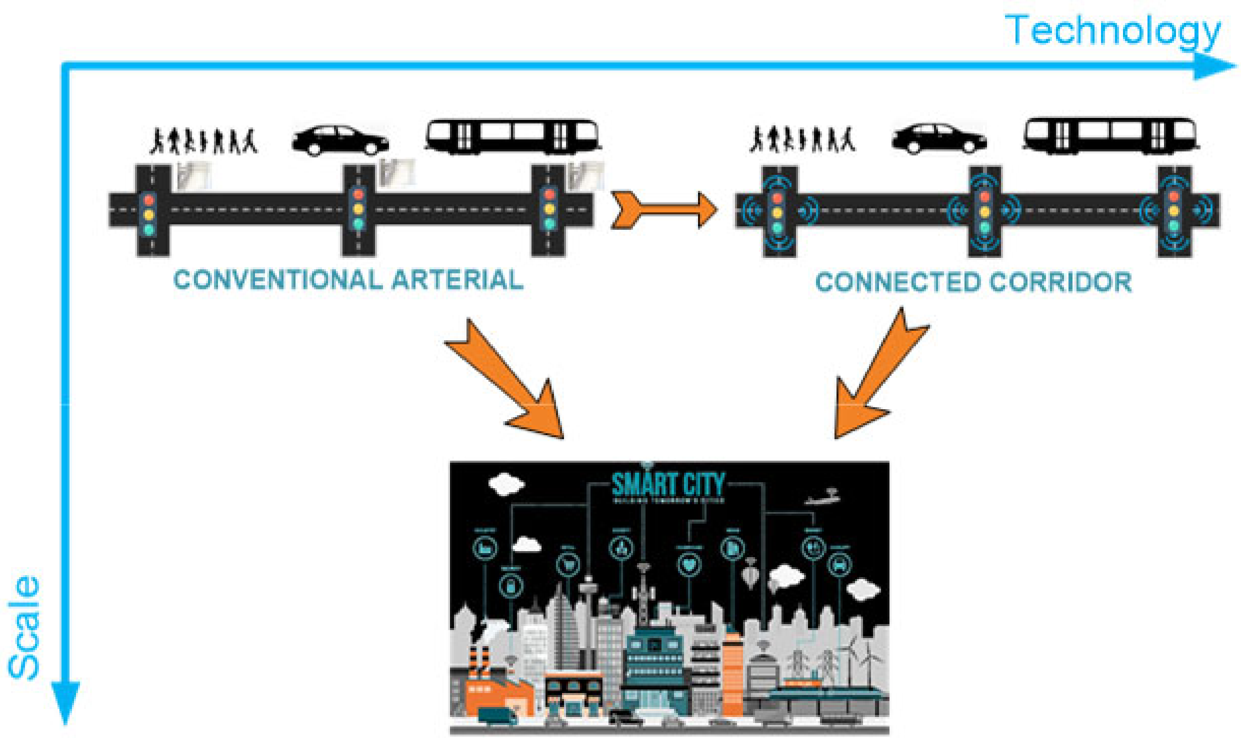
Introduction

Project Vision

Mobility Strategies for Multimodal Transportation



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Introduction
Project Objectives

- Impact of speed management strategies on conventional roadways
- Effects of speed management strategies on connected corridors
- Pedestrian delay at signalized intersections

Acknowledgment

PIMA COUNTY

UDOT Keeping Utah Moving

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Conventional Corridors

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Speed Management Strategies
Conventional Corridors

- What are the primary outcomes of an effective speed management strategy?

Improve mobility and vehicle progression by:

- ✓ Reducing nonrecurrent delays
- ✓ Reducing incident-induced delays

Improve public health and traffic safety by:

- ✓ Reducing the number of speeding-related crashes
- ✓ Reducing average speed
- ✓ Increasing speed limit compliance

(NHTSA, 2014; NHTSA, 2017)

Speed Management Strategies

Conventional Corridors

(FHWA 2014)

Countermeasure	Road Environment
Speed Table	1- Small town
Transverse Rumble Strips	1- Posted Speed Limit=70mph 2- High-speed intersections
Converging Chevron Marking Pattern	1- Main Roads
Transverse Markings	1- Horizontal Curves 2- Interstate Work Zone
Speed humps	1- Local roadways
Optical Speed Bars	1- Main roads 2- Freeway Curves
Speed Limit Pavement Legend	1- Main roads
"Slow" Pavement Legend	1- Main roads


Speed Table


Transverse Rumble Strips


Speed humps

Speed Management Strategies
Conventional Corridors

- School zone
  - Texas (G. Ullman & Rose, 2005) => **Avg. Speed reduced by 9 mph**
  - South Korea (Lee et al., 2006) => **Avg. Speed reduced by 17.5%**
- Work zone
  - US, Interstate 80 (Pesti & McCoy, 2001;) => **Avg. Speed reduced by 5 mph**
- Transition areas
  - New Zealand (Wrapson et al., 2006) => **Avg. Speed reduced by 6 mph**
- Urban and rural road
  - London (Walter & Broughton, 2011) => **Avg. Speed significantly reduced**
  - Wisconsin (Santiago-Chaparro, 2012)

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Speed Management Strategies
Conventional Corridors

- Reduced aggressive and risky driving
  - United Kingdom (Stanojević et al., 2018)
- Reduce both mean speeds and variance in speed
  - London (Elliott and Broughton, 2005; Walter et al, 2011)
- Target the fatal crash
  - Queensland, Australia (Newstead, 2004)
- Increase seat belt use
  - London and Saudi Arabia (Bendak S, 2005; Stanojevic et al., 2012)

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Speed Management Strategies
Conventional Corridors

- Roadway Designs are not Always Applicable
- Continuous Enforcement is Costly
- Spatial Halo Effect (Fixed-point)
- Speed Enforcement Cameras are not legal in all states

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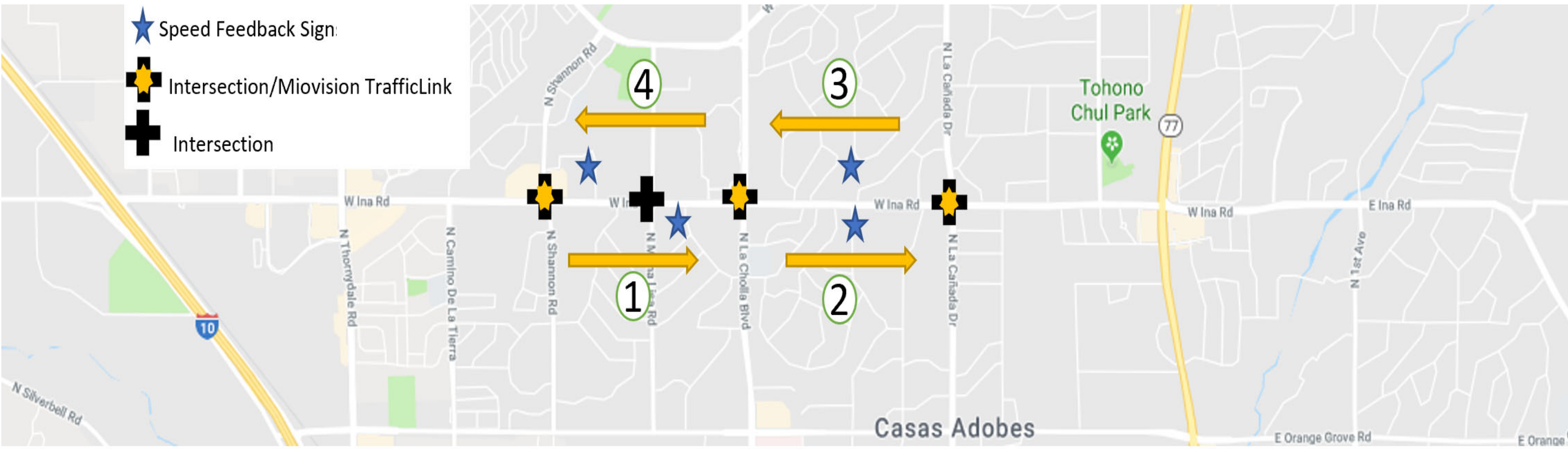
Speed Feedback Sign

Impact on Intersections Performance Measure



Segment ID	Direction	County	Upstream Intersection	Downstream Intersection	Segment Length (miles)	SFS Distance to Downstream (miles)	Speed Limit (mph)
1	Eastbound	Pima	N Shannon Rd	N La Cholla Blvd.	0.98	0.24	45
2	Eastbound	Pima	N La Cholla Blvd	N La Canada Dr.	1.02	0.4	45
3	Westbound	Pima	N La Canada Dr	N La Cholla Blvd.	1.02	0.47	45
4	Westbound	Pima	N La Cholla Blvd	N Shannon Rd.	0.98	0.38	45

Speed Feedback Sign

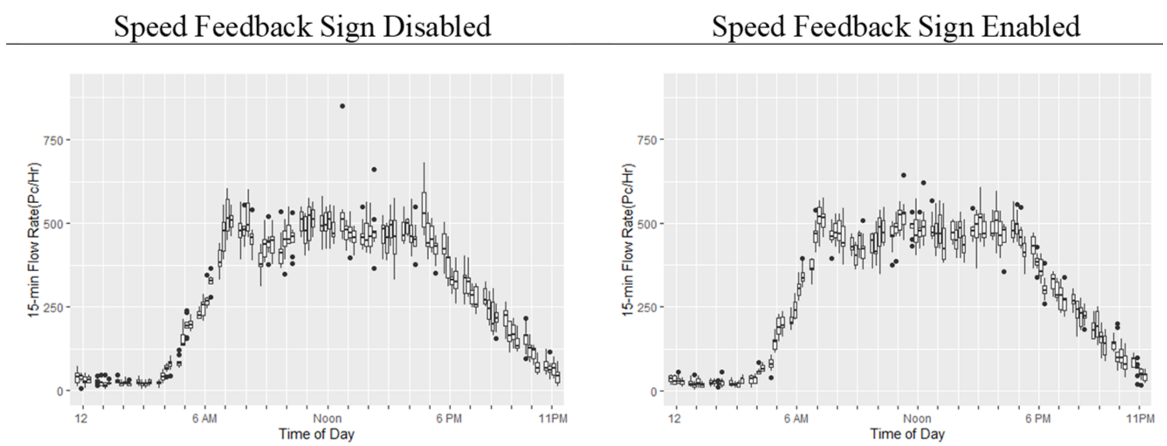
Impact on Intersections Performance Measure

Active SFS → Disable SFS → Active SFS

- Vehicle Volume
- Delay
- Arrival on Red
- Split Failure
- WiFi Speed

← **Data Collected**

No significant change in the volume



Segment 1: Eastbound from N Shannon Rd. to N La Cholla Blvd.

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Speed Feedback Sign

Impact on Intersection Arrival on Red

*Fail to reject (✗), Reject (✔); AR: Percent of Arrival on Red

	Friedman Test	Period	Chi-Square (X^2)	P-Value	Decision*
Mean	$H_0: \mu^{Si}_{AR\,ON} = \mu^{Si}_{AR\,OFF}$ H_a= for at least one segment, the mean percent arrival on red before and after disabling the SFS is different	AM-Peak	6	0.11	✗
		PM-Peak	6	0.11	✗
		Off-Peak	6	0.11	✗
Variance	$H_0: {\sigma^2}^{Si}_{AR\,ON} = {\sigma^2}^{Si}_{AR\,OFF}$ H_a= for at least one segment, the variance of percent arrival on red before and after disabling the SFS is different	AM-Peak	6	0.11	✗
		PM-Peak	5.4	0.14	✗
		Off-Peak	6	0.11	✗

At a significance level of $\alpha = 0.05$, there is not sufficient evidence to reject the null hypothesis.

The operation of SFS does not have a statistically significant impact on the percent of arrivals on red

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Speed Feedback Sign

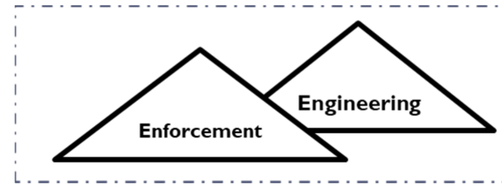
Impact on Speeding Behavior

Study Sites

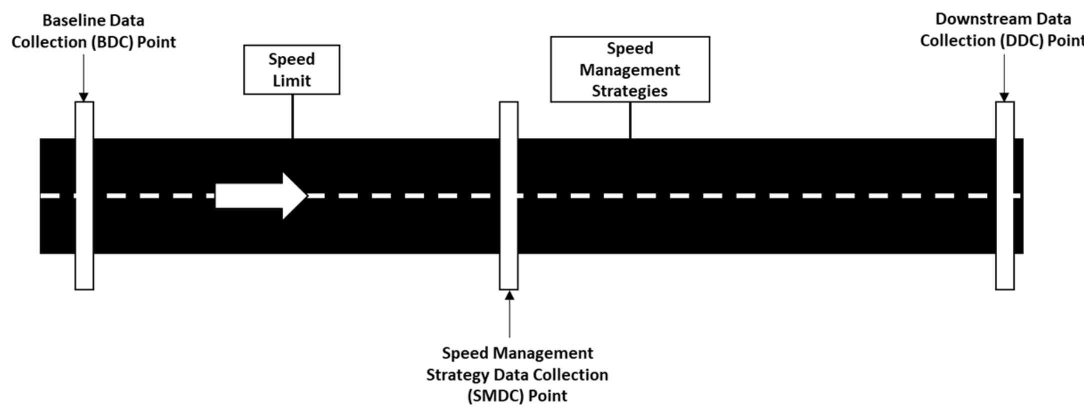
Three Sites with SFS-only

Three Sites with Periodic Law Enforcement

Three Sites with Periodic Law Enforcement + SFS



SFS + PERIODIC LAW ENFORCEMENT



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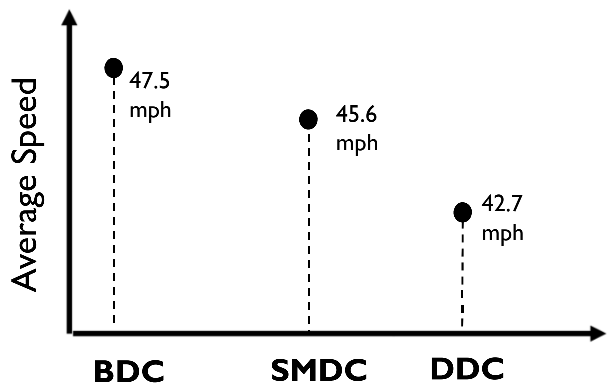
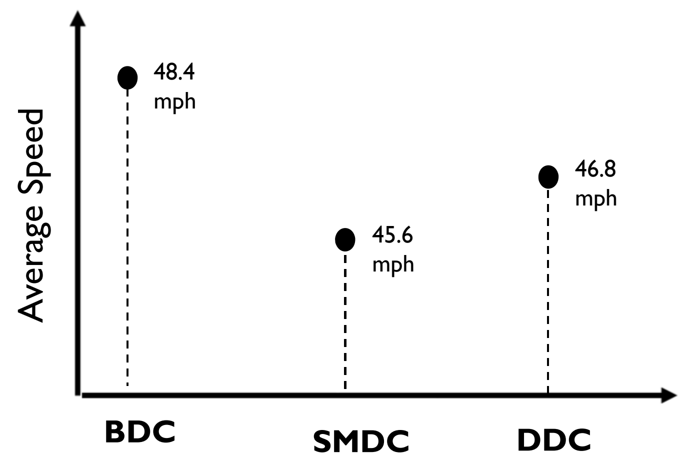
Speed Feedback Sign

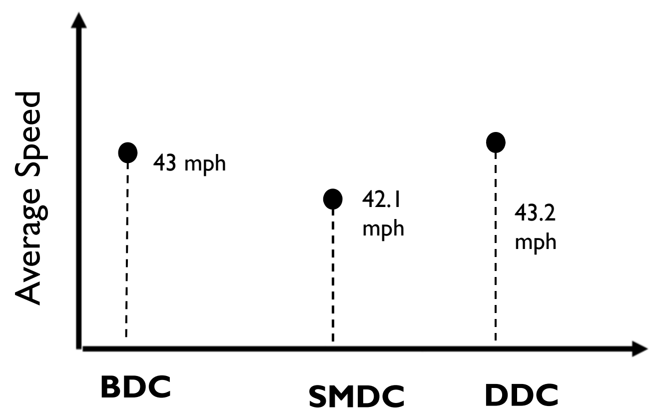
Impact on Average Speed



SFS+E



Periodic Law Enforcement-Only



SFS-Only

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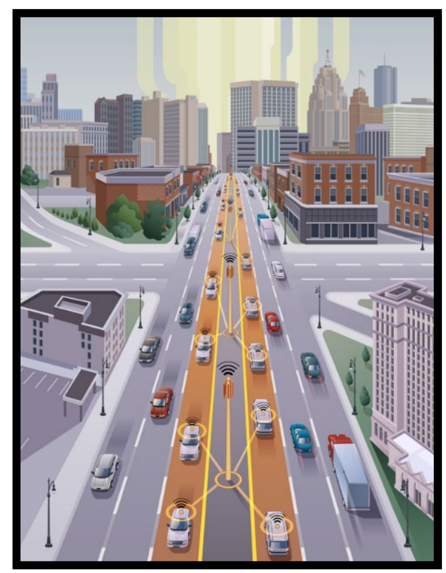
Conclusion

- Identify a key speed management strategy
  - Increase the spatial effectiveness of SFS (fixed-point)
  - No impact on intersection performance measures
- DOTs looking to expand SFS coverage can consider adding enforcement areas at their new SFS locations
- Coordinated efforts between transportation agencies and law enforcement will help to address speeding

Connected Corridors



https://www.dbusiness.com/business-features/tech-track/ [Illustration by Garth Glazier]

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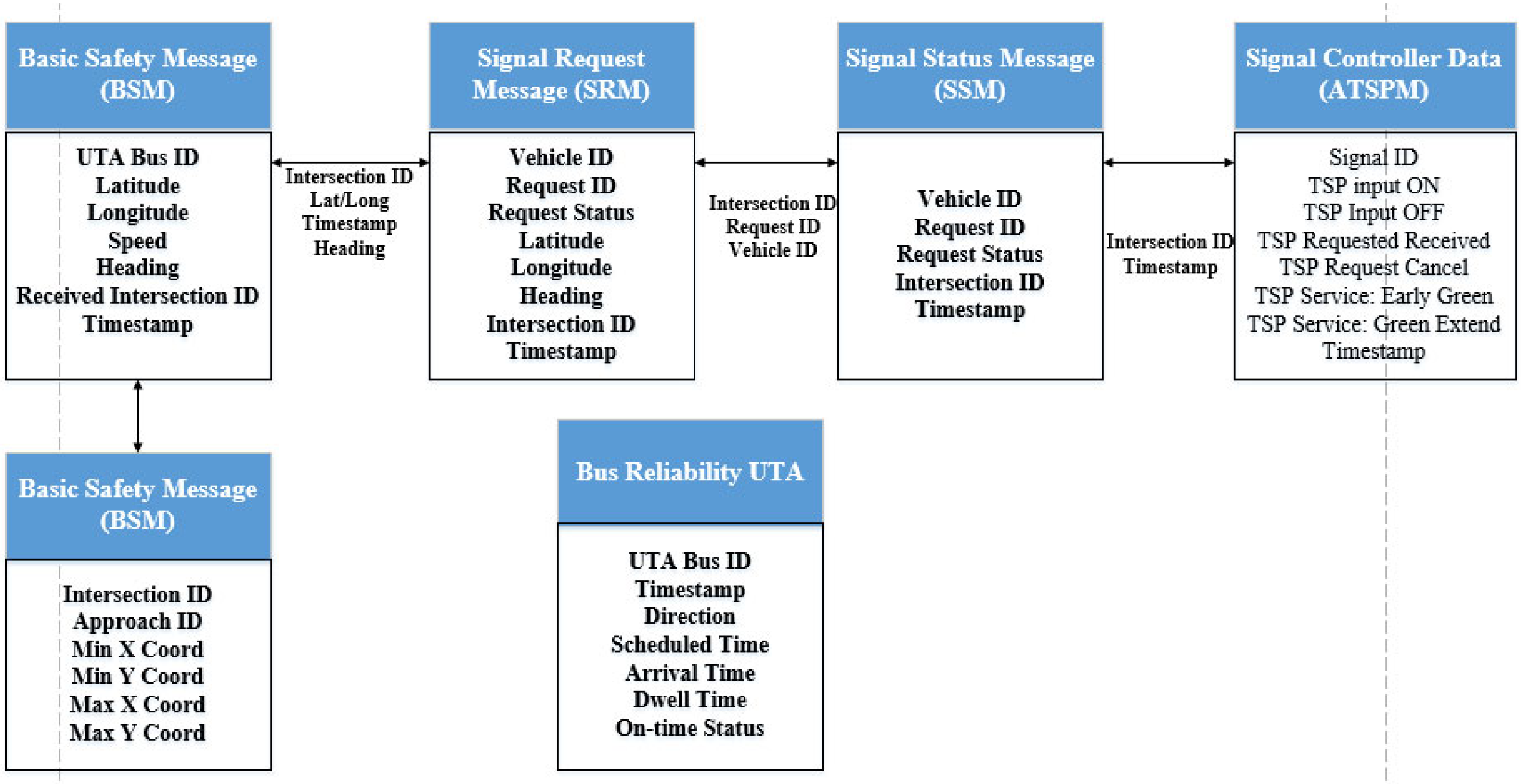
Introduction
Data

Time period: August, September, November and December in 2018.



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Received from Blaine Leonard and David Bassett

Data Processing

BSM Data

1,494,142 records

Timestamp	ReceivedA	VehicleId	Cnt	Latitude	Longitude	Elevation	Heading	Speed	MinOfX	MaxOfX
08/27/2018 22:05:01	7229	12029	10	40.60668	-111.939	1319.52	356.925	13	40.60402	40.60753
08/27/2018 22:05:02	7229	12029	10	40.60672	-111.939	1319.76	359.005	17.2	40.60402	40.60753
08/27/2018 22:05:03	7229	12029	10	40.60677	-111.939	1319.9	359.0425	22	40.60402	40.60753
08/27/2018 22:05:04	7229	12029	10	40.60684	-111.939	1320.06	359.3175	25.6	40.60402	40.60753
08/27/2018 22:05:05	7229	12029	10	40.60691	-111.939	1320.18	359.595	28.8	40.60402	40.60753
08/27/2018 22:05:06	7229	12029	8	40.60698	-111.939	1320.2	225.0875	30.375	40.60402	40.60753

- The Timestamp in the raw database is Greenwich Mean Time (GMT), it needs to be transformed to Mountain Standard Time (MST).

- The "Heading" column in this database is to determine the driving direction of buses. Route 217 have four directions (Northbound, Southbound, Eastbound and Westbound). As this project focuses on northbound and southbound, the data with eastbound and westbound need to be removed.

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Data Processing

BSM Data

1) GMT to MST

For the date from Aug 1st, 2018, to Sep 30th, 2018, and Nov 1st, 2018, to Nov 4th, 2018:

$$MST = GMT - 6$$

For the date from Nov 4th, 2018, to Dec 31st, 2018:

$$MST = GMT - 7$$

2) Direction filtering:

Northbound: heading is from 315 to 360 and 0 to 45; Westbound: heading is from 45 to 135;

Southbound: heading is from 135 to 225; Eastbound: heading is from 225 to 315.

Timestamp	AtInters	VehicleI	Cnt	Latitude	Longitud	Elevatio	Heading	Speed	MinOfX	MaxOfX	MST
2018-08-27 22:05:01	7229	12029	10	40.60668	-111.939	1319.52	356.925	13	40.60402	40.60753	2018-08-27 16:05:01
2018-08-27 22:05:02	7229	12029	10	40.60672	-111.939	1319.76	359.005	17.2	40.60402	40.60753	2018-08-27 16:05:02
2018-08-27 22:05:03	7229	12029	10	40.60677	-111.939	1319.9	359.0425	22	40.60402	40.60753	2018-08-27 16:05:03
2018-08-27 22:05:04	7229	12029	10	40.60684	-111.939	1320.06	359.3175	25.6	40.60402	40.60753	2018-08-27 16:05:04
2018-08-27 22:05:05	7229	12029	10	40.60691	-111.939	1320.18	359.595	28.8	40.60402	40.60753	2018-08-27 16:05:05
2018-08-27 22:05:07	7229	12029	10	40.60706	-111.939	1320.2	0.345	32.9	40.60402	40.60753	2018-08-27 16:05:07
2018-08-27 22:05:09	7229	12029	7	40.60725	-111.939	1320.043	154.6286	36.28571	40.60402	40.60753	2018-08-27 16:05:09
2018-08-27 22:05:11	7229	12029	9	40.60744	-111.939	1319.956	1.538889	39	40.60402	40.60753	2018-08-27 16:05:11

837,325 records

Received from Blaine Leonard and David Bassett

Data Processing

SRM Data

69,575 records

Timestamp	Seque	VehicleId	VehicleName	VehicleRole	Inboun	IntersectionI	Request	RequestType	VehicleLat	VehicleLon	VehicleEle	VehicleHe	Vehicle	DateCreated
08/01/2018 00:29:49	1	7278	12029	transit	22	7111	33	request	40.65124	-111.939	1328.4	179.875	6	08/01/2018 00:29:51
08/01/2018 00:29:50	1	7278	12029	transit	22	7111	33	request	40.65124	-111.939	1328.4	179.875	6	08/01/2018 00:29:51
08/01/2018 00:29:50	1	7278	12029	transit	22	7111	33	request	40.65124	-111.939	1328.4	179.875	6	08/01/2018 00:29:56
08/01/2018 00:29:50	1	7278	12029	transit	22	7111	33	request-update	40.65122	-111.939	1328.3	179.4375	7	08/01/2018 00:29:56
08/01/2018 00:29:51	1	7278	12029	transit	22	7111	33	request-update	40.65122	-111.939	1328.3	179.4375	7	08/01/2018 00:29:56
08/01/2018 00:29:51	1	7278	12029	transit	22	7111	33	request-update	40.6512	-111.939	1328.2	179.175	8	08/01/2018 00:29:56
08/01/2018 00:29:52	1	7278	12029	transit	22	7111	33	request-update	40.6512	-111.939	1328.2	179.175	8	08/01/2018 00:29:56

The Timestamp in the raw database is Greenwich Mean Time (GMT), it needs to transform to Mountain Standard Time (MST).

The "VehicleHeading" column in this database is to determine the driving direction of buses. Route 217 have four directions (Northbound, Southbound, Eastbound and Westbound). As this project focuses on northbound and southbound, the data with eastbound and westbound need to be removed.

The date in the SRM database need to be same as the date in ATSPM database.

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Data Processing

ATSPM Data

19,263 records

SignalID	Timestamp	EventCode	EventParam
7091	2018-08-03 16:58:28	112	2
7091	2018-08-03 16:58:29	114	2
7091	2018-08-03 16:58:36	115	2
7091	2018-08-03 16:58:38	112	2
7091	2018-08-03 16:58:38	114	2
7091	2018-08-03 16:58:46	115	2
7091	2018-08-22 12:56:19	115	2
7091	2018-08-22 12:56:19	115	6

The date in the ATSPM database need to be same as the date in SRM database.

Since the TSP served enumerations depend on the controller type, it needs to add controller type for each SignalID.

Data Processing

ATSPM Data

1) Direction filter:

Remove the data records whose date are not same as the date in SRM.

2) Controller type added:

The controller type are Econolite for Signal 7094, 7095, 7111, 7115, 7116, and 7229 and the rest are Intelite.

SignalID	Timestamp	EventCode	EventParam	ontroller_type
7091	2018-08-03 16:58:28	112	2	Intelite
7091	2018-08-03 16:58:29	114	2	Intelite
7091	2018-08-03 16:58:36	115	2	Intelite
7091	2018-08-03 16:58:38	112	2	Intelite
7091	2018-08-03 16:58:38	114	2	Intelite
7091	2018-08-03 16:58:46	115	2	Intelite
7091	2018-08-22 12:56:19	115	2	Intelite
7091	2018-08-22 12:56:19	115	6	Intelite

14,412 records

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Data Processing

UTA Data

08-01-2018	1000	2655	L. Olsen	W. Tharp	04:08:00	12029	217	TO 7800 S	13-N1754	04:08:00	04:08:19	ON TIME		19	11	0
08-01-2018	1000	5952	S. Stanton	C. Stewart	13:21:00	12029	217	TO ROSE F	62-SRDWL	13:29:00	13:28:27	Early		-33	4	78
08-08-2018	1002	3808	L. Shaw	E. Taft	06:53:00	99055	217	TO 7800 S	13-N1754	06:53:00	06:47:42	Critical Ear		-318	618	618
08-01-2018	1000	2655	L. Olsen	W. Tharp	05:14:00	12029	217	TO ROSE F	13-N1754	06:07:00	06:16:01	Late		541	0	1117
08-01-2018	1127	9238	S. Peterse	S. Middlet	17:07:00	17024	217	TO ROSE F	BLNDCNTF	17:59:00	18:19:05	Critical Lat		1205	58	570

Since the bus status contains "ON TIME", "Early", "Critical Early", "Late", "Critical early", we need to calculate the number of records whose status is "ON TIME" to calculate the reliability. Also, we performed analysis for both northbound and southbound, where we need to split the directions ("To 7800S" is southbound and "To ROSE PARK" is northbound).

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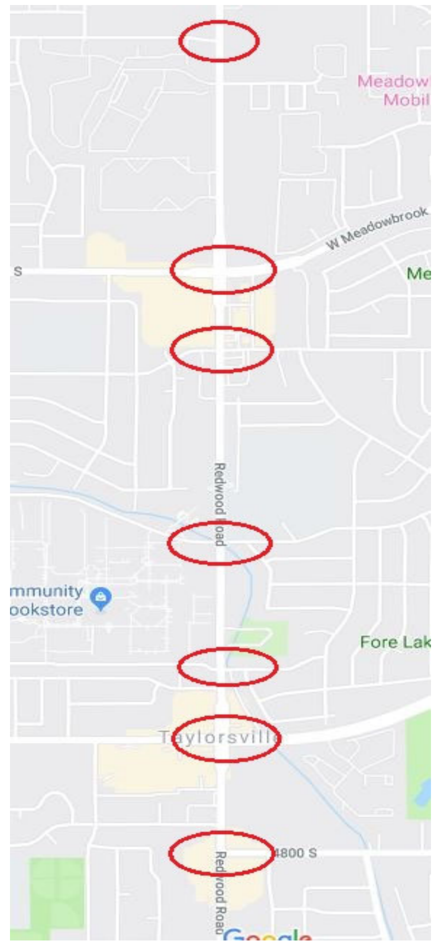
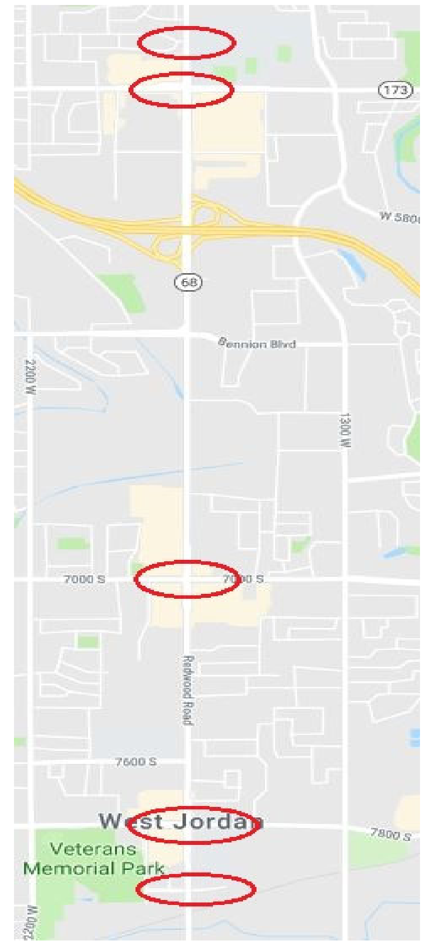
Case Study
Intersections

Based on the filtered data, 18 intersections on Redwood road was selected.





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Result Analysis

Metrics

Data source	Result
BSM data	Count the number of buses that drive at a certain intersection
SRM data	Count the number of TSP requested for a certain intersection
ATSPM data	Count the number of TSP served for a certain intersection
UTA data	Calculate the reliability, travel time and operation time
Delay data	Calculate the intersection delay

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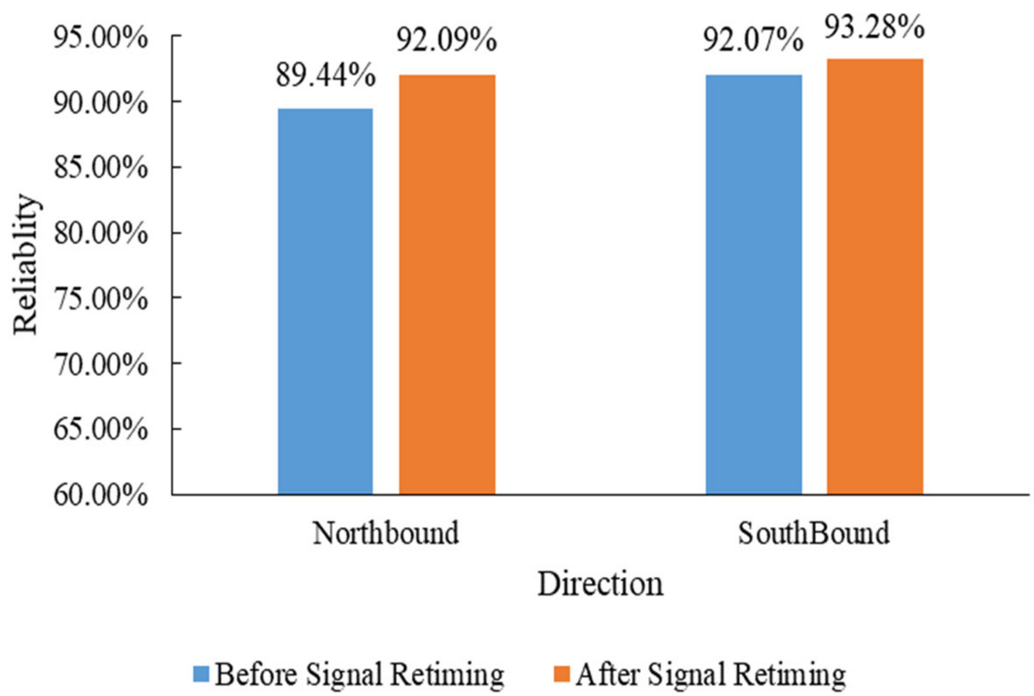
Result Analysis

Reliability

Method: calculate the summation of all on-time arrivals for each timepoint and divides them by the total arrivals for that point. A bus is considered "on time" when it is less than five minutes behind its scheduled arrival time.



The reliability for northbound and southbound all improve after signal retiming.

Result Analysis

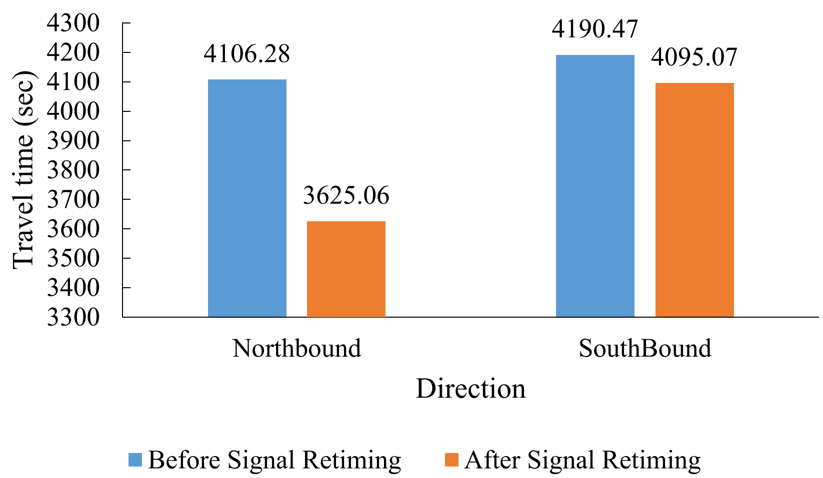
Travel Time and Operation Time

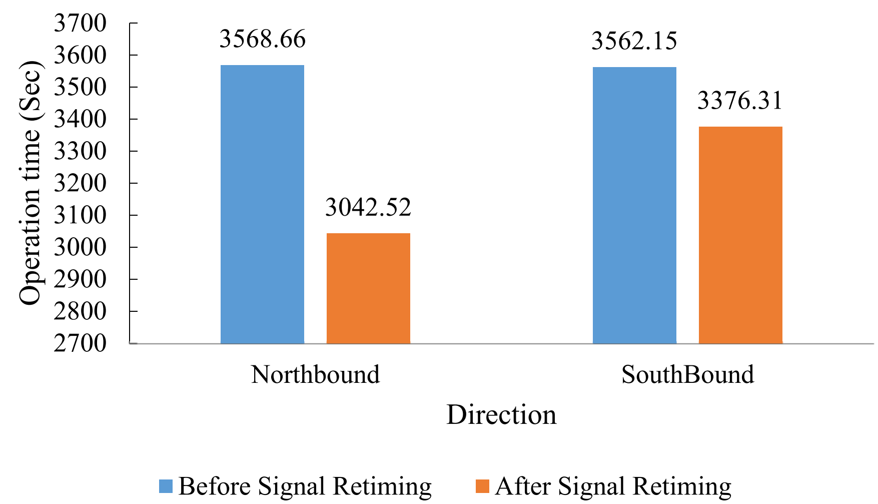
Travel Time

The time that a vehicle travel from the departure station to the terminal station.

Operation Time

The driving time that a vehicle from the departure station to the terminal station (not include dwell time).





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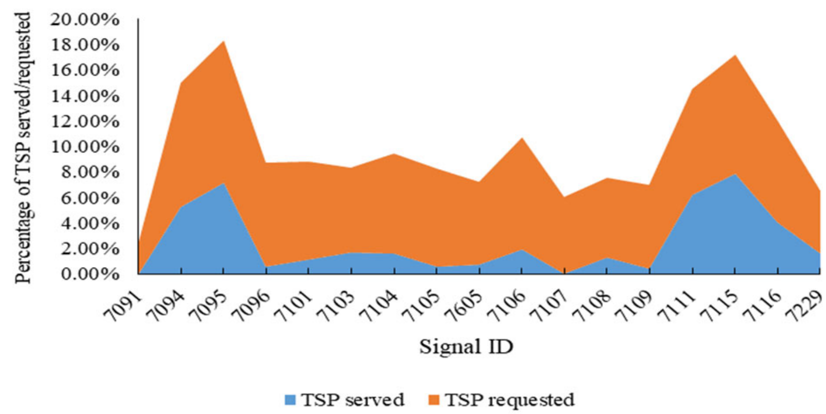
Result Analysis

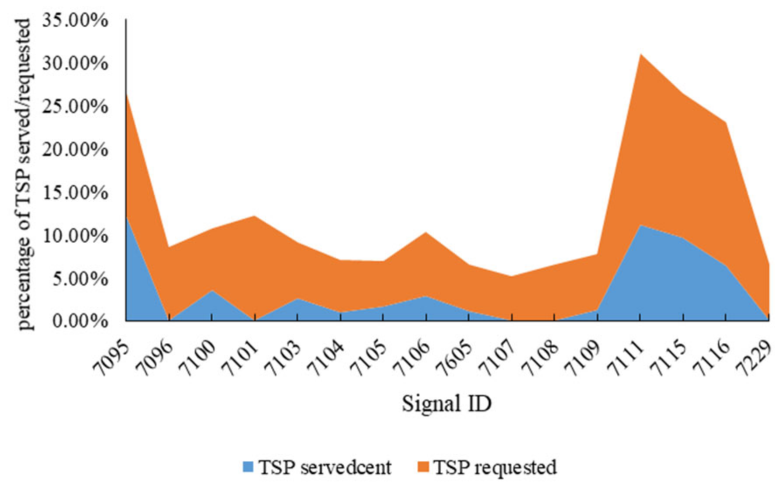
TSP Requested and Served

The yellow areas and blue areas represent the percent of bus event with TSP requested and TSP served, respectively. The average ratio of TSP served to requested before signal retiming is 33.13%. The average percentage of TSP served to requested after signal retiming is 35.29%.

Before Signal Timing



After Signal Timing



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Pedestrian Delay

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Estimating Pedestrian Delay

Why?

- Pedestrians' level of frustration grows with the increase of pedestrian Delay.
- Delay, in general, is one of the most significant signal performance measures
  - Quantifies the operation level of service of intersections.
- Delays affects pedestrians disproportionately when compared to other users.

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Methodology & Data Collection

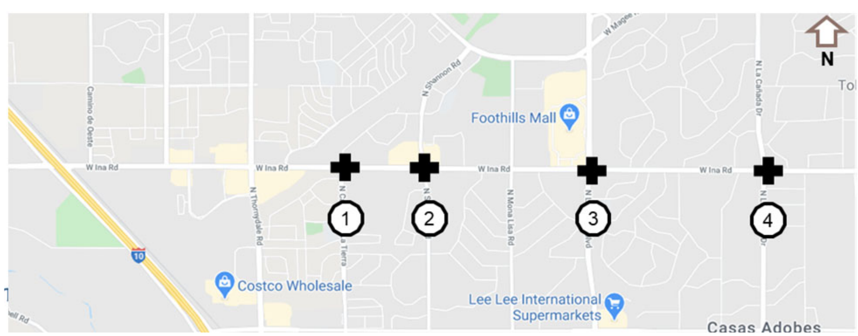
Cycle Length

Traffic Flow

Ped. Delay

Ped. Green Time

High Resolution Event-based Data

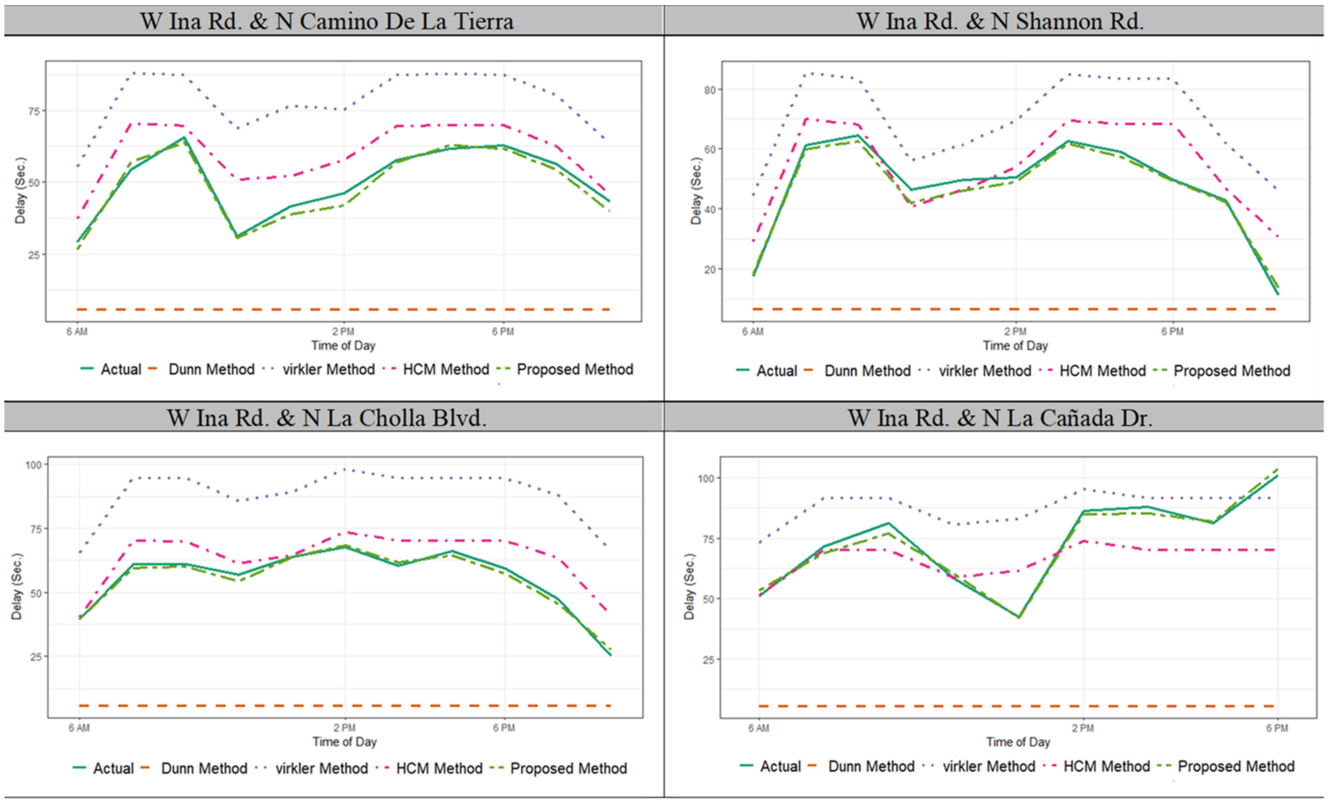


Identify specific variables that can best characterize pedestrian delay distribution function

Develop a pedestrian delay estimation model using finite mixture modeling

Assess transferability to other intersections on the network

Model Evaluation & Comparison



HCM 2010 Method (similar to HCM 6th edition):

$$d_p = \frac{0.5\,(C-g)^2}{2g}$$

Virkler Method (Virkler 1998) :

$$d_p = \frac{(c-(g+0.69A))^2}{2c}$$

Dunn Method (Dunn and Pretty, 1984):

$$d_p = \frac{(g+10)^2}{2(g+15)}$$

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Test of disaggregated prediction

(Hubbard et al., 2008)

Model Transferability

- Calibrating estimation models is usually a costly, complex, and time-consuming procedure
- It is not always feasible for agencies to collect sufficient traffic data at each individual intersection

	RMSE (Seconds)	**Predicted based on**			
		W Ina Rd. & N Camino De La Tierra	W Ina Rd. & N Shannon Rd.	W Ina Rd. & N La Cholla Blvd.	W Ina Rd. & N La Cañada Dr.
Trained based on	W Ina Rd. & N Camino De La Tierra		17.64 (40.24)	19.17 (39.46)	22.35 (42.92)
	W Ina Rd. & N Shannon Rd.	10.91 (38.98*)		12.34 (39.46)	14.78 (42.92)
	W Ina Rd. & N La Cholla Blvd.	15.4 (38.98)	14.7 (40.24)		13.06 (42.92)
	W Ina Rd. & N La Cañada Dr.	19.56 (38.98)	18.1 (40.24)	17.91 (39.46)	

Application

- More reliable, robust, and accurate approach for estimating pedestrian delay at signalized intersections
- Develop pedestrian delay density function
  - For analyzing the risk of pedestrians violating the signal
- Network-wide model for estimating pedestrian delay

Project Takeaways

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Key Learnings

- Understand the impacts of speed feedback sign along traditional corridors
- Understand the impacts of signal retiming and coordination, on transit signal priority
- Feasibility of using controller event-based traffic data for estimating multimodal signal performance

Broader Impacts

- Improved corridor safety by proposing innovative speed management strategies
- Improved corridor mobility by proposing signal timing practices
- Encouraged the use of eco-friendly mode choices on the corridors
- Encouraged more people to walk and bike
- Triple University Collaboration
- University-Public agency collaboration

Thank you! Questions?

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Appendix

Speed Feedback Sign

Impact on Intersection Delay

Delay					
$H_0: \mu^{Si}_{De_{ON}} = \mu^{Si}_{De_{OFF}}$ H_a= for at least one segment, the mean delay before and after disabling the SFS is different	Through	AM-Peak	6	0.11	✗
		PM-Peak	6	0.11	✗
		Off-Peak	6	0.11	✗
	Left	AM-Peak	6	0.11	✗
		PM-Peak	6	0.11	✗
		Off-Peak	6	0.11	✗
$H_0: {\sigma^2}^{Si}_{De_{ON}} = {\sigma^2}^{Si}_{De_{OFF}}$ H_a= for at least one segment, the variance of delay before and after disabling the SFS is different	Through	AM-Peak	5.4	0.14	✗
		PM-Peak	5.4	0.14	✗
		Off-Peak	6	0.11	✗
	Left	AM-Peak	6	0.11	✗
		PM-Peak	6	0.11	✗
		Off-Peak	6	0.11	✗

At a significance level of 0.05, there is not sufficient evidence to reject the null hypothesis

The existence of SFS does not have a statistically significant impact intersection delay

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Speed Feedback Sign

Impact on Intersections Split Failure

	Friedman Test	Movement	Period	Chi-Square (X^2)	P-Value	Decision*
Split Failure						
Mean	$H_0: \mu^{Si}_{SF\,ON} = \mu^{Si}_{SF\,OFF}$ H_a= for at least one segment, the mean split failure before and after disabling the SFS is different	Through	AM-Peak	5.4	0.14	✗
			PM-Peak	6	0.11	✗
			Off-Peak	6	0.11	✗
		Left	AM-Peak	6	0.11	✗
			PM-Peak	6	0.11	✗
			Off-Peak	6	0.11	✗
Variance	$H_0: {\sigma^2}^{Si}_{SF\,ON} = {\sigma^2}^{Si}_{SF\,OFF}$ H_a= for at least one segment, the variance of split failure before and after disabling the SFS is different	Through	AM-Peak	5.4	0.14	✗
			PM-Peak	6	0.11	✗
			Off-Peak	5.4	0.14	✗
		Left	AM-Peak	6	0.11	✗
			PM-Peak	6	0.11	✗
			Off-Peak	6	0.11	✗

The existence of SFS does not have a statistically significant impact on either the split failure

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