

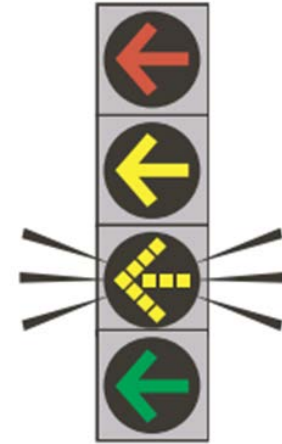
Flashing Yellow Arrow

Andi Bill and Kelvin Santiago-Chaparro

Evaluation of the Impact of Separate
and Shared Yellow Signal Sections
and Head Arrangements for
Flashing Yellow Arrow (FYA)
Left-Turn Control

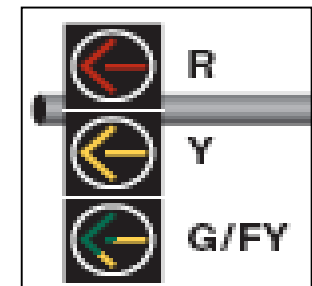
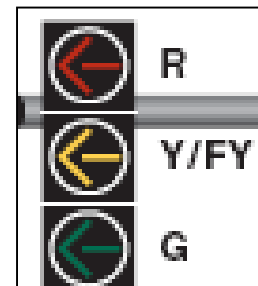
Problem Statement

- FYA approved by FHWA in 2006
 - Four-Section Vertical or Horizontal
 - Level of implementation has varied across the country



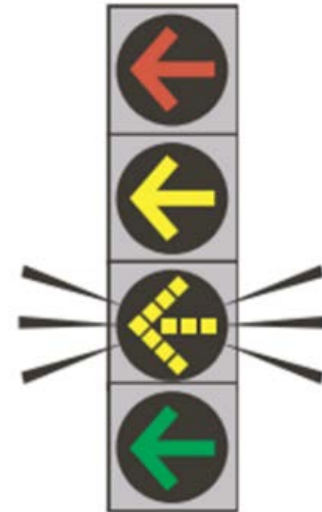
- Retrofitting existing signal displays with bimodal FYA

- Cost-Effective & Quicker Implementation
- Limited Research



Literature Review

- Summary of NCHRP Report 493
 - FYA indication shows significantly higher level of driver comprehension than CG
 - Recommended the FYA for permissive left-turn control



Literature Review

- Summary of FYA Driver Comprehension Studies after NCHRP Report 493
 - FYA in the five-section clustered signal display has potential to be used as a retrofit
 - FYA does not reduce comprehension of CG
 - FYA does not reduce comprehension of YA

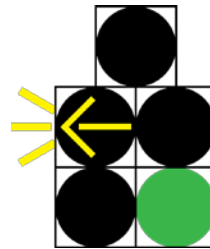
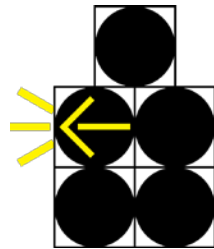
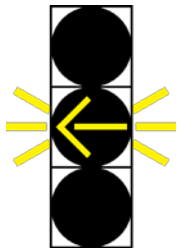
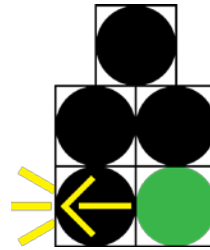
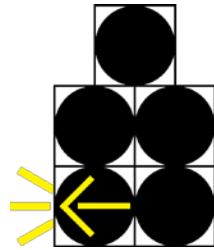
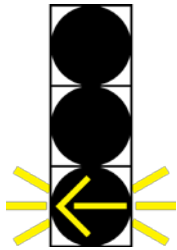
Study Design

- Computer Based Evaluation
- Data Collection Locations
 - Madison, WI
 - Amherst, MA
- Demographic Questions
 - Gender
 - Age
 - Driving Experience
- 15 Questions per Participant



Study Design: Experimental Scenarios

- 36 Experimental Scenarios



Primary Variables:

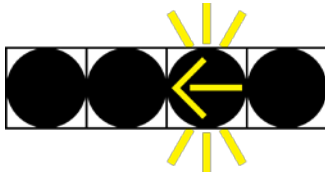
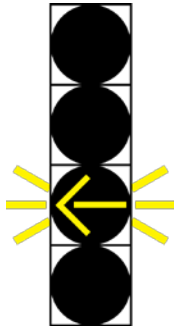
- FYA Location
- Display Type

Other Variables:

- Through Indication
- Opposing Traffic

Study Design: Baseline Scenarios

- 12 Baseline Scenarios (MUTCD Standard)



Primary Variable:

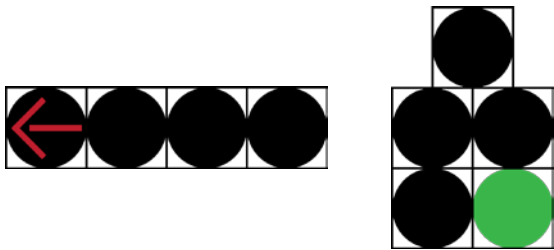
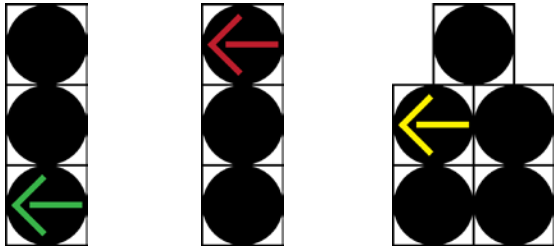
- Display Type

Other Variables:

- Through Indication
- Opposing Traffic

Study Design: Control Scenarios

- 36 Control Scenarios



Left-Turn Indications:

- Red Arrow
- Green Arrow
- Yellow Arrow
- Circular Green or Red

Variables:

- Display Type
- Through Indication
- Opposing Traffic

Study Design: Evaluation Screenshot

If you want to turn left and see the signal indications shown below, you are...



- not allowed to turn left, stop
- allowed to turn left; however, you must wait for a large enough opening in the oncoming traffic before doing so, yield
- allowed to turn left since the oncoming traffic must stop, go
- not sure whether or not a left-turn is allowed

Next Question

Introduction to Results

447 Participants

8,948 Scenarios Evaluated

5,723 Scenarios featured Bimodal FYA

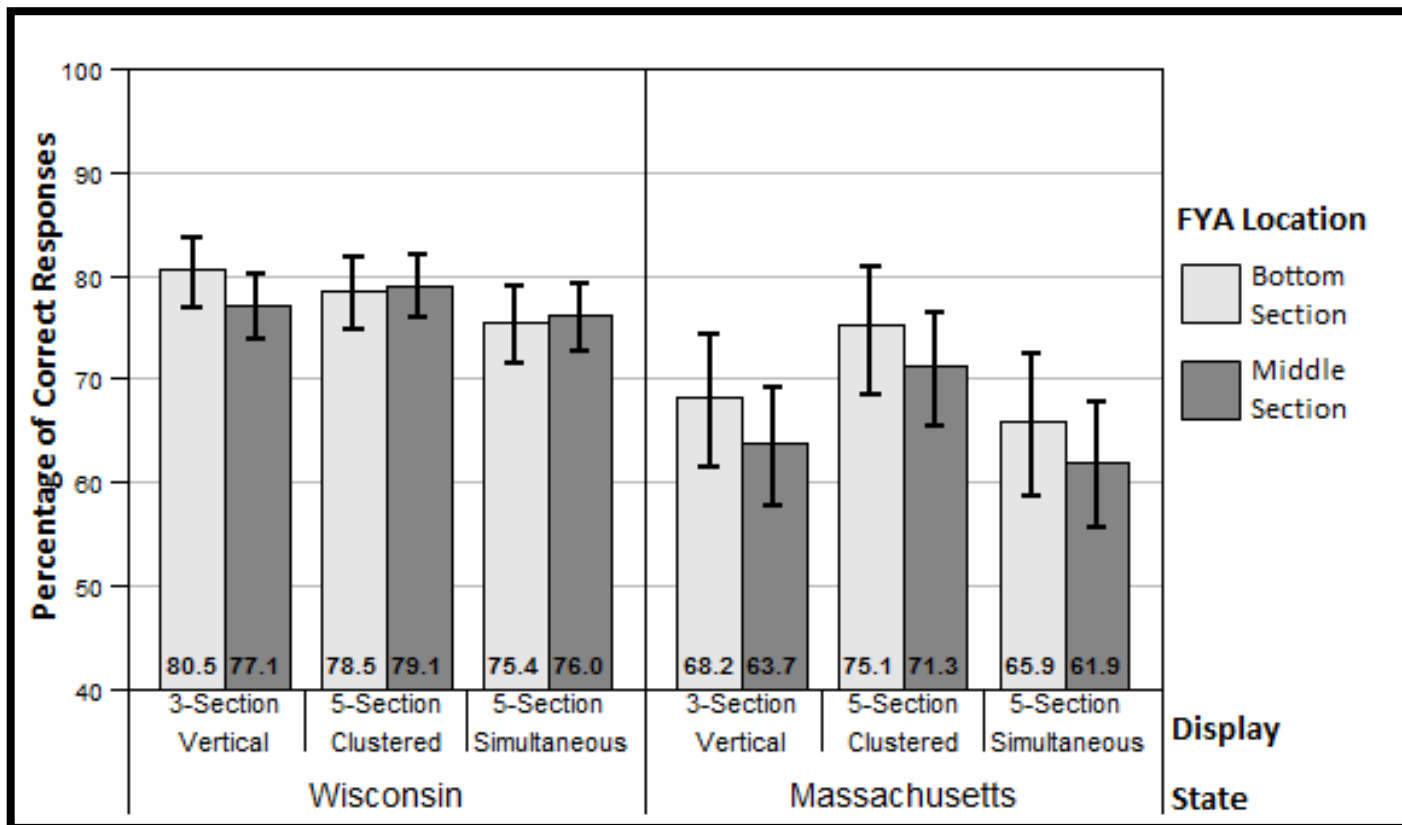
FYA Location Comparisons

FYA w/ Green Bimodal (Bottom) vs FYA w/ Yellow Bimodal (Middle)

FYA Section	Wisconsin		Massachusetts	
	(%)*	P Value	(%)*	P Value
Middle	77.4	0.6170	68.1	0.3421
Bottom	78.1		70.0	
*Percentage of Correct (Yield) responses				
FYA Section	Wisconsin		Massachusetts	
	(%)**	P Value	(%)**	P Value
Middle	6.4	0.8125	11.1	0.3677
Bottom	6.6		9.9	
**Percentage of Fail-Critical (Go) responses				

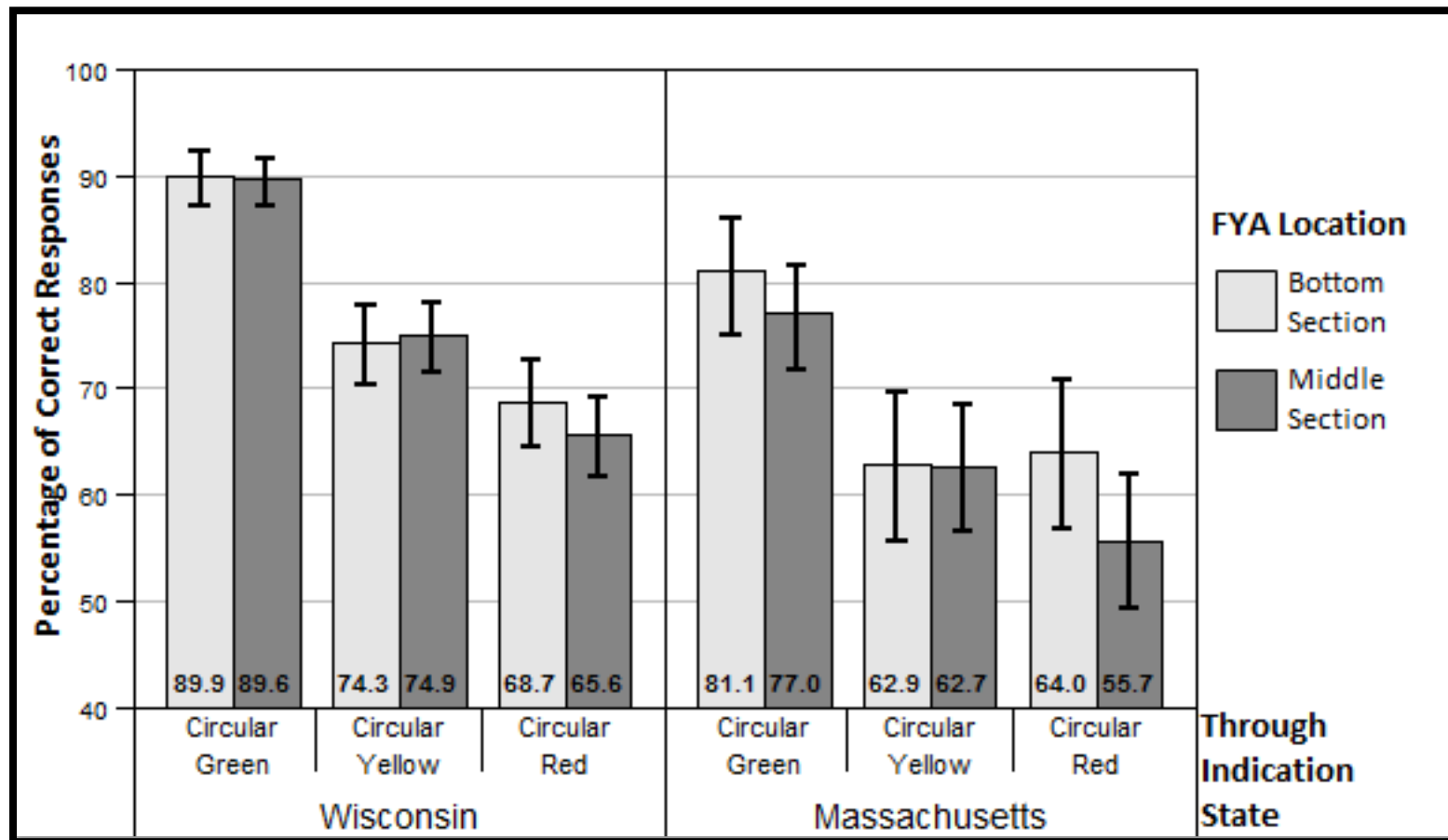
FYA Location Comparisons

FYA w/ Green Bimodal (Bottom) vs FYA w/ Yellow Bimodal (Middle)
Separated by Signal Display Type



FYA Location Comparisons

FYA w/ Green Bimodal (Bottom) vs FYA w/ Yellow Bimodal (Middle)
Separated by Through Indication



Observations from Evaluation

- Several participants thought they were being asked same question over and over again
- Participants expressed confusion regarding the solid yellow arrow
- A few participants commented about the use of supplemental signage

Conclusions

- Not a significant difference in driver comprehension when FYA was displayed bi-modally in the bottom section or bi-modally in the middle section.
- Driver comprehension was significantly lower when FYA was added to the five-section clustered display with simultaneous indications.
- Driver comprehension was significantly higher when through indication was green compared to red.

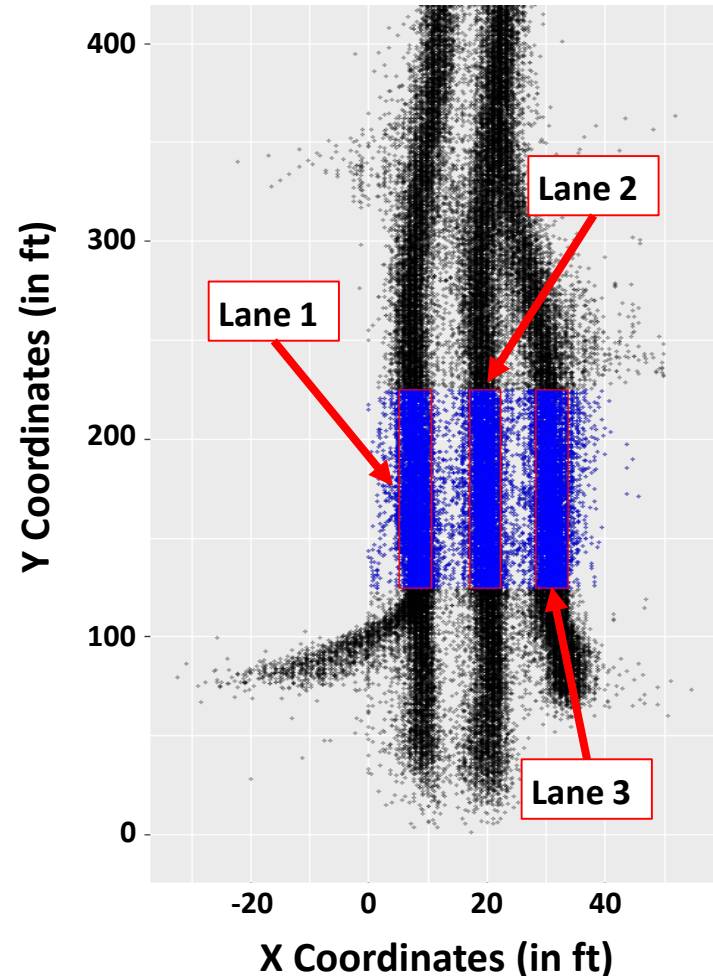
Contributions

- Potential to retrofit existing three-section vertical displays.
 - Quicker FYA implementation
 - Reduces cost of FYA implementation
- Through indication significantly impacts comprehension
 - Identifies potential future research
 - Need to develop ideas to improve this issue.

FYA for Left Turns

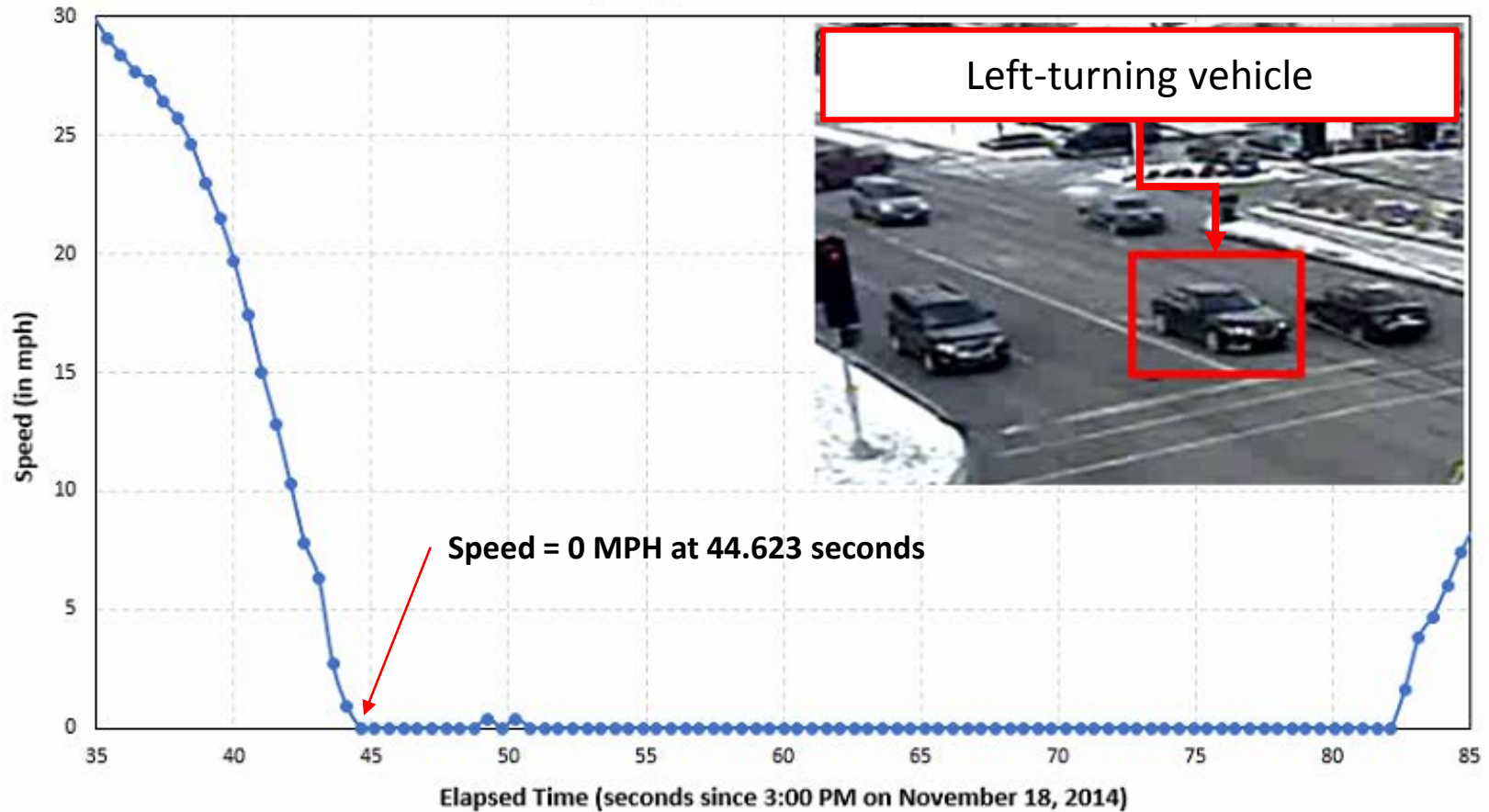
Identifying Trajectory Data of Interest

- Vehicle trajectories for left-turn lanes were identified for analysis
- Allows identifying the time-space diagram of left-turning vehicles
- Time-space diagram allows computation of detailed performance measures



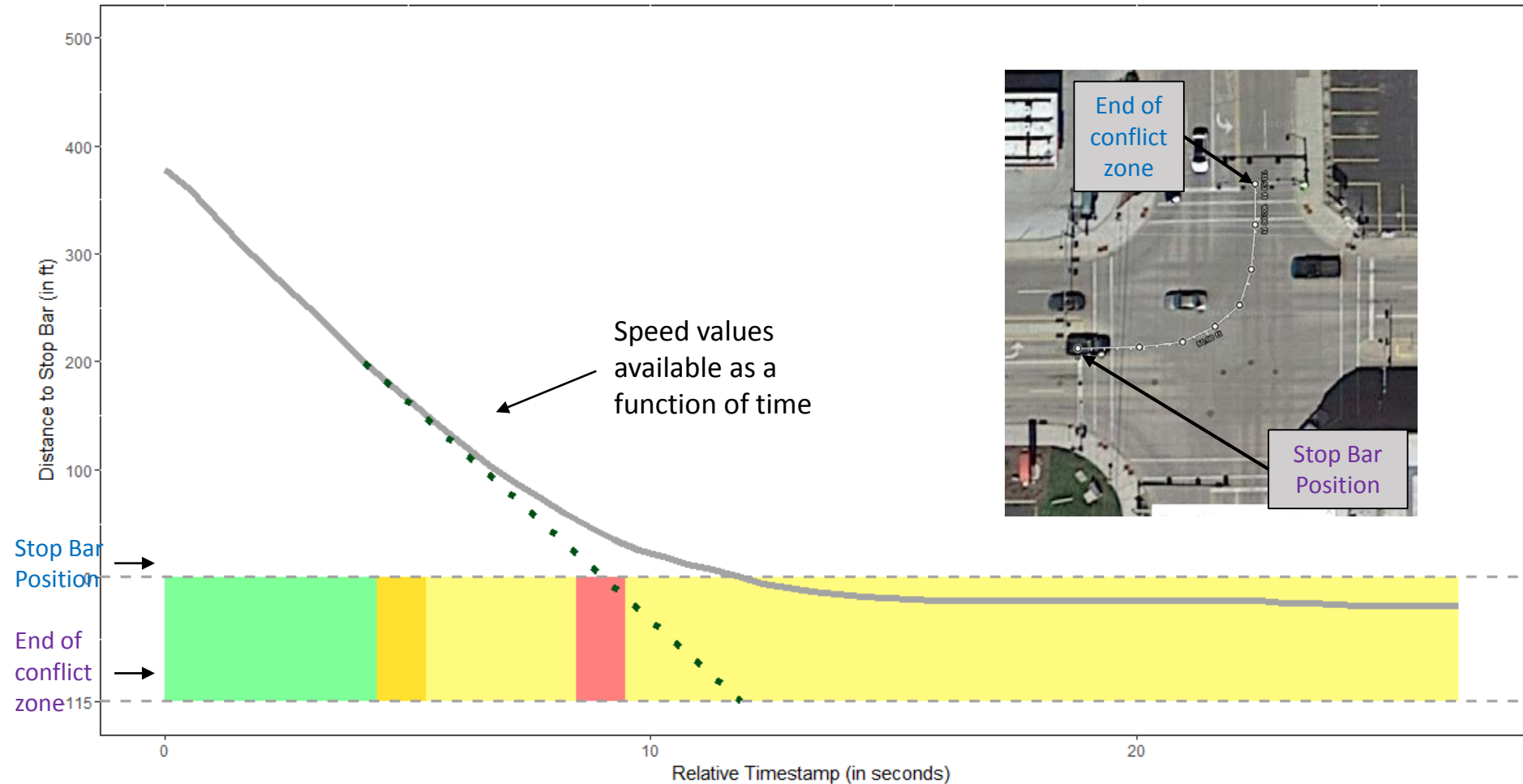
Example of Time-Space Diagram

Sample Speed Profile for SB Vehicle

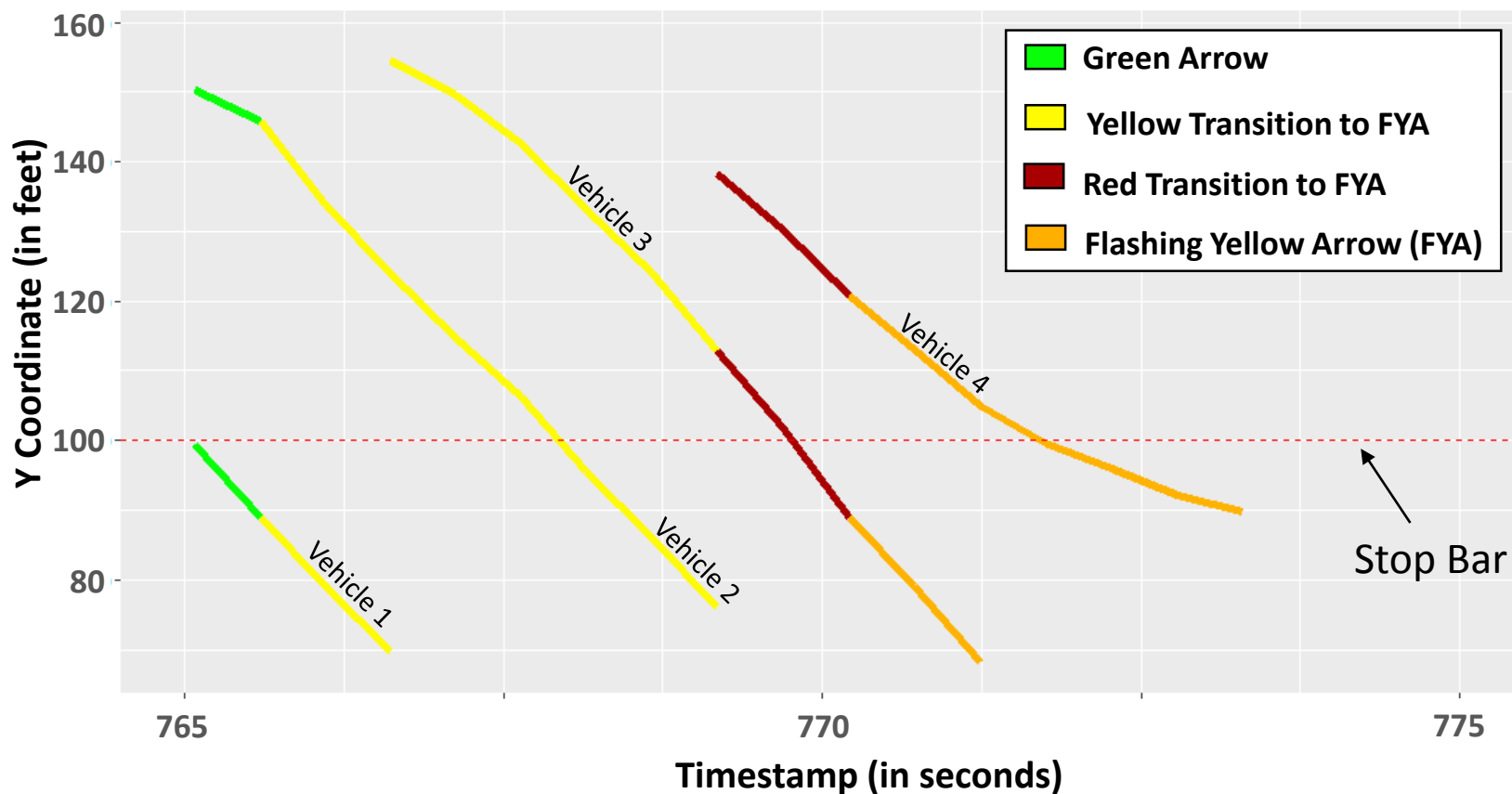


Adding Signal Status Information

Dilemma Zone Support Plot: EB_60_2014_11_18_15_20_9



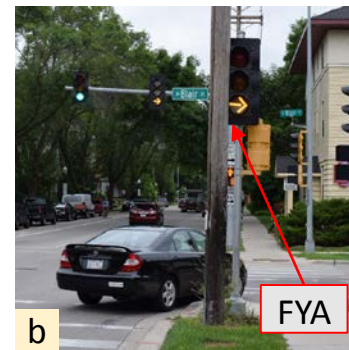
Possible to Study Interactions



FYA for Right Turns

Vehicle-Pedestrian Interaction Analysis

- Vehicle and pedestrians interactions analyzed on sites with and without FYA right turn indication
- Analysis focused on a reduction in the time a vehicle takes to complete a right turn
 - As a function of the pedestrian position
- Relied on a frame-by-frame analysis of video from study sites



Definition of Analysis Parameters

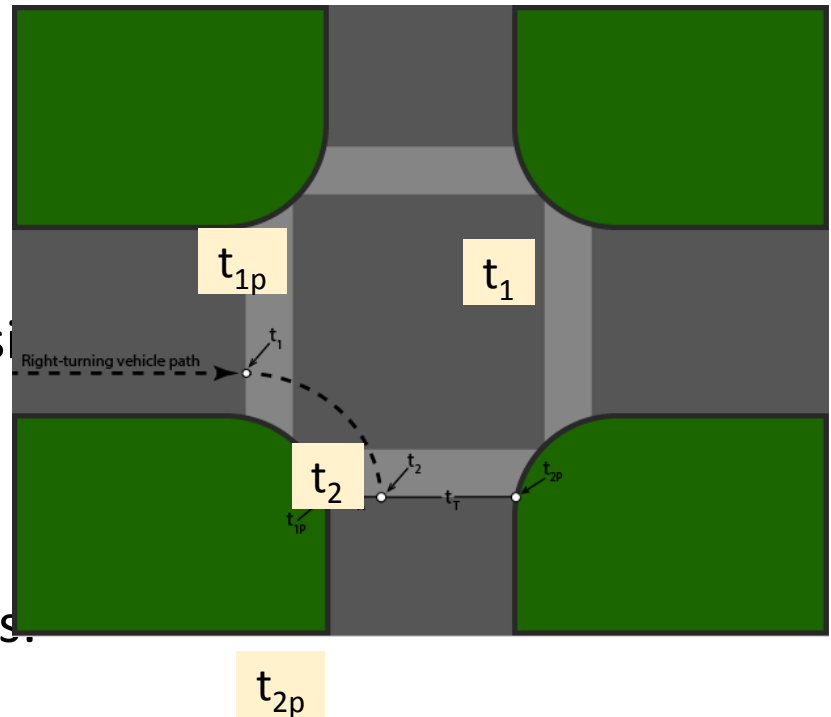
- Travel time for right turn (R_{TT}) computed for each vehicle-pedestrian interaction

- Computed as $t_2 - t_1$

- Average $\overline{R_{TT}}$ computed for the site when no pedestrians present

- Percentage difference between vehicle R_{TT} and $\overline{R_{TT}}$ computed as:

- $100 * (R_{TT} - \overline{R_{TT}}) / \overline{R_{TT}}$



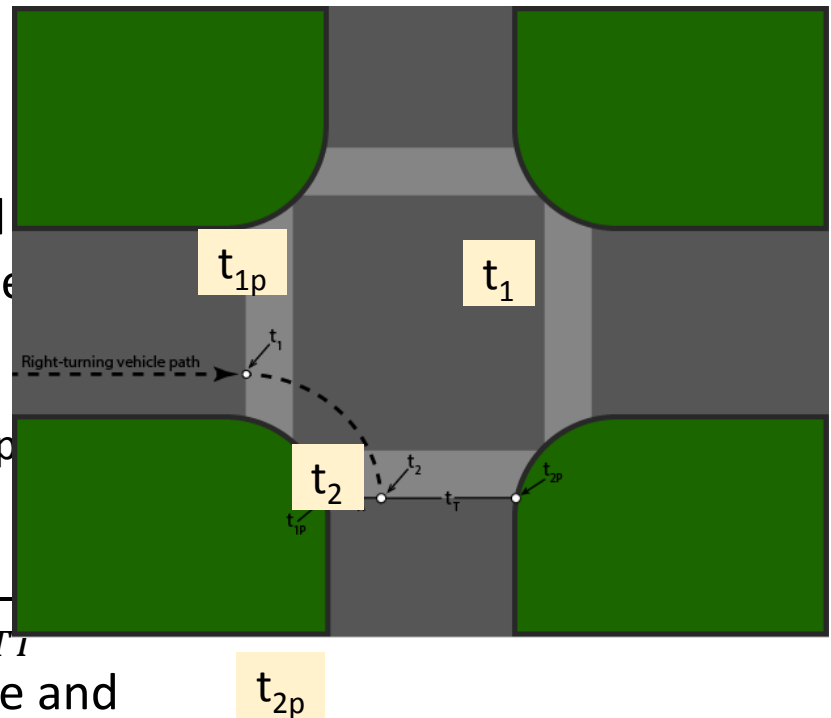
Definition of Analysis Parameters

- Position of pedestrian along the crosswalk (P_p) expressed as a percentage of completed crossing

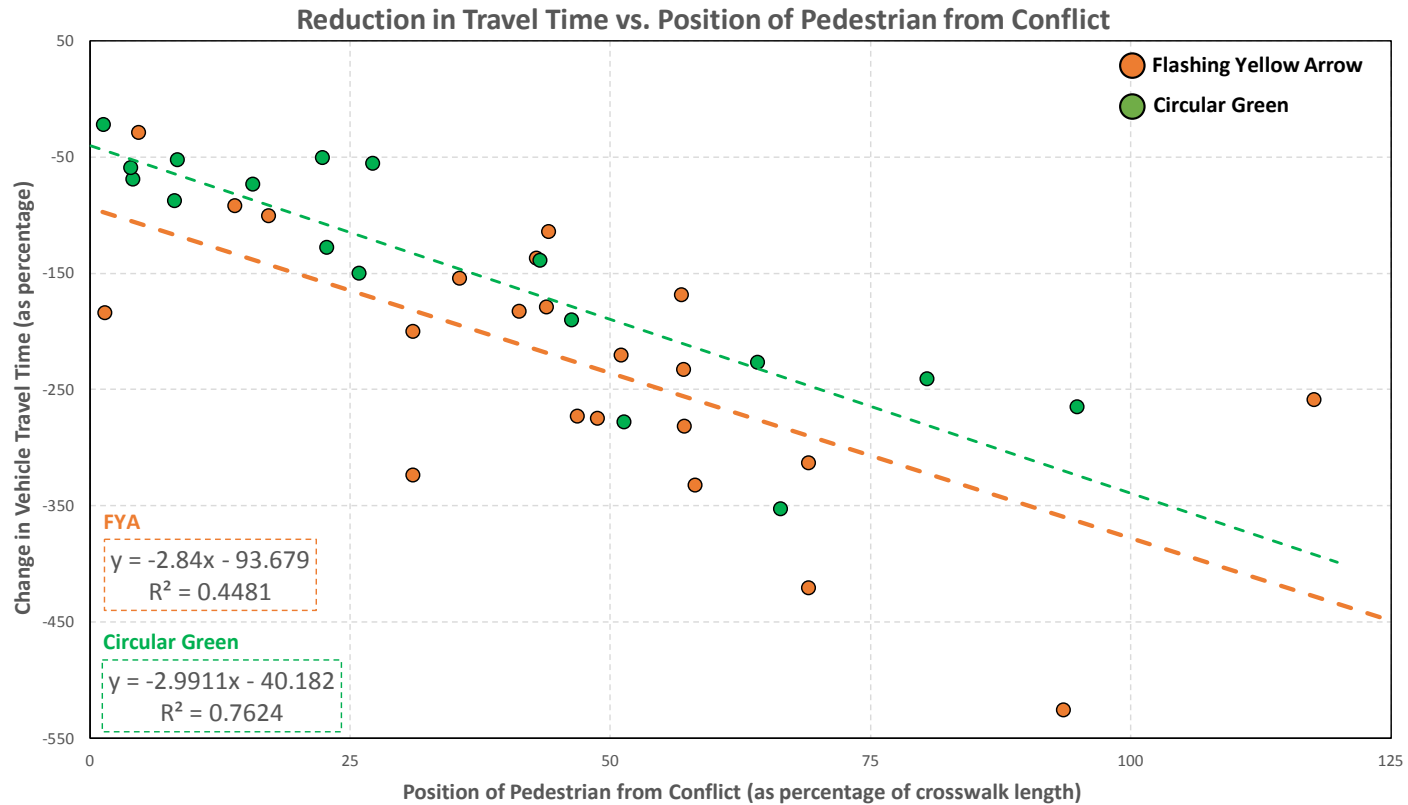
- P_p used to compute “distance” until conflict point is reached by the pedestrian

- Assumption of uniform pedestrian speed

- P_p is used along with the R_{TT} and \bar{R}_{TT} difference to understand the vehicle and pedestrian interactions



Preliminary Results



NCHRP 03-125 Evaluation of Change and Clearance Intervals Prior to the Flashing Yellow Arrow Permissive Left-Turn Indication

NCHRP 3-125 Respondents

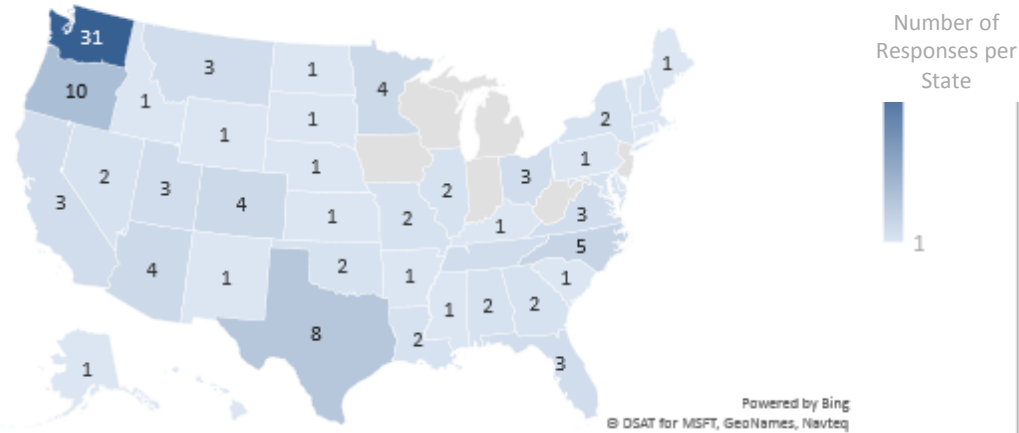


Figure 2: FYA and FRA Use

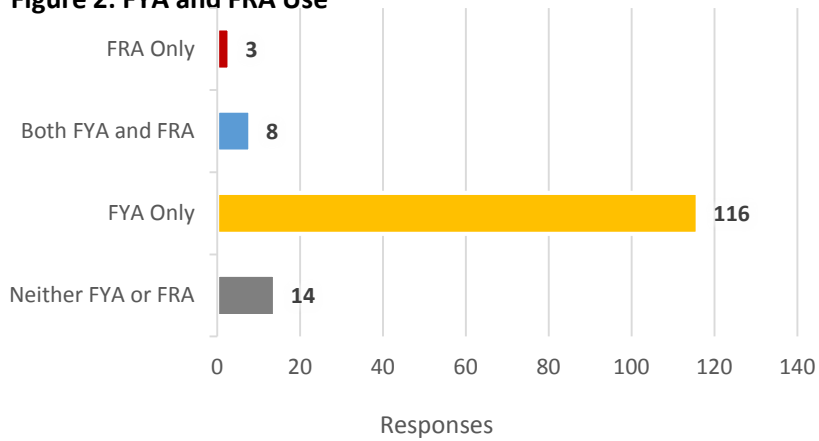


Figure 3: How is the Yellow Change Interval Timed

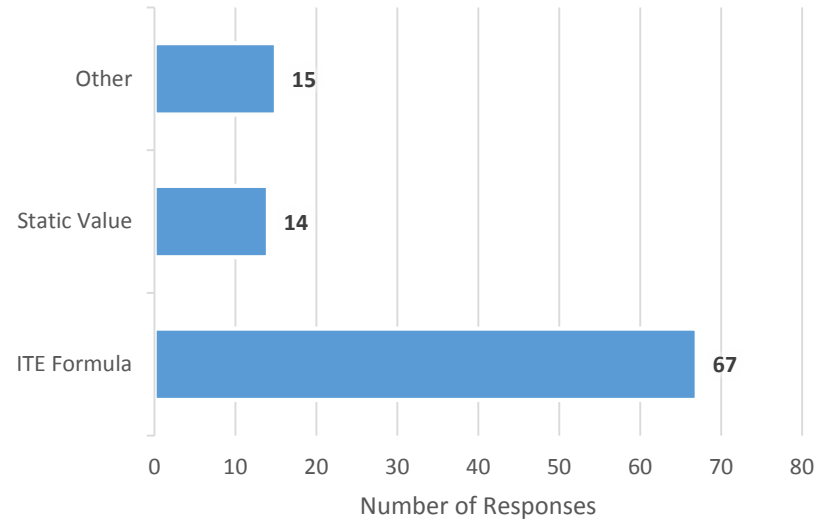


Table 1: Signal Head Configuration and Sequence

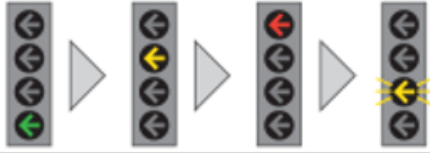
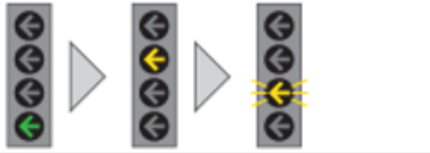
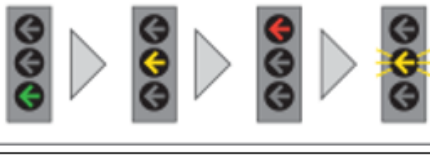
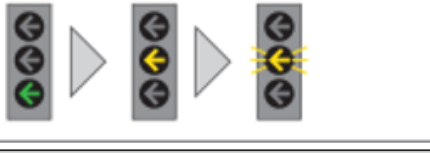
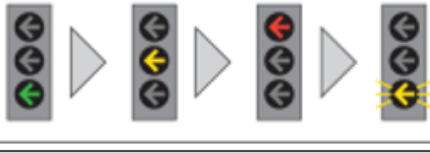
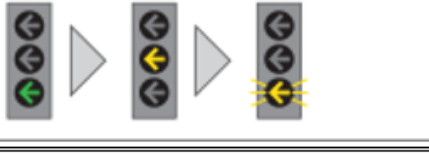
Display Type	Signal Head Configuration and Sequence of Signal Displays	Is Red Clearance Used?	Number of Respondents Using this Display
4-Section Displays		Yes	82
		No	24
3-Section Displays		Yes	9
		No	1
		Yes	15
		No	4

Figure 3: How is the Yellow Change Interval Timed

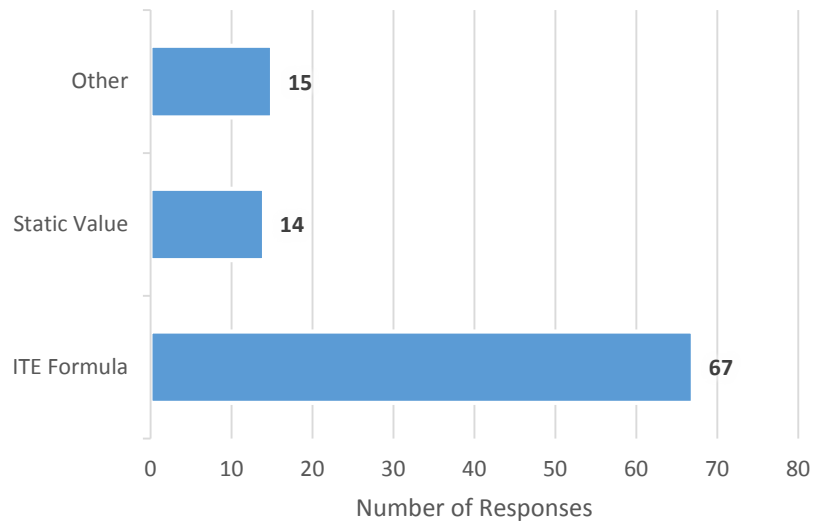
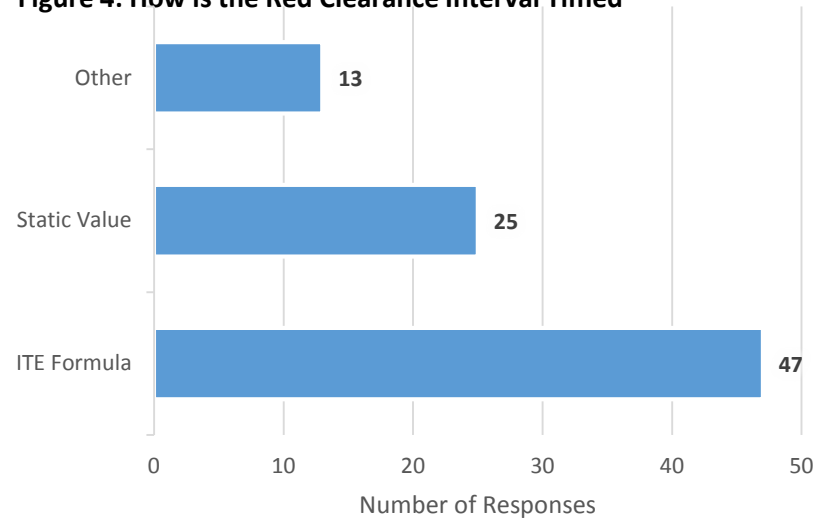


Figure 4: How is the Red Clearance Interval Timed



Next Steps

The identified variables are listed as follows:

Human Factors

Driver age
Driver experience
Driver distraction
Driver expectancy
Driver familiarity
Driver behavior (response)
Changes in driver behavior due to operational impacts (response)
Failure responses (response)

Intersection and Operational Variables

Geographic location	Opposing left-turn phasing strategy
Area type	Delay of onset of opposing green
Intersection geometrics	Signal pre-emption affects
Number of opposing lanes	Controller capabilities
Opposing vehicle at the transition	Time of day
Ped presence during yellow phase	Varying environmental factors
Conflicting pedestrian volumes	Time in queue
Conflicting vehicle volumes	Length of queue behind vehicle
Conflicting vehicle types	Number of legs
Conflicting right turn lane	
Opposing vehicle moving or stopped	
Opposing approach operating speed	
Traffic control devices used	
Cycle length and phase durations	
Yellow and red interval timing methods and duration	

Thank you!