Driver Yielding Behavior at RRFB-Enhanced Crosswalks in Alabama

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AUBURN UNIVERSITY
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Research Project 931-110R
Develop RRFB Supplemental Strategies for Improving Pedestrian Safety

- Tasks

Part 1 (05/24-08/25)

1. Literature Review
2. Data Collection
3. Pedestrian and Driver Behavior Data Analysis
   - **RRFB Push Button Placement**
   - **Pedestrian Sight Distance**

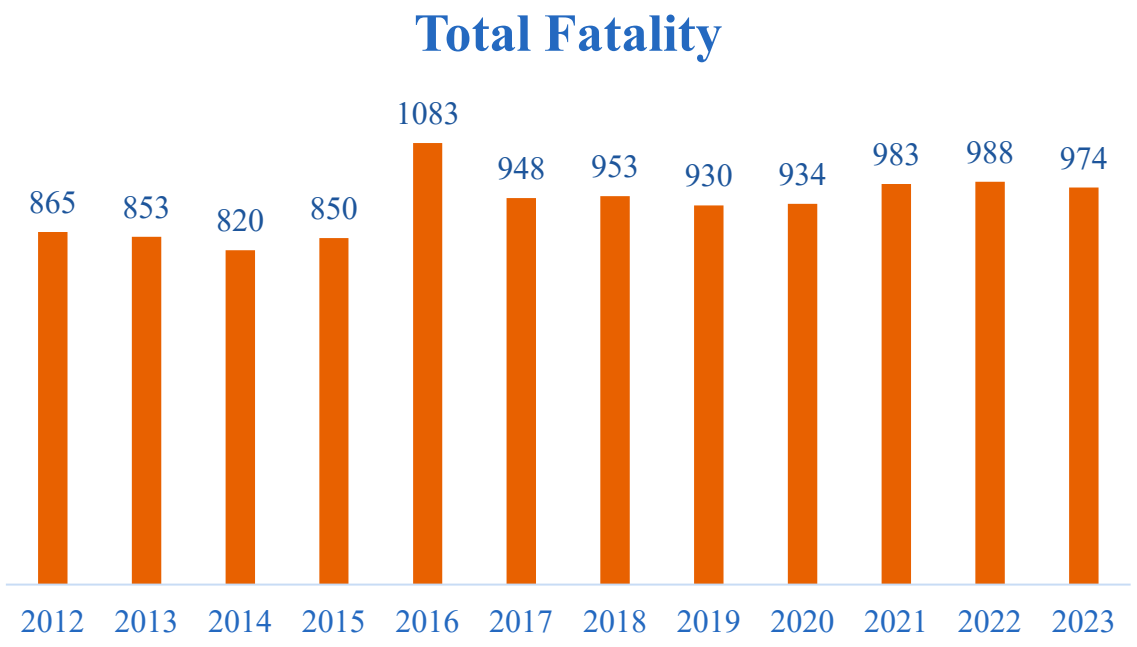
Part 2 (08/25-05/26)

1. Develop RRFBs Improvement Strategies and Evaluate their Effectiveness

BACKGROUND

PEDESTRIAN FATALITY : ALABAMA CASES

- Pedestrian fatality increased by **60%** (2012-2023) while overall fatality on Alabama roads increased by 12%
- **124** people died in 760 pedestrian crashes in 2023



Total and Pedestrian Fatalities in Alabama Roads (2012-2023) [Source: FARS]

BACKGROUND

RRFB: CHALLENGES

❑ **Mixed Effectiveness**

✓ Inconsistent results, with wide range of rates from 45% to 98% at RRFB crosswalk

❑ **Before-and-After RRFB**

✓8% reduction to 28% increase from past studies

✓17% increase based on a case study at Auburn

❑ **Potential Factors**

✓Roadway geometry

✓Pedestrian characteristics

✓Vehicle characteristics

LITERATURE REVIEW

- CONTRIBUTORY FACTORS

Road Geometry, Pedestrian and Vehicle Characteristics

Author		Year	Study Sites	Road Geometry						Pedestrian							Vehicle			
Names		Publication	# of study sites (midblock)	Type of crosswalk	# of lanes	Width of the traffic lanes	Width and length of crosswalk	Pedestrian Refuge Island	Stopping Distance	Gender	Age	Volume	Position at Waiting Area	Waiting time	Crossing time	Behavior whilst crossing	Type of vehicles	Speed of Vehicles	Traffic Volume	Traffic Density
Fitzpatrick et al		2014	7	✓	✓		✓	✓												
Porter et al		2016	2		✓		✓	✓		✓	✓	✓	✓				✓		✓	
Zheng et al		2020	19	✓			✓					✓	✓			✓			✓	
Govindaa et al		2020	2	✓			✓			✓	✓	✓				✓			✓	
Anciaes et al		2020	20	✓				✓		✓	✓	✓			✓		✓	✓	✓	
Torres et al		2020	4	✓						✓	✓	✓				✓	✓		✓	
Kadali and Vedagir		2020	8		✓			✓						✓			✓			
Olszewski et al		2015	1			✓				✓	✓							✓		
Bendak et al		2021	5		✓					✓	✓	✓		✓		✓				
Tezcan et al		2019	4		✓					✓	✓		✓						✓	
Sucha et al		2017	4				✓					✓						✓	✓	✓
Figliozzi and Tipagornwong		2016	1						✓			✓	✓			✓	✓	✓	✓	
Bella and Ferrante		2021	2	✓			✓						✓					✓		
Avinasha et al		2020	4		✓											✓	✓	✓	✓	
Count			*83*	*6*	*6*	*1*	*6*	*4*	*1*	*7*	*7*	*8*	*5*	*2*	*1*	*6*	*6*	*6*	*9*	*1*

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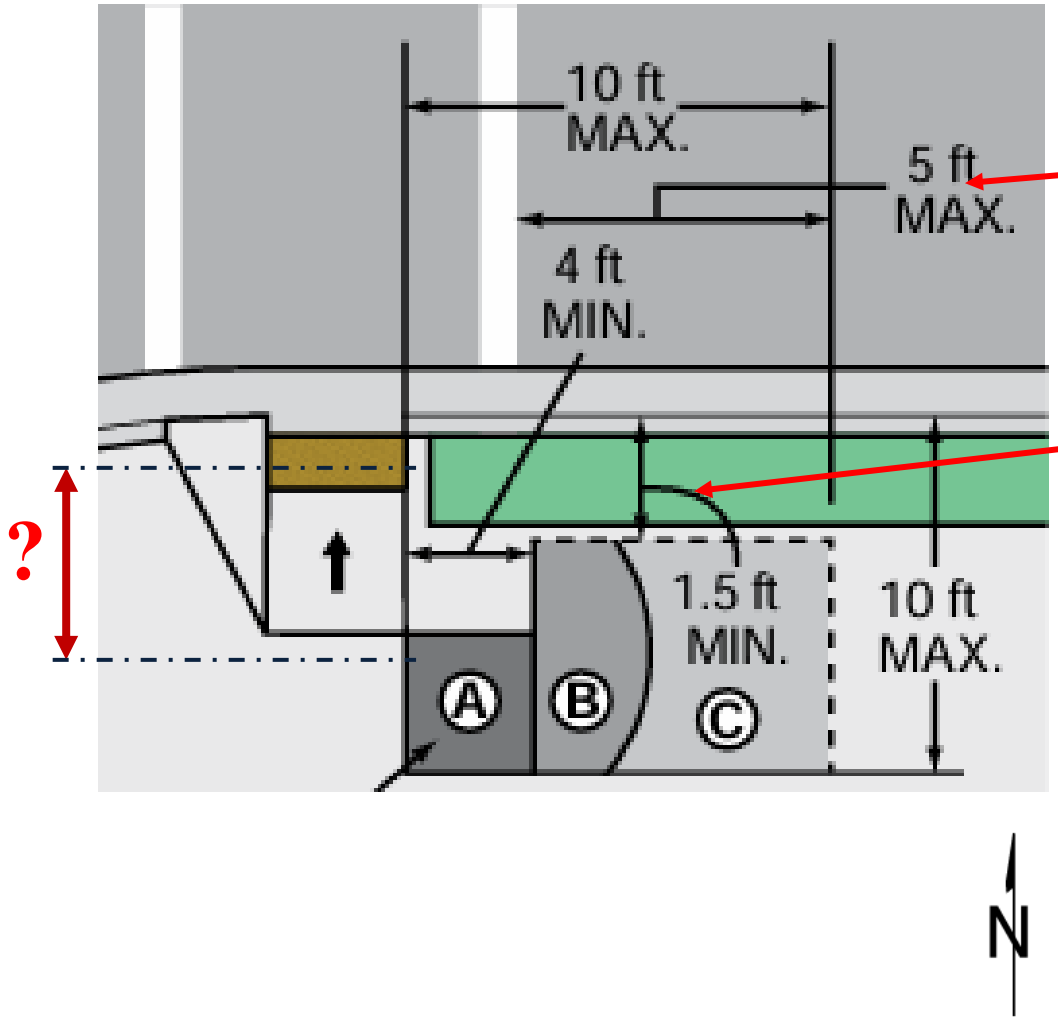
LITERATURE REVIEW

- MUTCD SPATIAL GUIDELINES



Section 4I.05 : **Pedestrian Detectors**

- ✓ Push Button detector should be located <=5ft from the outside edge of marked crosswalk
- ✓ Between 1.5 and 6ft from the face of the curb or from outside edge of shoulder
- ✓ With the face of the push button parallel to the crosswalks

MAX and MIN dimensions are recommendations

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DATA COLLECTION

- SPATIAL FACTOR – DISTANCE FROM EDGE OF CURB

✓ Push Button <=3feet

✓ Push Button > 3 feet

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RESEARCH GAP

- Few studies on how **spatial placement** of RRFB Push Button and **pedestrian crossing sight distance affect yielding rates**

OBJECTIVE

- Study pedestrian and driver behavior at RRFB crosswalks
- Develop supplementary strategies to enhance pedestrian safety

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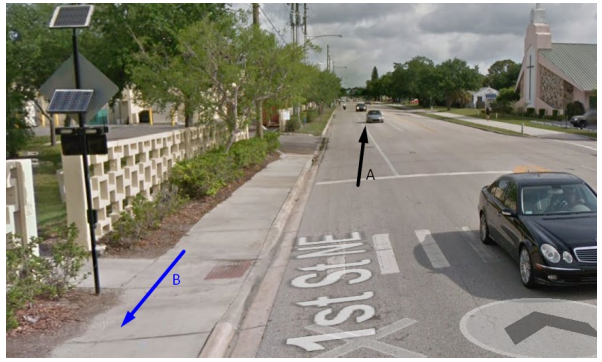
DATA COLLECTION

- SPATIAL FACTOR – FACE OF PUSH BUTTON

Type-1



Type-2

Type-3

Type-4

Face of RRFB Push Button

Face of Push Buttons

- ✓ Type 1 – Parallel to crosswalk, pedestrian facing traffic
- ✓ Type 2 – Parallel to crosswalk, pedestrian back toward traffic
- ✓ Type 3 – Parallel to sidewalk, pedestrian facing traffic
- ✓ Type 4 – Parallel to sidewalk, pedestrian back toward traffic

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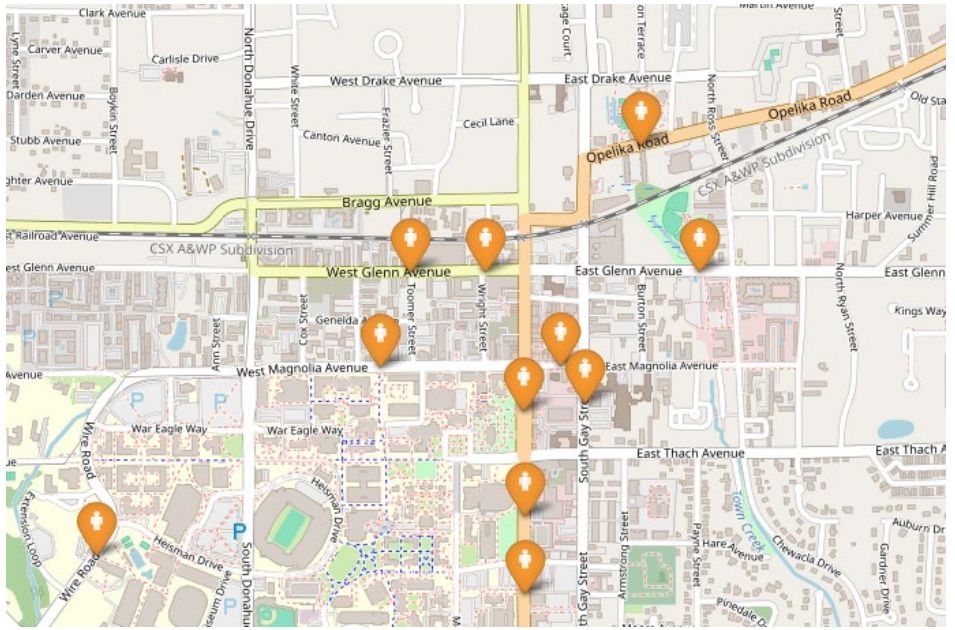
DATA COLLECTION

- STUDY SITE

Site ID	Land Use	Speed limit (mph)	AADT (vpd)	Number of Lanes	Median Type	Crosswalk offset	Type of Crosswalk	Number of RRFB
1	Mixed	15	10,184	3	TWLTL	Straight	Raised	2
2	Residential	30	3,141	2	Undivided	Straight	Raised	2
3	Residential	30	9,979	2	Undivided	Straight	Raised	2
4	Commercial	25	13,001	3	TWLTL	Straight	Flat	2
5	Mixed	25	16,113	4	TWLTL	Straight	Flat	2
6	Mixed	35	8,850	3	Left Turn Lane	Straight	Flat	2
7	Commercial	35	10,911	4	Raised	Offset	Flat	3
8	Commercial	25	15,162	2	Raised	Straight	Flat	2
9	Commercial	25	16,034	4	Raised	Offset	Flat	3
10	Residential	25	15,965	3	TWLTL	Straight	Flat	2
11	Mixed	25	12,213	4	Raised	Offset	Flat	3
12	Commercial	35	2,139	2	Undivided	Straight	Flat	2



Locations of 12 Crosswalks in Auburn

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DATA COLLECTION

- STUDY DESIGN

- ❑ **Duration**: 3 days per location
- ❑ **Distance**: 50 ~ 100 ft away from crosswalk
- ❑ **Height:** 8 ~10 ft

CountCAM4 Camera Field Installation

- ❑ Events – 1,038
- ❑ 70 – 90 per site
- ❑ Dependent Variables
  - ✓ Driver Yielding Rate
  - ✓ Pedestrian Usage
- ❑ Independent Variables
  - ✓ 12

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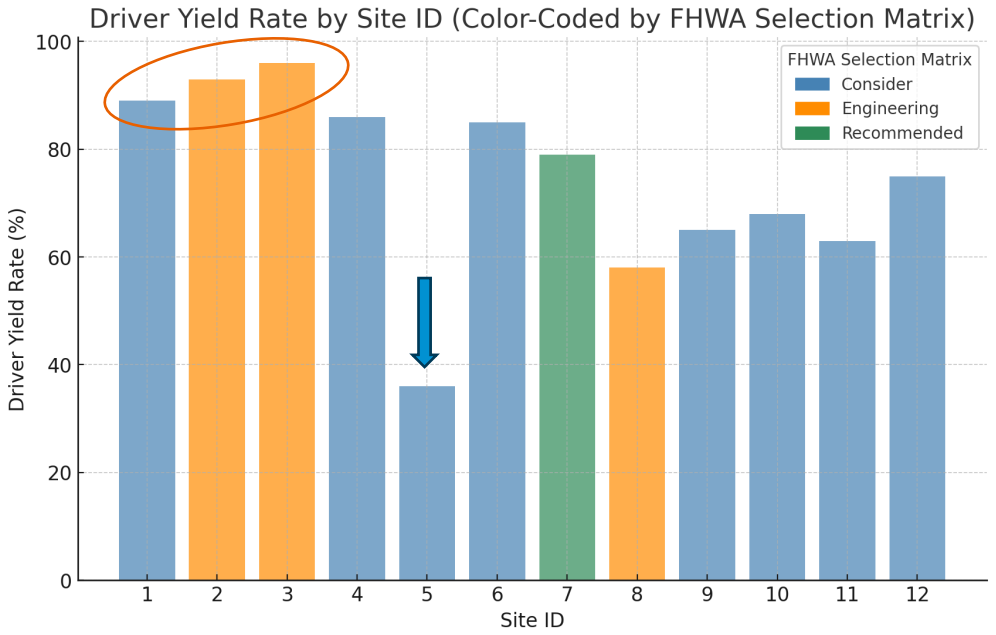
RESULTS

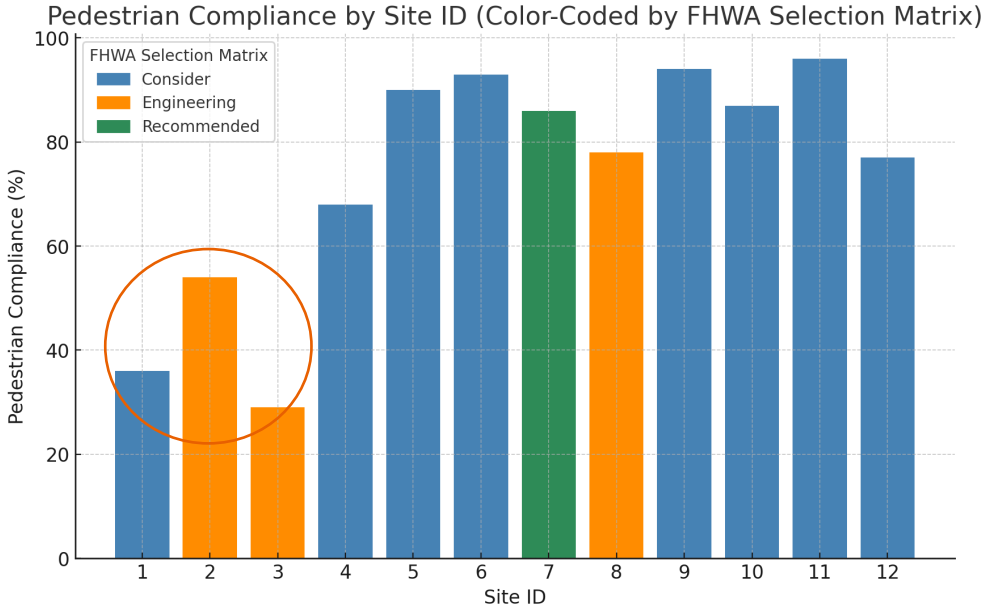
- DESCRIPTIVE ANALYSIS

❑ Driver Yielding Rate
✓ 24% Non -Yield

❑ Pedestrian Compliance
✓ 27% Non- Activate

❑ Events
✓ 64% Push Button <=3ft from road edge
✓ 68% Single Pedestrian
✓ 59% Traffic from one direction





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RESULTS

- DESCRIPTIVE ANALYSIS – DRIVER YIELD RATE

❑ Site 3 having the highest yielding rate (96%) with
- ✓ **2** lanes - **raised** crosswalk
- ✓ Push button parallel to crosswalk (**Type-1)**
- ✓ Push button > 3ft away from curb
- ✓ 30 mph

❑ Site 5 having the lowest driver yield (36%) with
- ✓ **4** lanes
- ✓ Push button **parallel to sidewalk** (**Type-4**)
- ✓ Push button > 3ft away from curb
- ✓ 25 mph

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RESULTS

- DESCRIPTIVE ANALYSIS – PEDESTRIAN USAGE

❑ Site 11 having the highest pedestrian usage (**96%**)
- ✓ **4** lanes
- ✓ Push button parallel to crosswalk - pedestrian faces oncoming traffic (Type-1)
- ✓ Push button **< 3ft** away from curb
- ✓ 25 mph

❑ Site 3 having the lowest pedestrian usage (**29%**)
- ✓ **2** lanes - **raised** crosswalk
- ✓ Push button (Type-1)
- ✓ Push button **> 3ft** away from curb
- ✓ 30 mph

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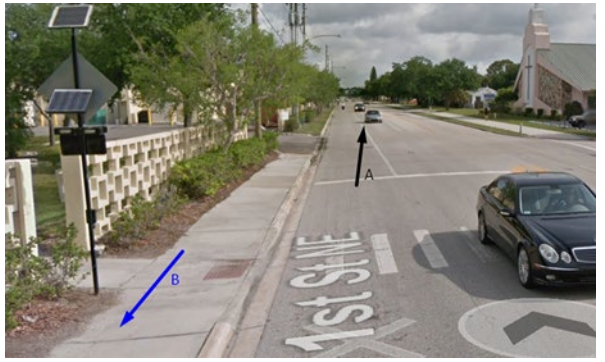
RESULTS

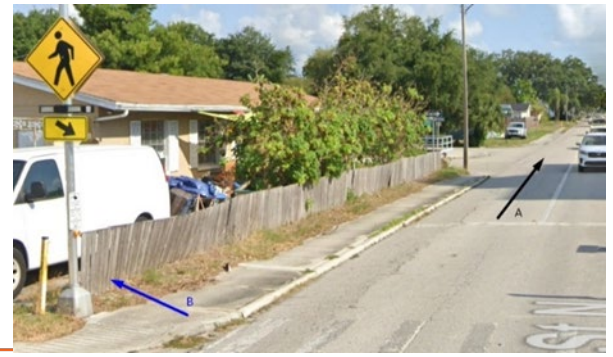
- STATISTICAL ANALYSIS

❑ Driver Yielding Rate

Significant predictors:

- ✓ Push button **>3 ft from curb** are increase yielding rate by **2.2 times** those **≤3 ft from the curb** (Increase reaction time before entering crosswalk)
- ✓ 2+ pedestrian increased yielding rate.
- ✓ Bi-directional traffic reduced yielding rate
- ✓ Face of Push button **parallel to sidewalk, pedestrian back toward traffic (Type 4) had lower** yielding rate **than** Type 1





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RESULTS

- STATISTICAL ANALYSIS

❑ **Pedestrian Compliance**

Significant predictors

Positive

✓ **Four-lane roads**: increase RRFB usage 5 times more than 2-lane roads

Negative

✓ **Distance from face of curb** >3 ft reduces the odds of usage by 87%

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PEDESTRIAN CROSSING SIGHT DISTANCE (PCSD)

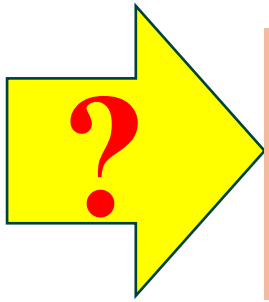
CURRENT SIGHT DISTANCE PRACTICE AND PEDESTRIAN NEEDS

CURRENT PRACTICE

- ❑ AASHTO SSD concept prioritize vehicle safety overlooking pedestrian needs
- ❑ Pedestrian variability is ignored
- ❑ No standardized sight distance metric for pedestrians

PEDESTRIAN NEEDS

- ❑ Variable reaction times and gap-judgment
- ❑ Yield rates influencing safety
- ❑ The impact of vehicle-pedestrian distance on yield rate remains underexplored



❑ If a pedestrian can see only up to the **SSD**, will the crossing be safe?

- ✓ Will the driver yield?
- ✓ Will it yield at a safe distance from crosswalk?

PEDESTRIAN CROSSING SIGHT DISTANCE (PCSD)

PEDESTRIAN CENTERED SIGHT DISTANCE

❑ Model by New Zealand Transport Agency:

$$PCSD = \frac{Crossing\ distance\ (m)}{Walking\ speed\ (m/s)} \times \frac{85th\ percentile\ vehicle\ speed\ (km/h)}{3.6}$$

CASE-STUDY

- ❑ Examine the correlation between driver yielding behavior and the pedestrian-vehicle distance at crossing initiation.
- ❑ Assess whether traditional SSD is sufficient for pedestrian safety, or a separate PCSD perspective is needed.

PCSD FOR DRIVER COMPLIANCE: A CASE STUDY

STUDY DESIGN : Site details

Marked crosswalk on South Gay Street adjacent to Town Creek park

- ✓ **Roadway Configuration** : 2-lane, 2-way undivided urban street
- ✓ **Posted Speed Limit** : 35 mph
- ✓ **AADT** : 2,139
- ✓ **Crosswalk Function** : Crossing between trail segments
- ✓ **Additional Features** : RRFBs, bike lanes
- ✓ **Observation Dates** : First 2 weeks of July 2025
- ✓ **Observation Time** : Daytimes (9:00 AM - 7:00 PM) on weekdays

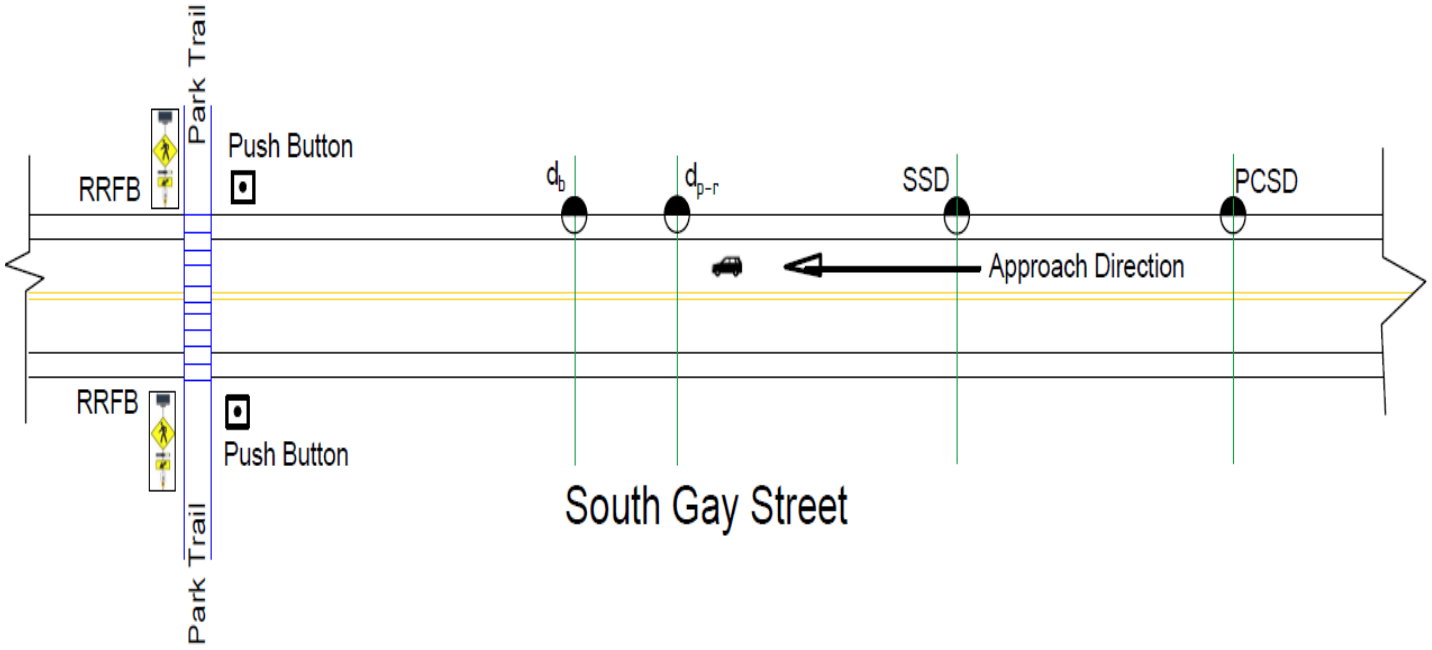
PCSD FOR DRIVER COMPLIANCE: A CASE STUDY

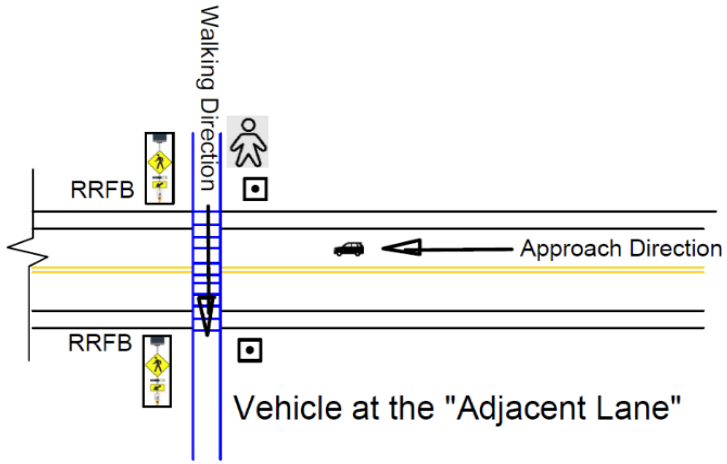
STUDY DESIGN : Field Experiment

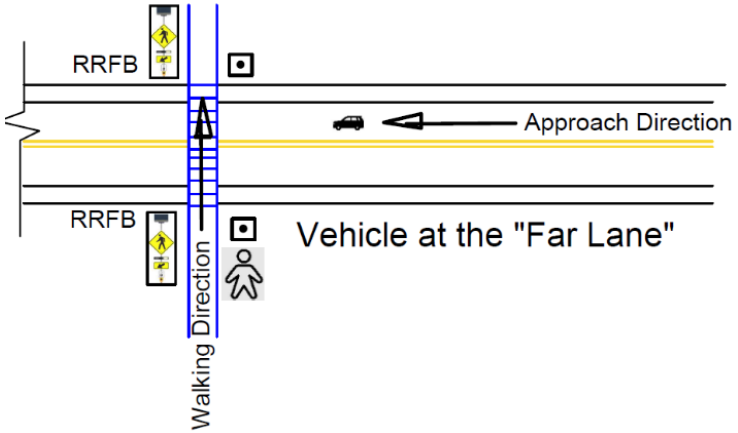
- ❑ Staged Crossings by a single researcher
- ❑ Recorded using video cameras and camera-fitted eyeglass
- ❑ Videos reviewed manually to extract event data
- ❑ A speed detector beyond the specific range recorded vehicle spot speeds

PCSD FOR DRIVER COMPLIANCE: A CASE STUDY

STUDY DESIGN : Data Collection Strategies







- A single direction of vehicle movement was studied
- Events recorded for vehicles positioned in five distinct ranges
- Events for “Adjacent Lanes” and “Far Lanes” based on crossing direction

PCSD FOR DRIVER COMPLIANCE: A CASE STUDY

STUDY DESIGN : Statistical Analysis

❑ **Chi-squared tests** to compare yield rates across categorical conditions,

$$Yield\ Rate(\%) = \frac{Number\ of\ motorist\ yielded\ to\ pedestrian}{Total\ number\ of\ vehicle - pedestrain\ interaction} \times 100$$

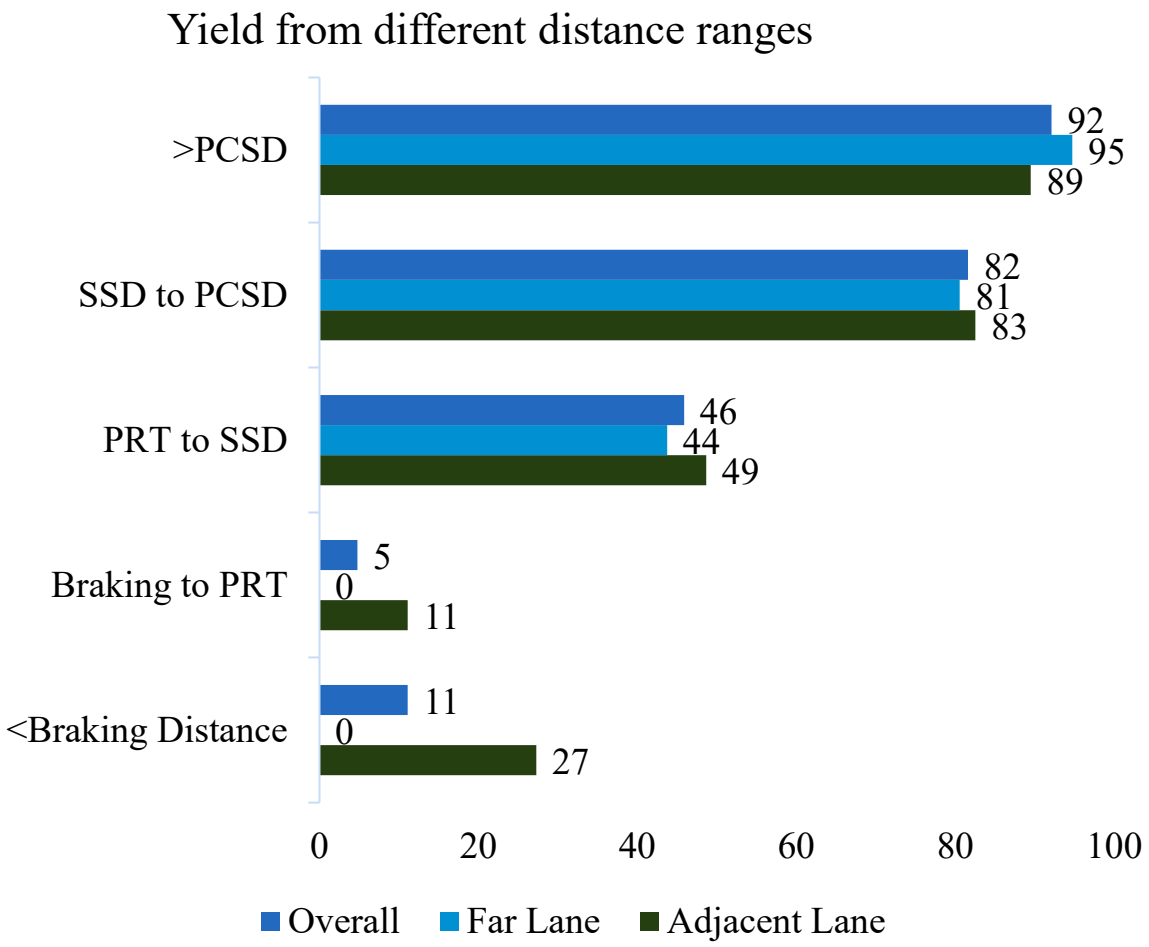
❑ **Binomial logistic regression** to model "Yield Rate" with approach speed, initial position, vehicle lane, and vehicle type.

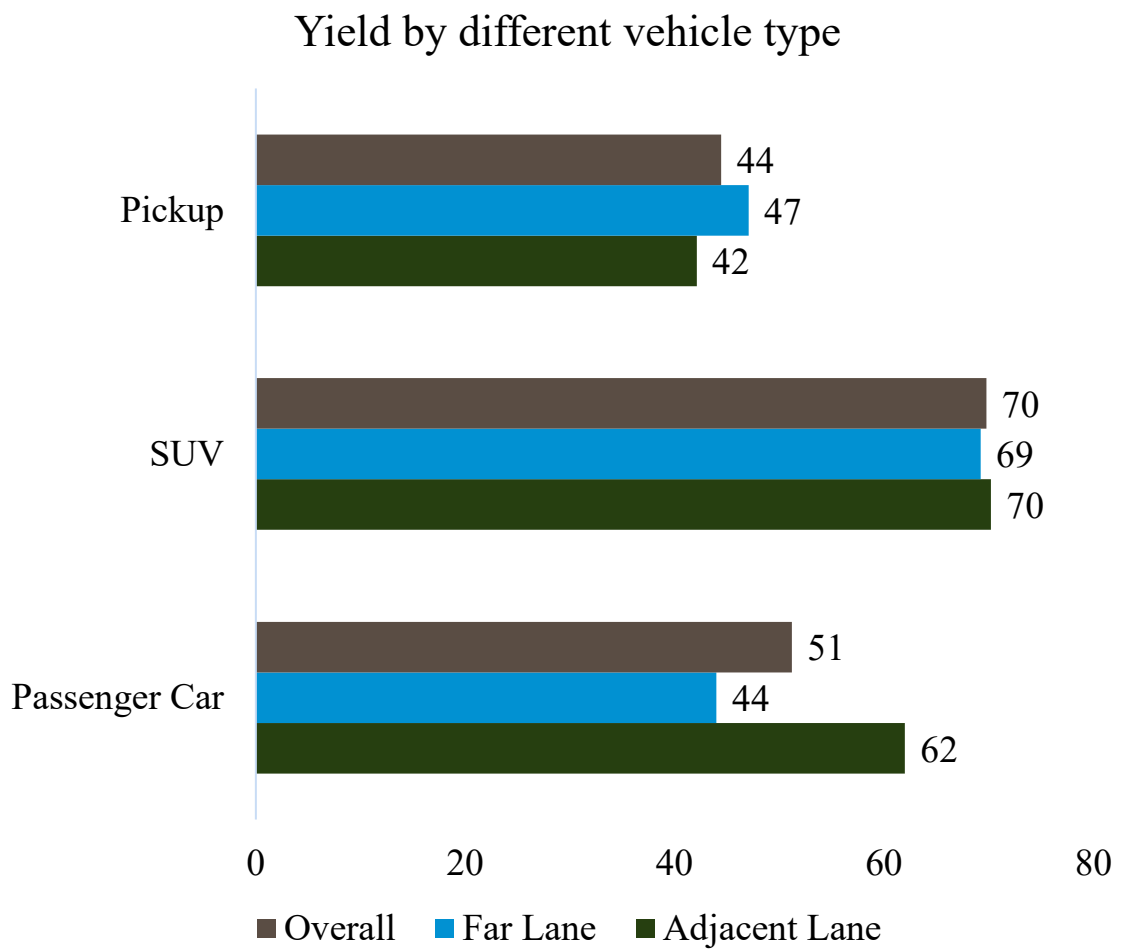
❑ **log-transformed linear regression** to model the yielded position with the same predictors.

Group	Variable Name	Type	Range/ Levels	Observations	
				Count	%
Dependent	Compliance	Categorical	Yield	144	56
			Non Yield	112	44
	Yielded Position	Numerical	5 – 180 ft	256	100
Independent	Approach Speed	Numerical	10 – 39 mph	256	100
	Initial Vehicle Position	Numerical	35 – 470 ft	256	100
	Initial Vehicle Position Range	Categorical	< braking distance	29	11
			braking to PRT distance	22	9
			PRT to SSD	88	34
			SSD to PCSD	76	30
			> PCSD	41	16
	Vehicle Lane	Categorical	Adjacent Lane	120	47
			Far Lane	136	53
	Vehicle Type	Categorical	Passenger Car	125	49
			SUV	86	33
			Pickup	36	14
			Other	9	4

PCSD FOR DRIVER YIELDING RATE: A CASE STUDY

RESULTS: YIELD RATE OBSERVATION





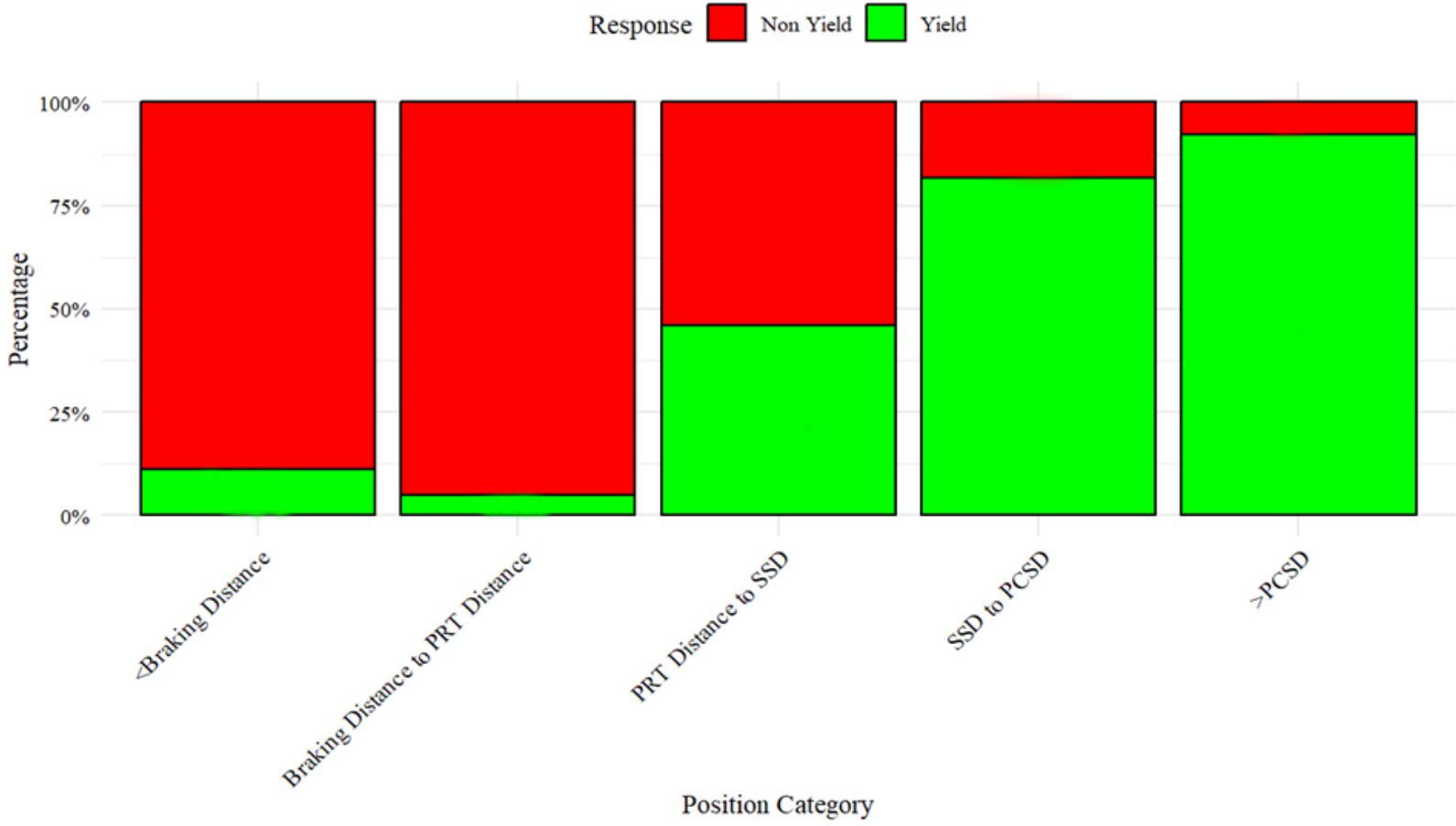
Lane specific yield rates for different distance ranges and different vehicle types

PCSD FOR DRIVER YIELDING RATE: A CASE STUDY

RESULTS: YIELD RATE OBSERVATION

- Highest yield beyond the PCSD (92%) and approaching SSD (82%), while minimal in early braking zones (5-11%)

- **Gap > SSD** is generally required to achieve high compliance and **Gap > PCSD** offers a reliable chance for safe pedestrian crossings



Yielding rate by vehicle position ranges

PCSD FOR DRIVER YIELDING RATE: A CASE STUDY

RESULTS: COMPLIANCE PREDICTION MODELS

$$Log - Odds = log\left(\frac{p}{1-p}\right) =$$

$$\beta_0 + \beta_1.Approach\ Speed + \beta_2.Initial\ Vehicle\ Position + \beta_3.Vehicle\ Lane:\ Far + \beta_4.Vehicle\ Type:\ Pickup + \beta_5.Vehicle\ Type:\ SUV \dots\dots\dots\dots (1)$$

p = probability of Yield

Model Type	Response	Predictor	Estimate	Std. Error	z/ t value	p-value
Logistic Regression (Equation 1)	Yield Probability	(Intercept)	7.047	1.900	3.709	0.0002
		Approach Speed	-0.316	0.061	-5.167	<0.001
		Initial Position	0.016	0.002	6.480	<0.001
		Vehicle Lane (relative to Adjacent)				
		Far	-0.349	0.350	-0.997	0.319
		Vehicle Type (relative to passenger car)				
		Pickup	-0.581	0.537	-1.082	0.279
		SUV	0.621	0.386	1.607	0.108

$$log(Yielded\ Position) = \beta_0 + \beta_1.Approach\ Speed + \beta_2.Initial\ Vehicle\ Position + \beta_3.Vehicle\ Lane:\ Far + \beta_4.Vehicle\ Type:\ Pickup + \beta_5.Vehicle\ Type:\ SUV \dots\dots\dots\dots (2)$$

Model Type	Response	Predictor	Estimate	Std. Error	z/ t value	p-value
Log-transformed Linear Regression (Equation 2)	Yielded Position	(Intercept)	4.077	0.25	16.11	< 0.001
		Approach Speed	-0.038	0.01	-4.46	< 0.001
		Initial Position	0.004	0.00	10.68	< 0.001
		Vehicle Lane (relative to Adjacent)				
		Far	-0.023	0.07	-0.33	0.745
		Vehicle Type (relative to passenger car)				
		Pickup	0.169	0.12	1.41	0.162
		SUV	0.037	0.08	0.48	0.635

PCSD FOR DRIVER COMPLIANCE: A CASE STUDY

RESULTS: COMPLIANCE PREDICTION MODELS

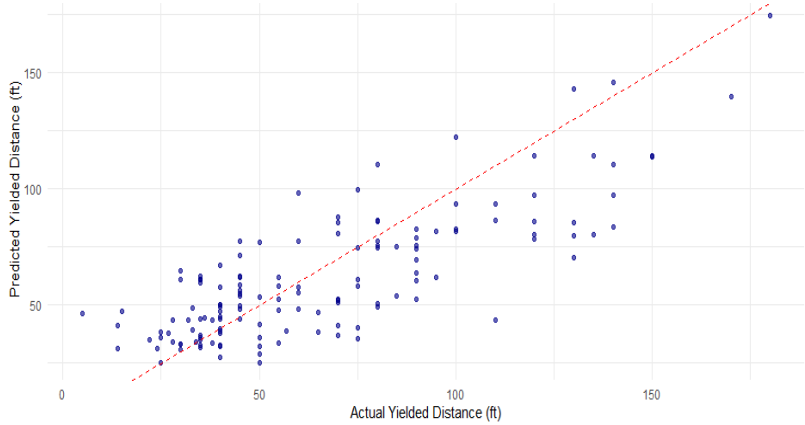
- ❑ **Approach speed** and **initial position** were statistically significant predictors of driver yield
  - ✓ An increase in speed significantly reduced the likelihood of yielding ($\beta = -0.316$, $p < 0.0001$)
  - ✓ A greater initial distance increased the possibility of yielding ($\beta = 0.016$, $p < 0.0001$)

- ❑ 23 false positives, and 27 false negatives correspond to an overall accuracy of 80%

Confusion matrix

- ❑ **Approach speed** and **initial position** were statistically significant to predict yielded position
  - ✓ Higher speeds led to shorter yield distances ($\beta = -0.3038$, $p < 0.001$)
  - ✓ Greater initial distances resulted in longer yields ($\beta = 0.004$, $p < 0.001$)

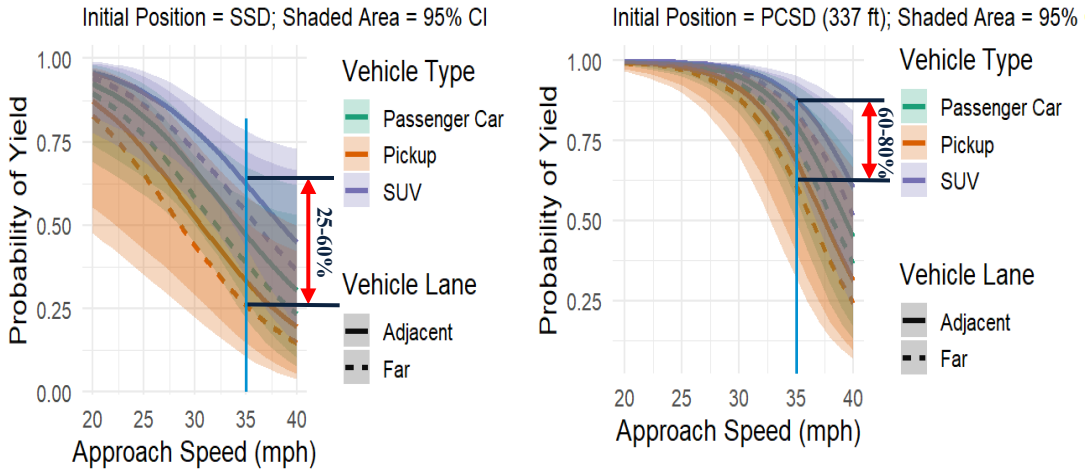
- ❑ Back-transformed predictions closely aligned with observed values



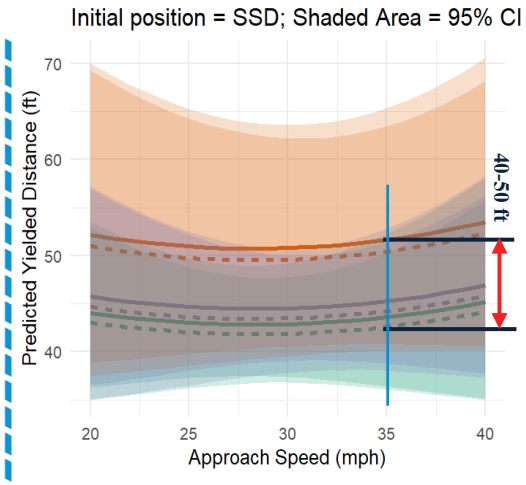
Actual vs predicted yielded position by log-transformed model

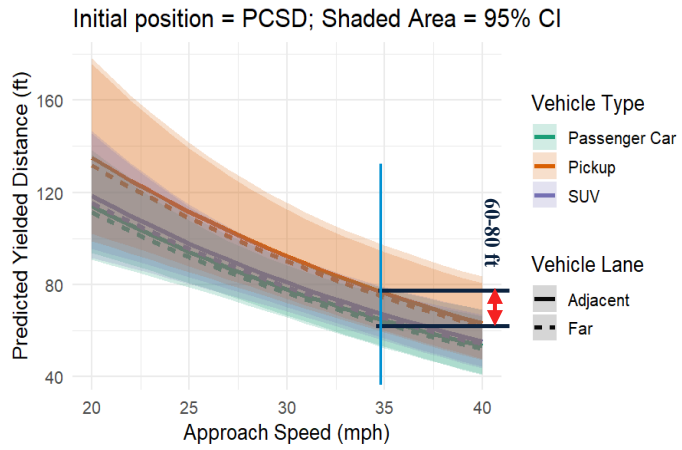
PCSD FOR DRIVER YIELDING RATE: A CASE STUDY

RESULTS: IMPORTANCE OF PCSD



Predicted probability of yield when the vehicle is at PCSD and at SSD





Predicted yielded positions when the vehicle is at PCSD and at SSD

- For 35 mph road, predicted probability of yield:
  - Vehicle at SSD : 25% – 60%
  - Vehicle at PCSD : 60% – 80%

- For 35 mph road, the gap between yielded position and crosswalk:
  - Vehicle at SSD : 40 – 50 ft
  - Vehicle at PCSD : 60 – 80 ft

- **Pedestrian visibility of at least up to the PCSD should be a fundamental design consideration for crosswalks, rather than the current practice of ensuring visibility only up to SSD**

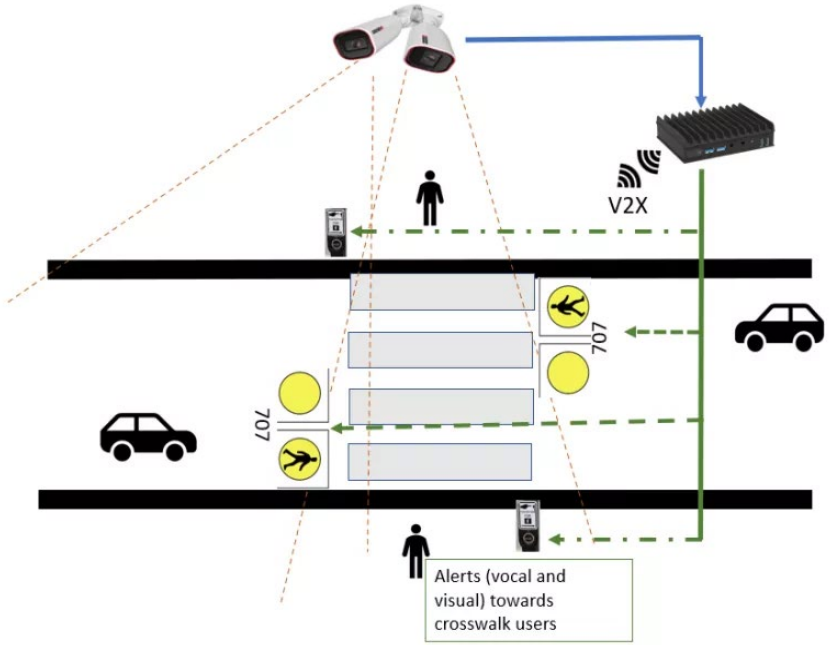
RRFB YIELDING BEHAVIOR: CONCLUDING REMARKS

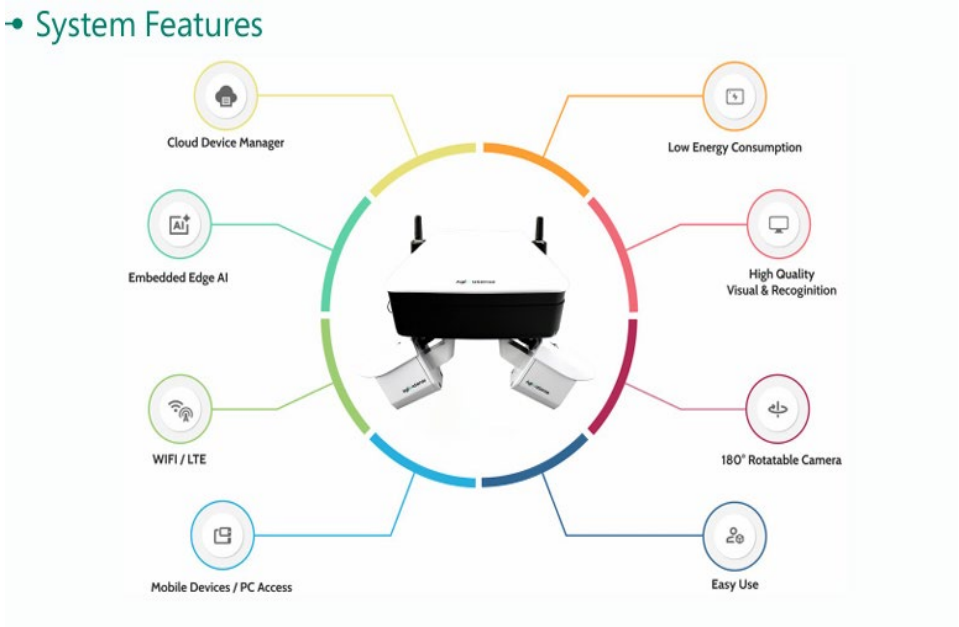
- Push Button placement within 3 feet from curb increases RRFB activation, however, decreases driver yielding rates.
- Push Button parallel to crosswalk increase motorist yielding rate.

- **PCSD** distance significantly increases driver yield rate.
- At 35 mph, yield probability at the PCSD was 60-80%, a substantial improvement over the 25-60% probability at the SSD.

RECOMMENDATIONS

- ❑ Face of Push Button parallel to crosswalk
- ❑ Incorporate PCSD in Crosswalk Design
- ❑ **NCHRP 15-86 Assessing Pedestrian Sight Distance for Crossing Decisions**





DRIVER YIELDING BEHAVIOR AT RRFB-ENHANCED CROSSWALKS IN ALABAMA

THANK YOU!

Q&A

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