Using SHRP 2's NDS Video Data to Evaluate the Impact of Offset Left-Turn Lanes on Gap Acceptance Behavior

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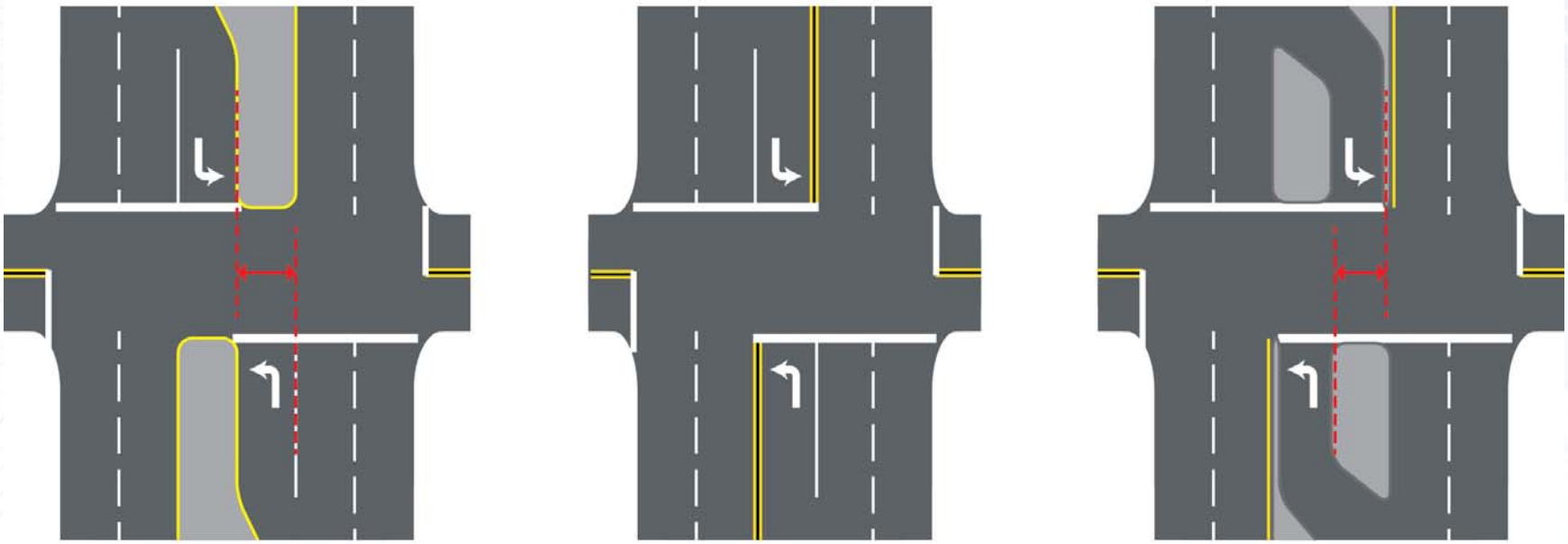
Research Objectives

- Answer the study questions:
  - How does left-turn lane offset affect turn behavior and gap acceptance?
  - What effect does the presence of a vehicle in the opposing left-turn lane have on gap-acceptance behavior? Does it vary by offset?
  - What other factors affect gap-acceptance behavior? (Driver age and gender, weather and lighting conditions, presence of following vehicle, time spent waiting for a gap, etc.)
- Develop design guidance for offset left-turn lanes
- Document experience for future users of NDS data

Background



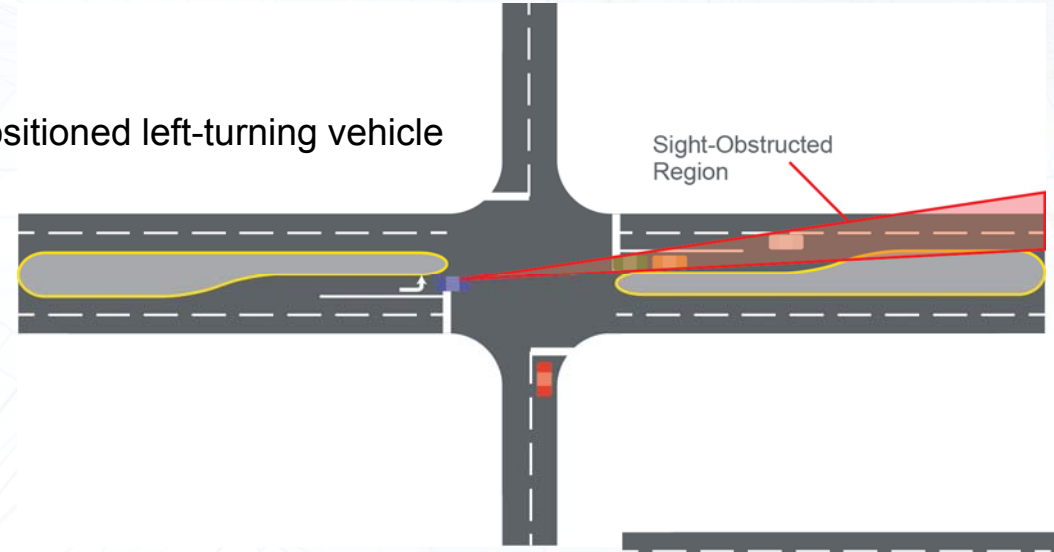
Negative Offset

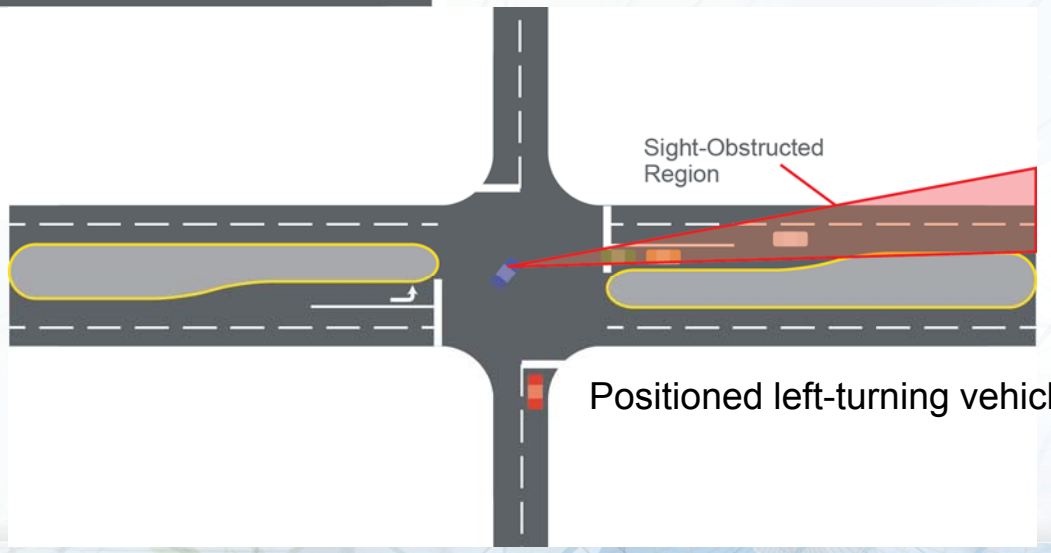
Zero Offset

Positive Offset

Background

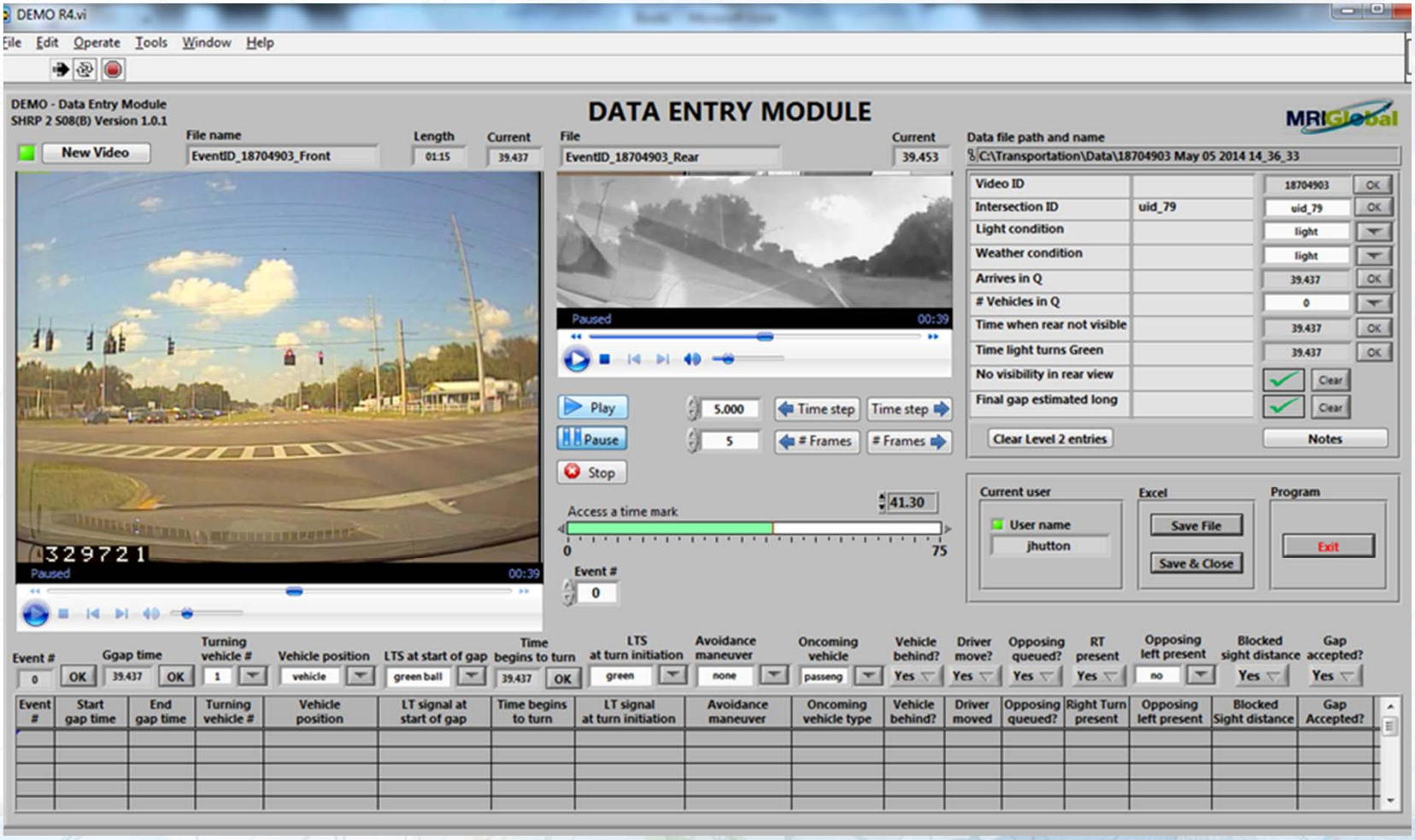
Unpositioned left-turning vehicle





Positioned left-turning vehicle

User Interface for Data Reduction



Variables Recorded from Video Data

Recorded once in each video; only for NDS vehicle

Video-Level Variables
Video ID
Intersection ID
Light condition
Weather condition
Arrives in Q
Number of vehicles in Q
Time when rear not visible
No visibility in rear view
Time light turns green
Final gap estimated long
Notes

Event-Level Variables
Event No.
Start gap time
End gap time
Turning vehicle No.
Vehicle position
LT signal at start of gap
Time begin turn
LT signal at turn initiation
Avoidance maneuver
Type oncoming vehicle
Vehicle behind?
Driver move?
Opposing queued?
RT present?
Opposing left present?
Sight distance blocked?
Gap accepted?

Recorded for every gap accepted or rejected by NDS driver or other drivers who can be observed in the video

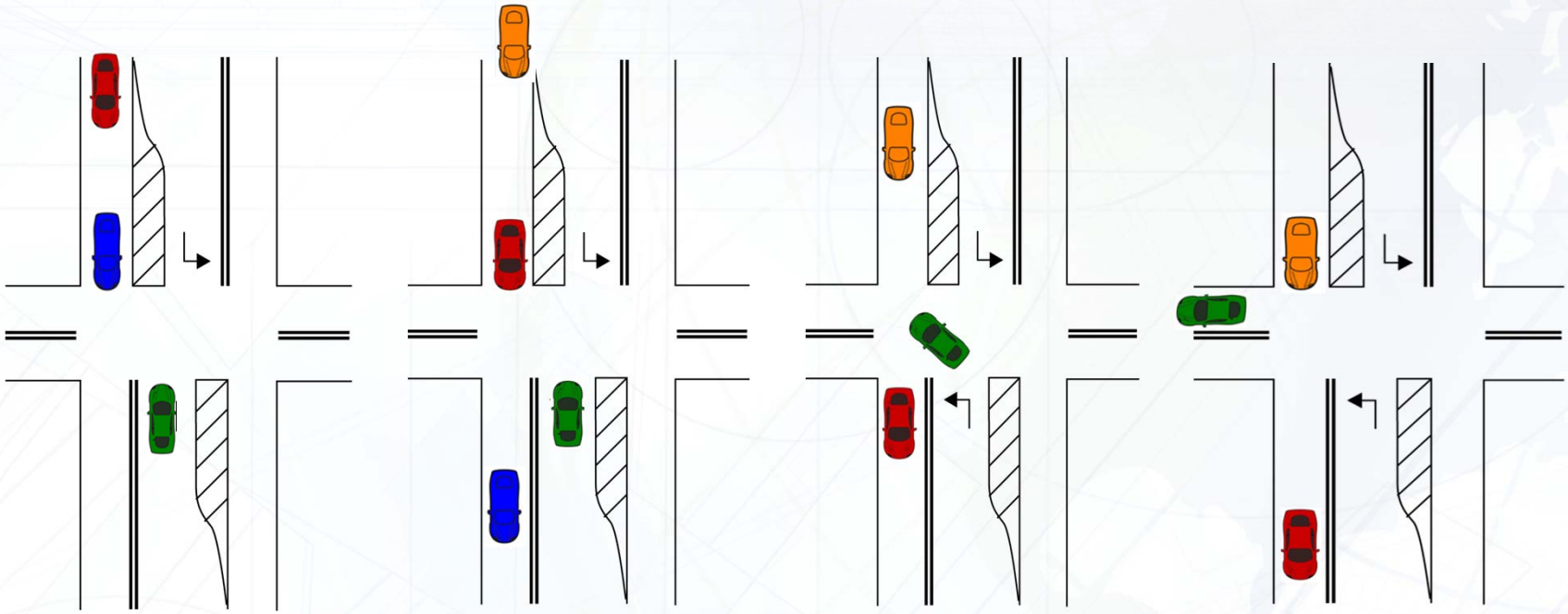
Definitions of Measured Variables

Time T_0: First opposing through vehicle reaches the stop bar after the study vehicle arrives

Time T_1: Next opposing through vehicle reaches the stop bar

Time T_2: Turn is initiated by study driver

Time T_3: First opposing through vehicle reaches the stop bar after the study vehicle makes the left turn



T_0, T_1 and T_2 are viewed in the forward-facing camera

T_3 is estimated from forward camera or viewed in rear camera

Rejected gap length = $T_1 - T_0$ PET = $T_3 - T_2$

Accepted gap length = $T_3 - T_1$ Time spent waiting for a gap = $T_2 - T_{\text{arrived in queue}}$

Surrogate Safety Measures

- ***Critical Gap***—Gap length equally likely to be accepted or rejected by a driver
- ***Post-Encroachment Time***—Time between when driver initiates the left turn and when the next opposing through vehicle arrives at the intersection. A measure of how much time separated the two vehicles from a collision.
- ***Near misses and avoidance maneuvers***—Non-crash events that indicate a potential safety concern

Data Overview

From the video reviews, data were collected:

- For 145 NDS and 204 non-NDS drivers
- At 44 signalized intersection left-turn pairs (33 intersections) and 14 two-way stop-controlled intersections
- In 4 states: Florida, Indiana, North Carolina, and Washington
- For 770 left-turning maneuvers by NDS vehicles
- For 3,350 events, where an event is defined as either an accepted or rejected gap, by either an NDS or non-NDS driver
- For 169 (sig) and 162 (unsig) gaps accepted by NDS drivers
- In 7 (sig) and 4 (unsig) offset categories in ~ 5-ft increment

Statistical Methodology

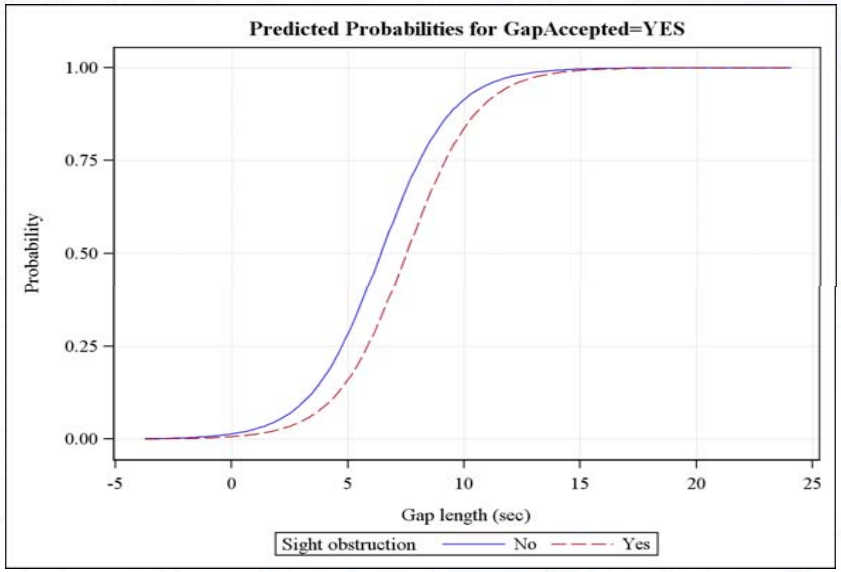
- Logistic regression analysis was used to model the relationship between (1) the probability of accepting or rejecting a gap of a given length and (2) the length of the gap and the left-turn offset distance
- From the regression model, the critical gap length, t_{50}, and its 95% confidence limits were estimated by inverse regression
- t_{50} is the gap length (on X-axis) that corresponds to a probability of 0.5 (on Y-axis); that is, the gap length where the probability of accepting = probability of rejecting
- The confidence intervals of the critical gaps were then compared in a pairwise fashion to assess which offset category differs statistically from which other offset category with respect to critical gap

Sight Obstruction Statistics

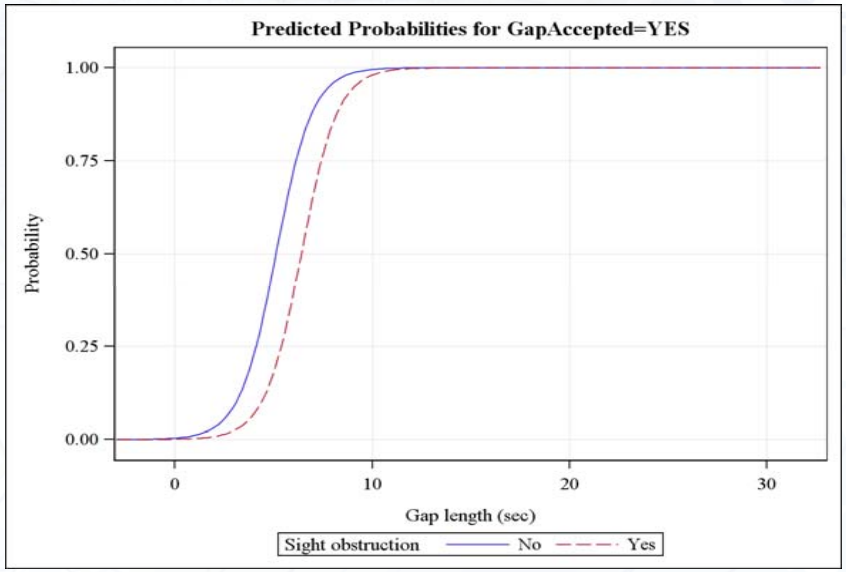
Offset Category	Available Gaps			Accepted Gaps Only		
	Percentage of Events when an Opposing Vehicle is Present	Percentage of events when Driver's View is Blocked	Ratio of Driver's View Blocked to Opposing Vehicle Present	Percentage of Events when an Opposing Vehicle is Present	Percentage of events when Driver's View is Blocked	Ratio of Driver's View Blocked to Opposing Vehicle Present
Signalized Intersections						
(a) –16 ft or less	34.7	30.1	86.8	7.4	7.4	100.0
(b) –11 to –15 ft	25.0	12.0	48.0	23.0	8.1	35.3
(c) –6 to –10 ft	48.0	44.9	93.5	32.8	25.0	76.2
(d) –1 to –5 ft	26.1	23.6	90.3	24.1	18.5	76.9
(e) 0 ft	26.5	3.9	14.6	21.3	4.7	22.2
(f) 1 to 3 ft	35.5	3.0	8.4	34.9	3.2	9.1
(g) 4 to 6 ft	21.4	3.1	14.3	30.6	4.1	13.3
Two-Way Stop-Controlled Intersections						
(a) –16 ft or less	4.4	0.0	0.0	9.5	0.0	0.0
(b) –11 to –15 ft	7.8	6.4	82.2	8.7	7.5	85.7
(c) –6 to –10 ft	23.9	18.9	79.2	9.6	8.2	85.7
(e) 0 ft	9.3	0.0	0.0	3.3	0.0	0.0
All Intersections Combined						
Negative offset	20.9	17.9	85.6	15.8	11.2	70.8
Zero offset	24.0	3.3	13.8	19.1	4.1	21.7
Positive offset	31.3	3.0	9.6	33.7	3.4	10.2

Sight Obstruction—Analysis Results

Signalized



Stop-Controlled



Signalized intersections: significant sight obstruction effect (p-value = 0.02)

Two-way stop-controlled intersections: significant sight obstruction effect (p−value = 0.03)

Traffic Control Type	Is Sight Distance Obstructed?	Critical Gap Estimate (sec)	95% Confidence Limits (sec)		Significant Difference Between Obstruction and No Obstruction?
			Lower	Upper)	
Signalized	Yes	7.5	6.6	8.5	No
	No	6.4	6.0	6.9	
Two-Way Stop	Yes	6.4	5.3	7.6	No
	No	5.1	4.8	5.4	

Safety Analyses

- Analysis of near-crashes
  - Only 6 events (of 3,350 observed by video reviewers) were found to include an avoidance maneuver by the turning driver, oncoming driver, or both. No pattern was observed among these events.
- Analysis of short post-encroachment times

Offset Category	All Accepted Gaps								
	Number of Observations	Percentile				Percent of Observations with Post-encroachment Time Less Than:			
		1st	5th	10th	15th	1 sec	2 sec	3 sec	4 sec
Signalized Intersections									
Negative	114	-1.33	0.34	2.28	2.71	6	9	18	36
Zero	95	0.02	2.15	2.97	3.58	1	3	11	21
Positive	60	-1.50	1.17	3.00	3.53	3	7	10	20
Two-Way Stop-Controlled Intersections									
Negative	196	2.14	2.42	2.85	3.38	0	1	11	19
Zero	13	1.76	1.76	3.97	3.97	0	8	8	15

Summary

- Critical gaps are longer at negative-offset left turn lanes than at zero or positive offset → reduce operational efficiency
- Sight distance restrictions due to the presence of opposing left-turn vehicles increases critical gap lengths → reduce operational efficiency
- Opposing left-turning vehicles are much more likely to obstruct the view of a left-turning driver at a negative offset than at a zero or positive offset
- Improving an offset from more negative to less negative will likely not adequately address the restricted view of the left-turning driver
- While on average, drivers tend to wait for longer gaps when their view of oncoming traffic is restricted, the shortest post-encroachment times are more likely to be taken by drivers with an obstructed view
- Safety issues resulting in crashes or near misses are rare for this specific scenario, but that does not mean intersections with negative offsets are not a safety concern
  - Proactive safety strategies seek to identify locations with conditions that may lead to crashes even if none have occurred
  - Restricted sight distance for left-turning drivers creates a potential safety concern

Advantages and Potential Limitations of NDS Data

- Field data collection has already been done (cost savings, a large number of locations can be studied compared to other traditional methods)
- Truly naturalistic behaviors (unlike simulator studies)
- Can view oncoming traffic from driver's perspective (don't have to make assumptions about sight restrictions)
- RID can be used to query locations with specific desired characteristics for the study. (However, many of the capabilities that the RID will provide when finalized were not yet available for our study)
- Data extraction can account for a large portion of budget and schedule
- Video image quality varies greatly depending on camera focus, position, lighting, and weather conditions. The rear-facing camera image is substantially less reliable than the forward-facing camera