RCCADS 2025-26 Program

Exploring Effects of ADS on Crash Injury Distribution through Integration of Field Data, Pre-Crash and Crash Simulations

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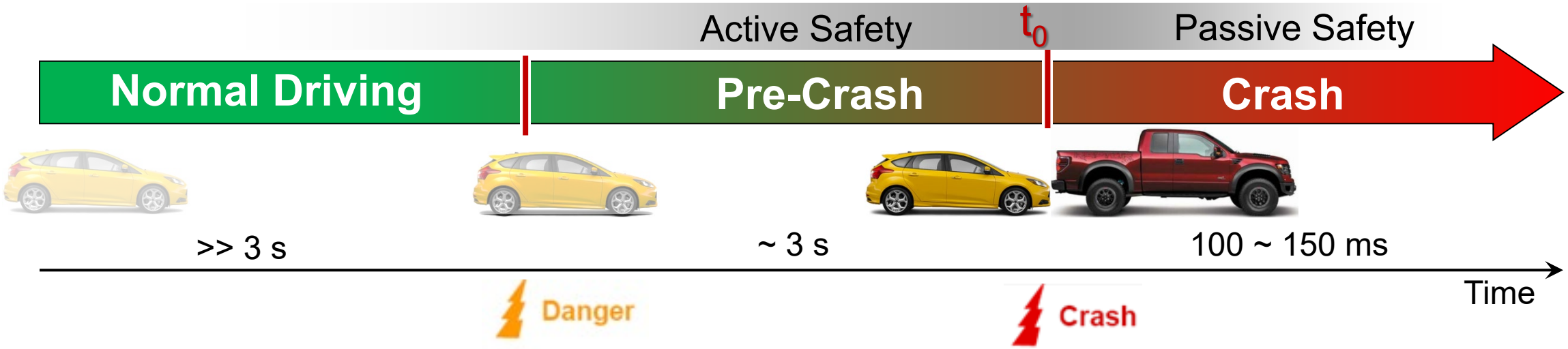
UMTRI TRANSPORTATION RESEARCH INSTITUTE UNIVERSITY OF MICHIGAN

Motivation



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Motivation

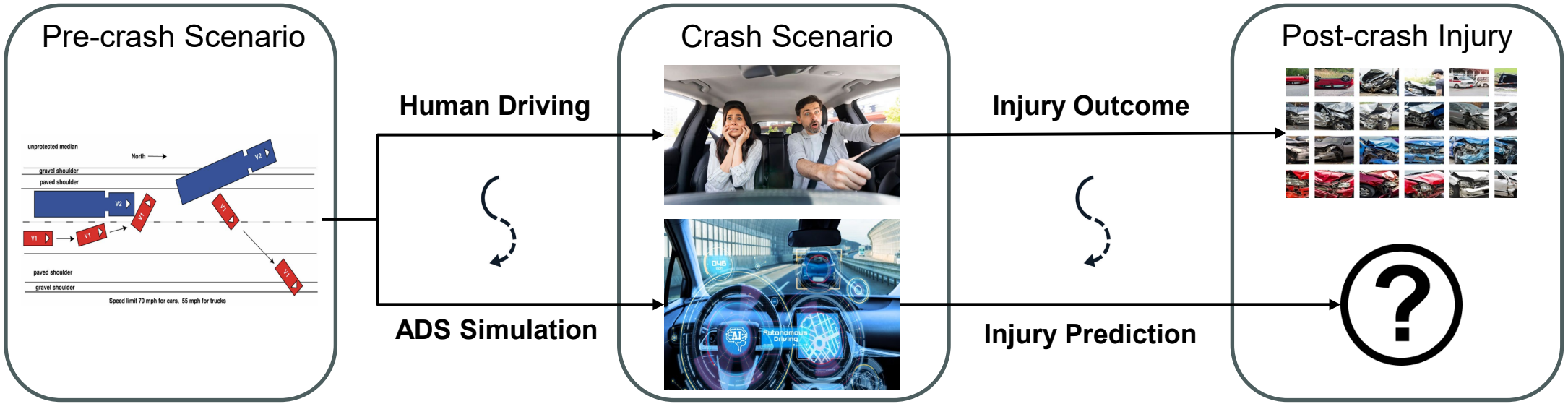
- An autonomous vehicle should travel 100 million miles without causing a fatal accident.

- Active and passive safety have been developed as two isolated systems:
  - **Active safety:** crash avoidance;
  - **Passive safety:** crash injury mitigation.

- **Integrative safety:** jointly optimize the active and passive safety systems to avoid fatal crashes.

- **Research need:** explore the injury risk distribution for ADS during inevitable crashes.

Research Challenges



- Noisy field data
- Isolated pre-crash and crash simulations
- Unknown ADS crash distribution

- Task 1: Automatic data extraction
- Task 2: ADS simulation with injury prediction
- Task 3: Statistical analysis

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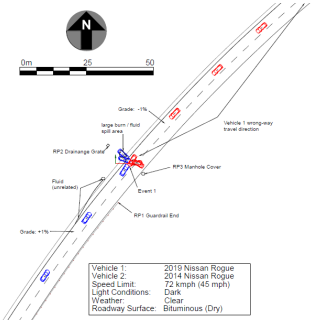
Proposed Project Framework

Crash Dataset

Crash Viewer CIREN Case

Task 1. Automatic data extraction

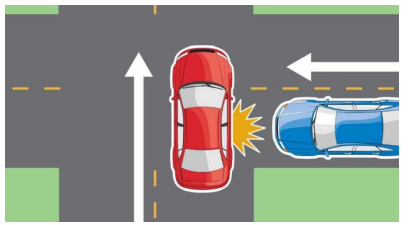
Pre-crash Scenario



Task 2. Vehicle trajectory simulation

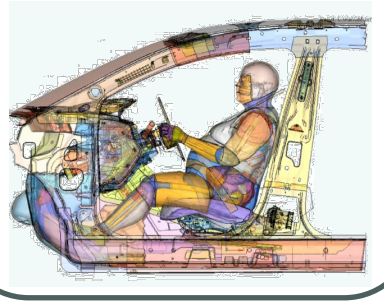
Active Safety

Crash Scenario



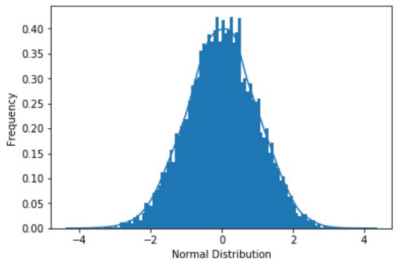
Passive Safety

Injury Severity Evaluation



Task 3. Statistical analysis

Injury Severity Distribution



Comparison study

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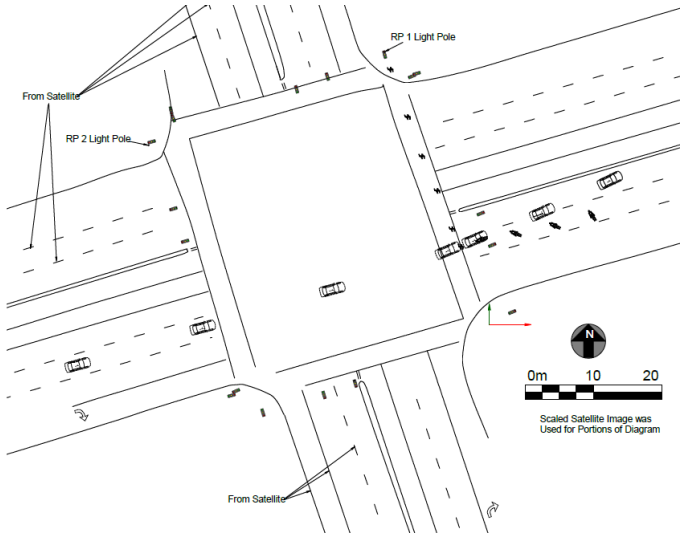
Task 1. Automatic Field Data Extraction

Crash Dataset



Crash Summary

Vehicle 1 (V1, 2016 Chevy Spark) was traveling east and Non-Motorist 1 (NM1, 26-year-old male) was crossing the roadway heading south. The speed limit was 72 km/h. At the time of the crash, it was dark with overhead streetlights and the weather was clear. No visual obstructions were noted. The non-motorist was crossing within the crosswalk located at an intersection. The front of V1 contacted NM1 on his right side. The pedestrian wrapped onto the hood of the vehicle and slid into the windshield and the windshield header, as evidenced by contact damage to the vehicle's bumper, hood, windshield, and windshield header. The pedestrian came to rest on the ground approximately 15 meters from the point of impact, and the vehicle came to rest north of the non-motorist and just beyond the non-motorist's final rest location.

Pre-Crash Information

- Initial Velocity
- Initial Location
- EDR Data

Crash Information

- Delta-V
- PDOF
- Subject Variables

Crash Outcome

- AIS Code

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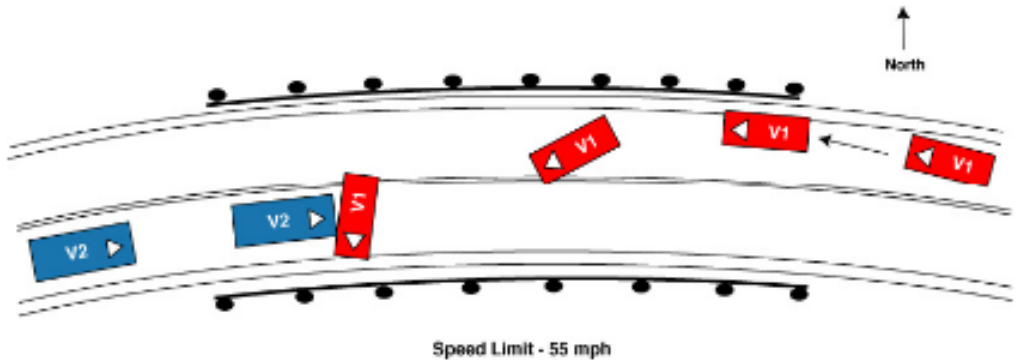
Additional Crash Information



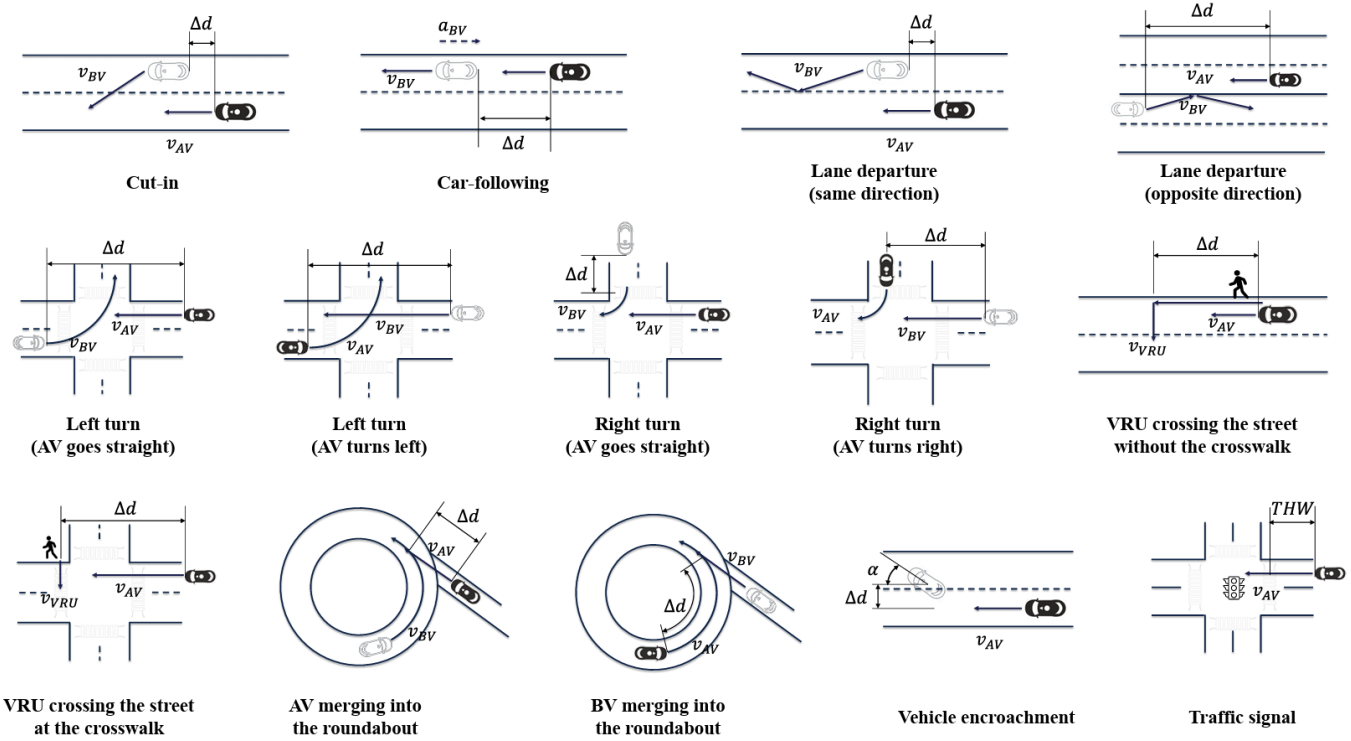
Crash Summary

Vehicle one (V1 - case vehicle), a 2002 Subaru Forester, 4-door utility vehicle was traveling west in the westbound lane of a two-lane, two-way roadway and was negotiating a right curve. Vehicle two (V2), a 2002 Buick Rendezvous, 4-door utility vehicle was traveling east in the eastbound lane of the same roadway and was negotiating a left curve. It was daylight, snowing, and the bituminous road was icy. The driver of V1 lost control on the icy road and began to rotate counterclockwise. V1 rotated approximately 90 degrees, crossed the centerline and entered the eastbound lane. The driver of V2 could not avoid V1 and the front of V2 struck the right side of V1 in a T-type configuration. Both vehicles were towed due to disabling vehicle damage. The 36-year-old male driver of V1 (case occupant) was using the available three-point seat belt but no airbags deployed in the driver's seating position. He was transported via ground ambulance to a regional level-one trauma center.

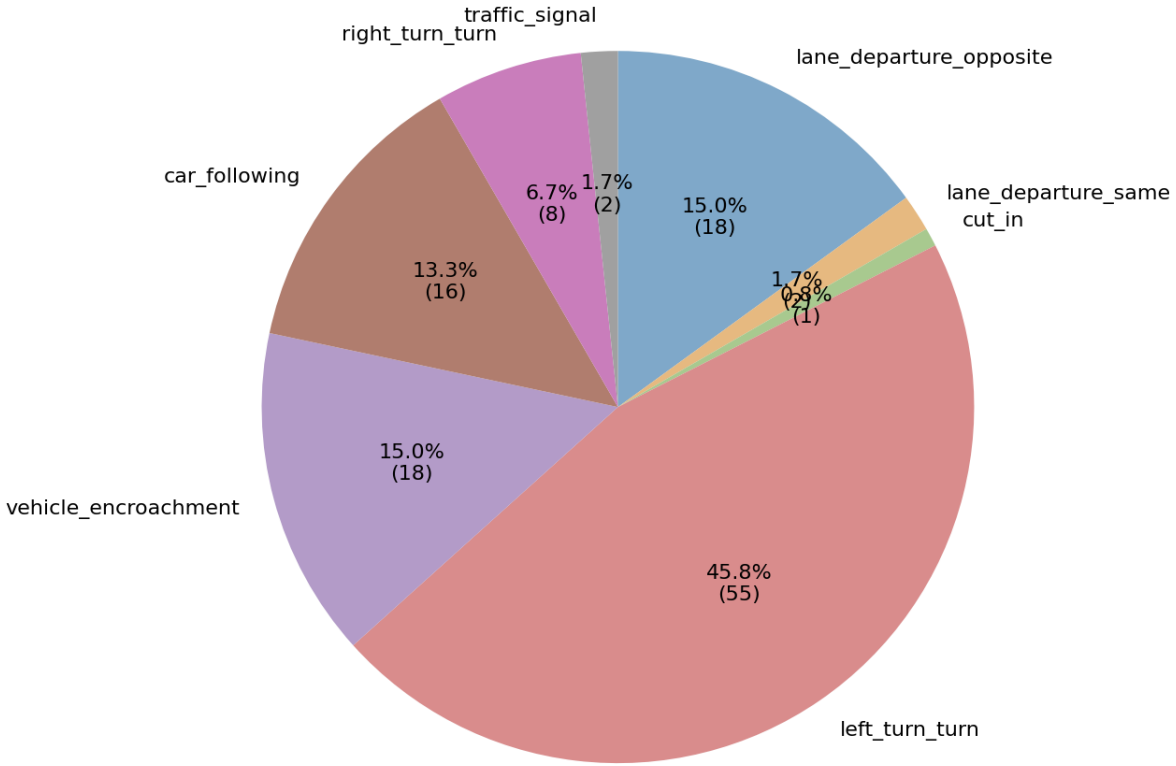
Type	Examples / Description
Crash diagram	Graphic/image not extracted.
Occupant-specific transport	Ambulance vs. helicopter, hospital transfer details.
Environment condition	Road type, lanes, weather, daylight, road surface.
Driver medical events	Seizure or loss-of-control events.
Occupant orientation	Forward/rearward movement relative to vehicle interior, child seat orientation.

Extracted Pre-crash Scenarios

ADS Simulation

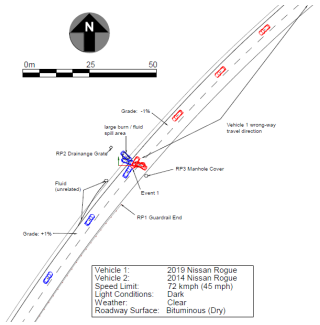


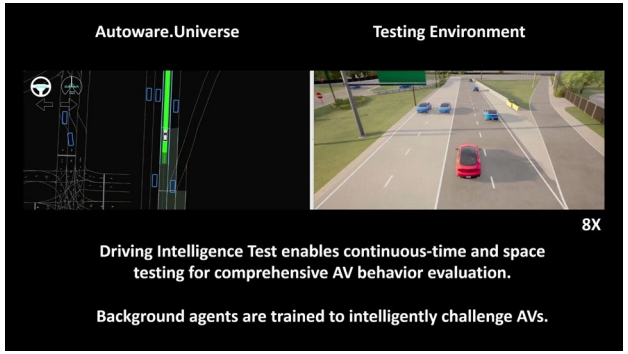
Extracted Field Data



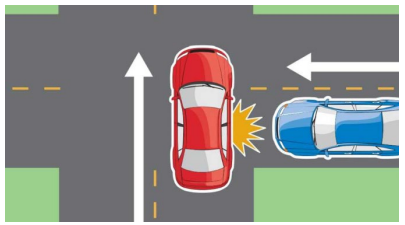
Task 2 ADS Simulation

Pre-crash Scenario





Crash Scenario



Pre-crash → ADS Behavior → Crash

Subject Info
Vehicle Speed

→ Braking Force
Trigger Time

→ Crash Speed
Crash Angle

→ Delta-V
Injury Risks

- Adjust simulation parameters to account for ADS effectiveness in real world crashes
- Evaluate injury outcomes for generated ADS simulations

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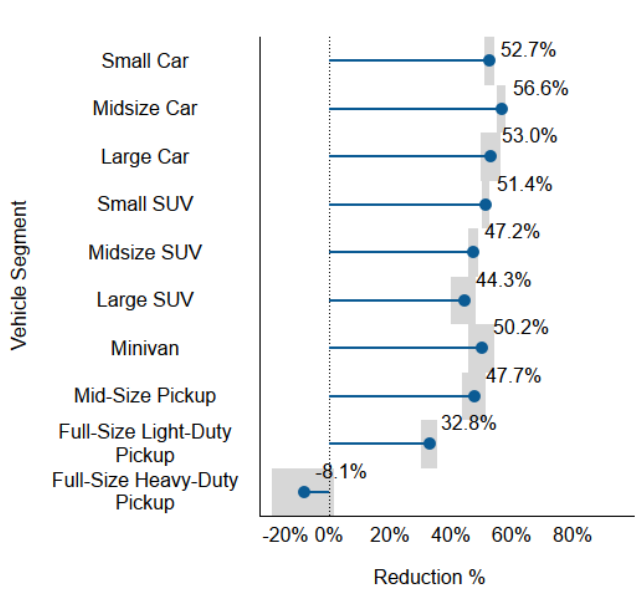
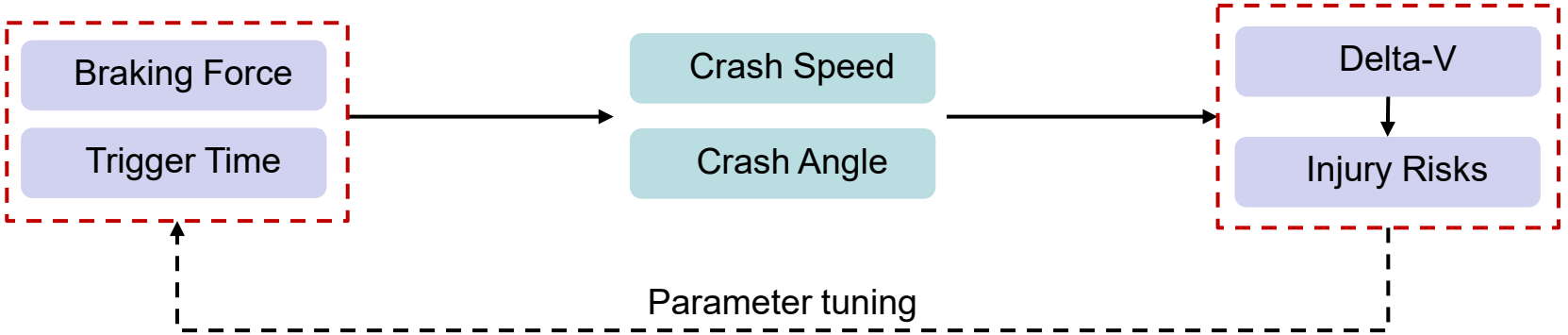
Simulation Parameter for ADS Effectiveness



		Equipped	Unequipped
Small Car	Control	50,488	91,920
	System-Relevant	21,490	92,918
Midsize Car	Control	62,769	113,437
	System-Relevant	18,452	91,033
Large Car	Control	11,080	42,298
	System-Relevant	4,021	38,496
Small SUV	Control	100,276	135,054
	System-Relevant	27,604	86,982
Midsize SUV	Control	73,778	115,513
	System-Relevant	19,028	71,030
Large SUV	Control	21,305	7,159
	System-Relevant	7,573	4,560
Minivan	Control	9,243	10,760
	System-Relevant	2,165	5,926
Mid-Size Pickup	Control	11,057	17,558
	System-Relevant	3,514	11,340
Full-Size Light-Duty Pickup	Control	22,287	64,016
	System-Relevant	9,555	46,127
Full-Size Heavy-Duty Pickup	Control	2,127	20,635
	System-Relevant	1,846	19,237



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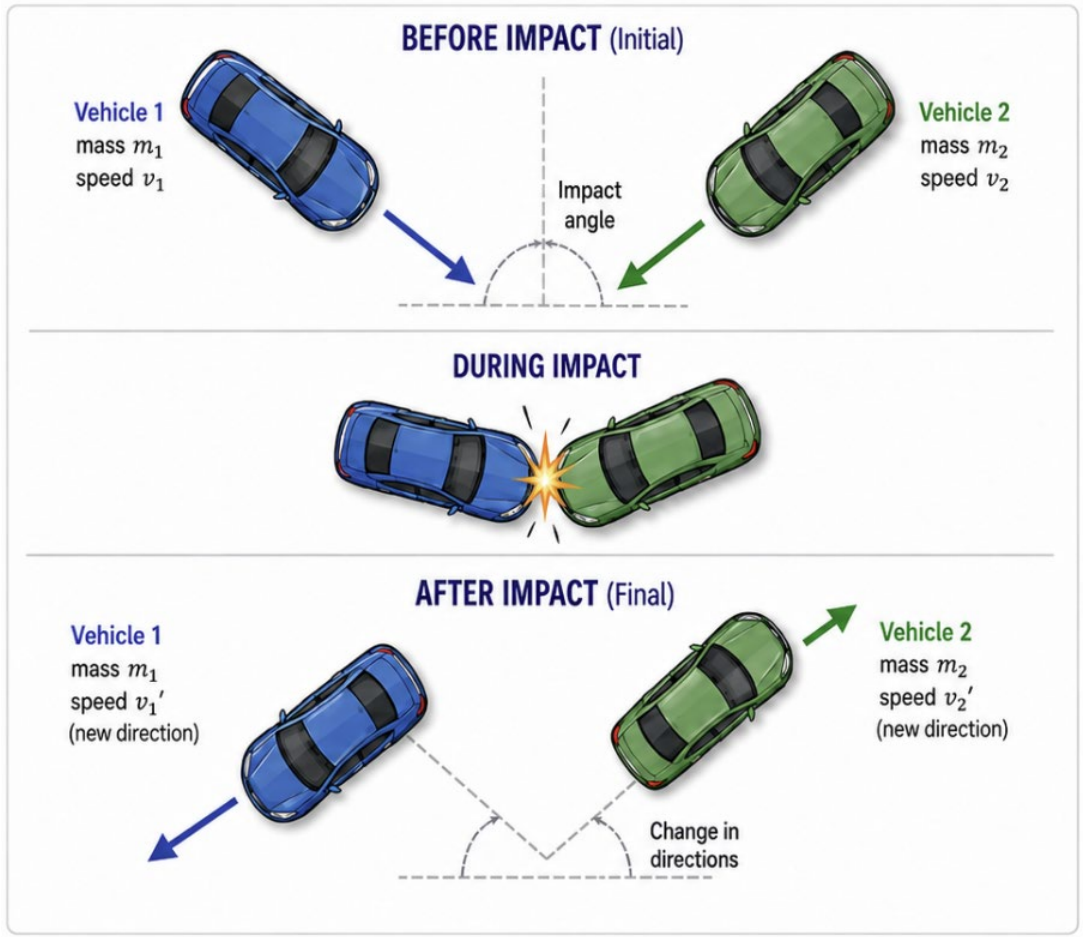
- *"A Study on Real-world Effectiveness of Model Year 2015–2023 Advanced Driver Assistance Systems." 2025 MITRE.*

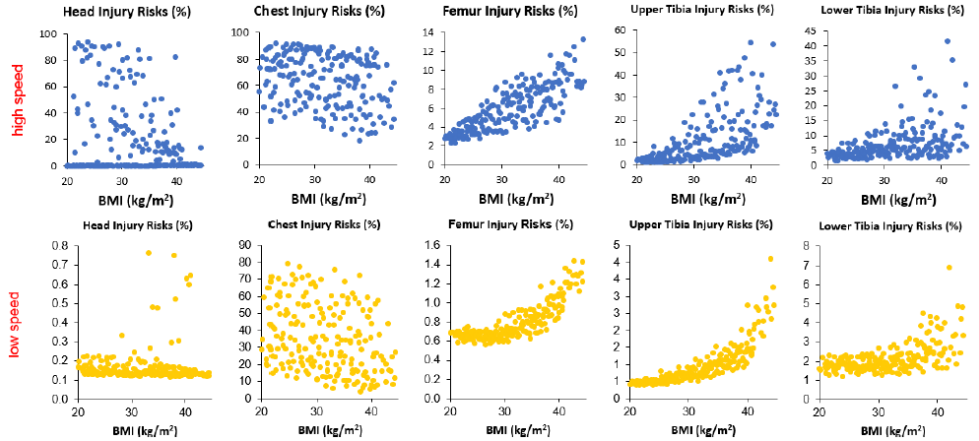
Crash Injury Evaluation

Delta-V calculation

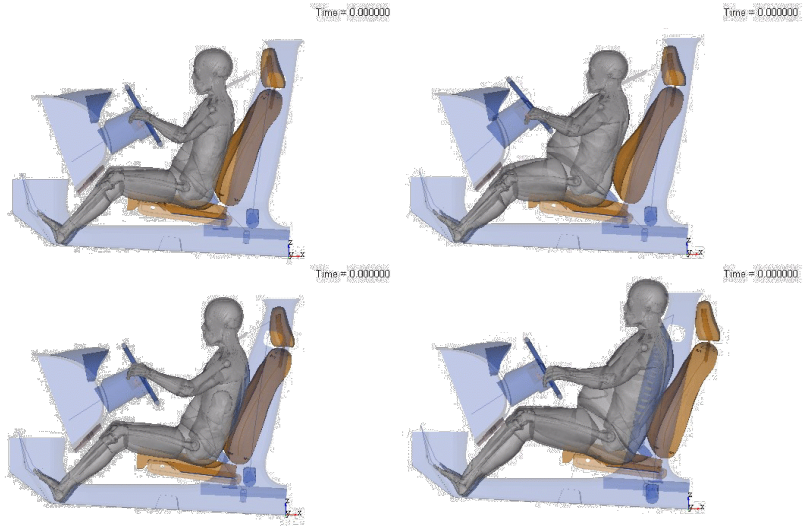


Injury risk prediction

Field data



Crash simulation



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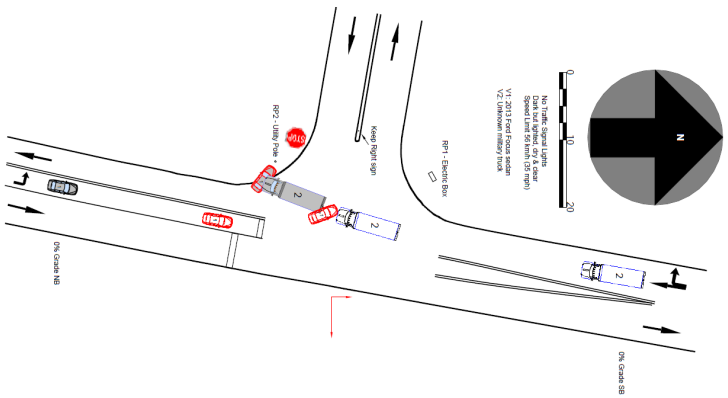
Automated Pipeline for Vehicle-to-Vehicle Crash

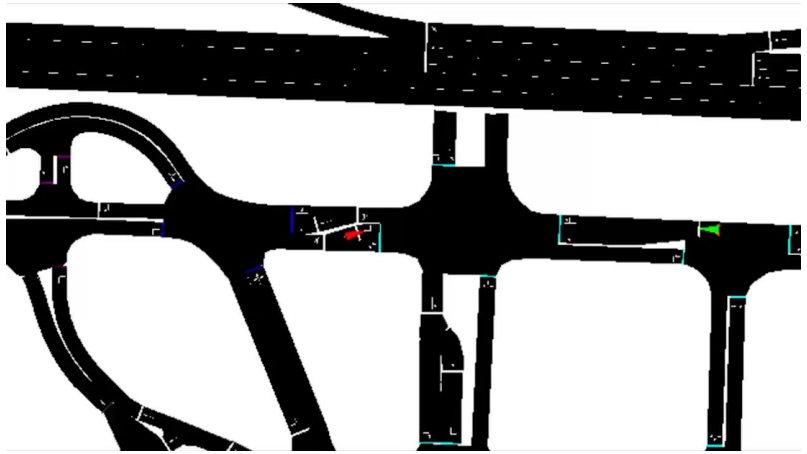
Field data



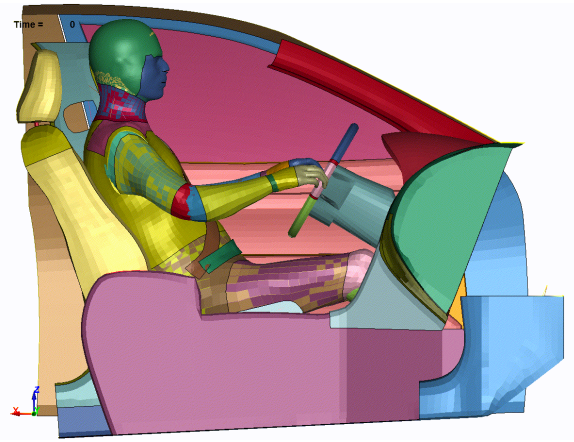
This investigation focused on the injury mechanisms of a belted, 30-year-old, male driver with deployed right curtain and left knee bolster airbags. He sustained critical injuries when the intermediate-size sedan he was driving was involved in a right plane, angled impact to the front of a medium/heavy truck. No other passengers were in the vehicle.

The crash occurred during early evening hours on dark but lighted dry road under clear skies. The roadway consisted of a three-leg suburban intersection with no signal light controls. The two vehicles were traveling on the north/south roadway approaching the intersection from opposite directions. The posted speed limit was 56 km/h (35 mph). The bituminous asphalt road was curved left in V1's northbound direction of approach with minimal superelevation or grade. V2's southbound approach was straight with minimal grade.

ADS simulation



Crash simulation



Injury outcome

Location	Injury Risk
Head	3.7%
Chest	4.3%
Lower Extremity	8.6%

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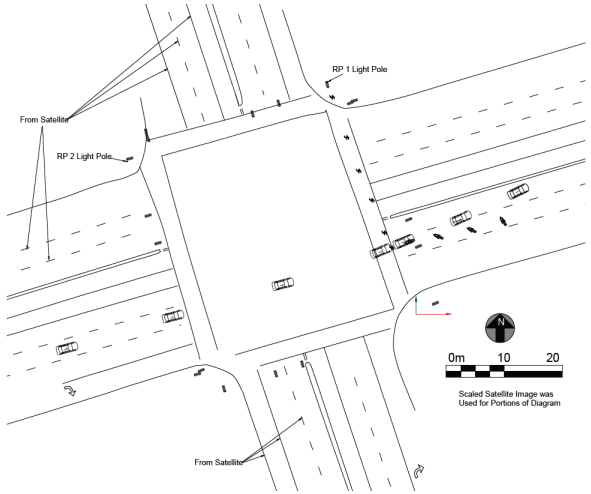
Automated Pipeline for Vehicle-to-Pedestrian Crash

Field data



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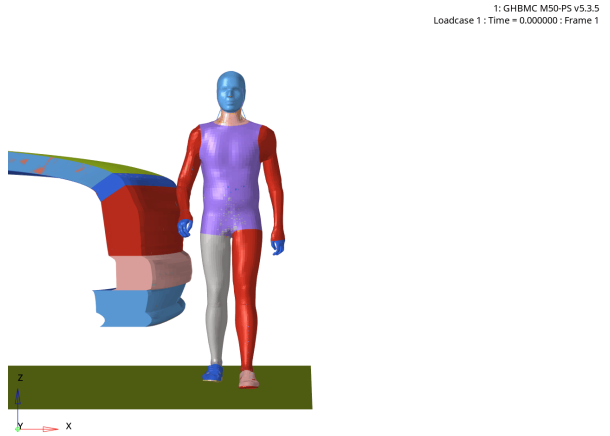
ADS simulation

Crash simulation



Injury outcome

Location	Injury Risk
Head	0.2%
Chest	3.0%
Lower Extremity	1.0%

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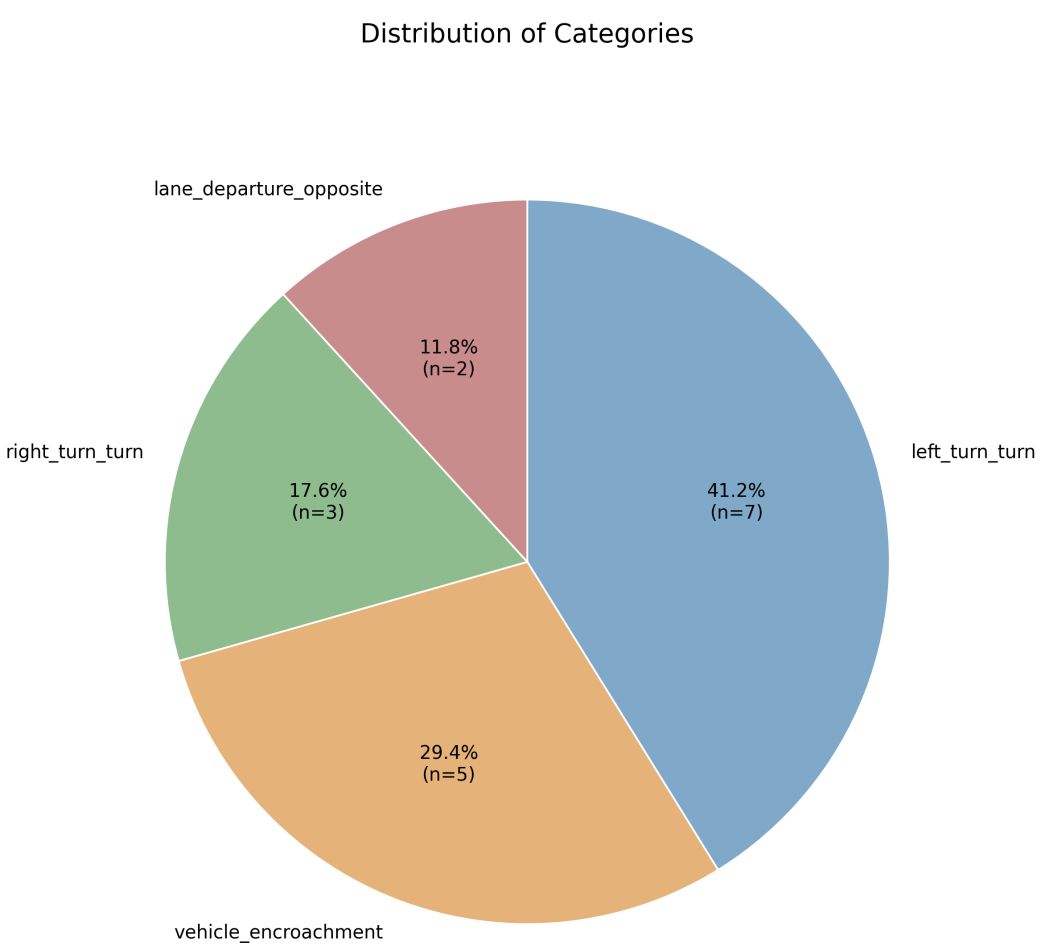
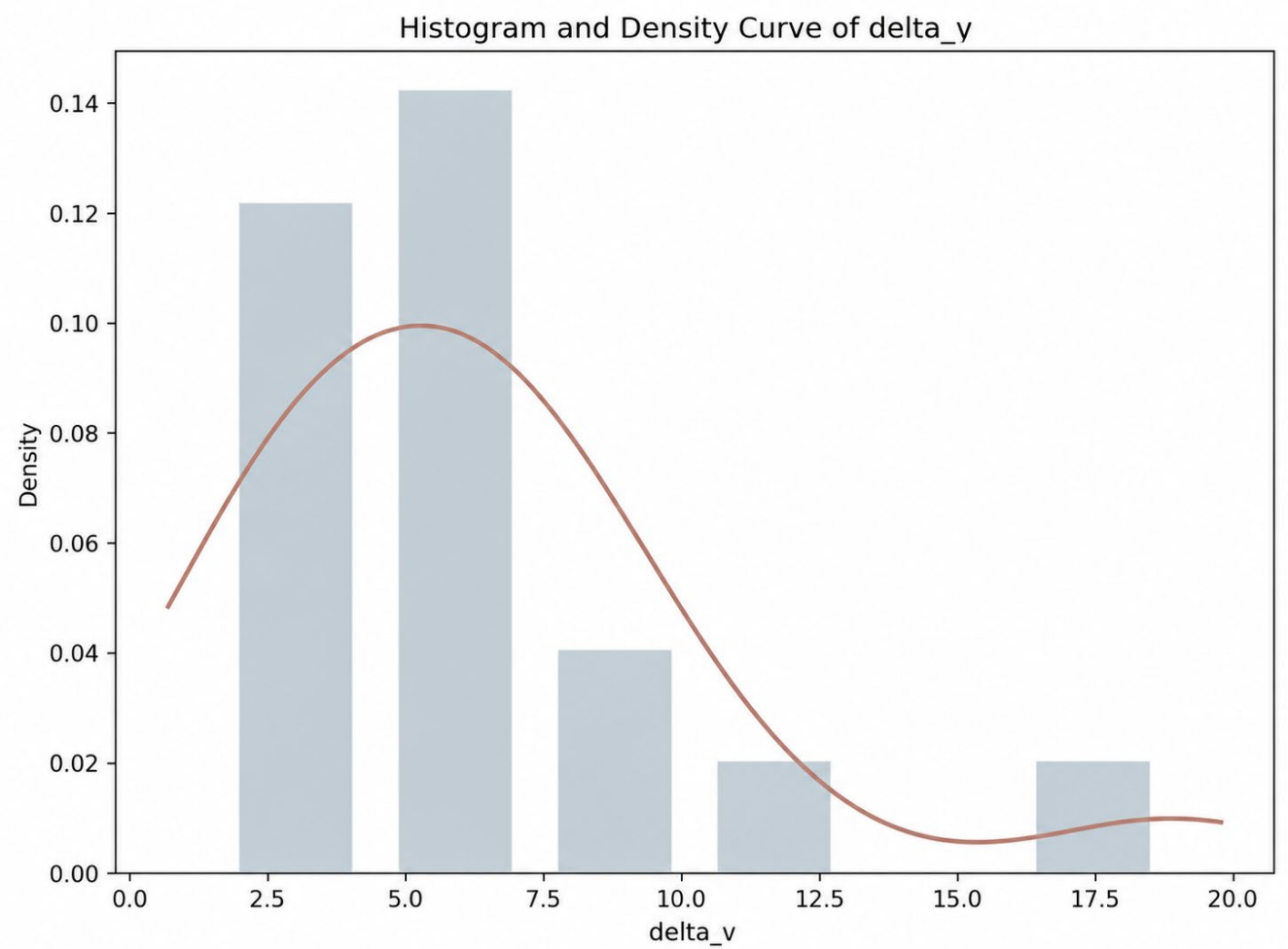
Task 3 Statistical Analysis





- ADS simulation and injury risk analysis have been conducted on 17 CIREN cases.

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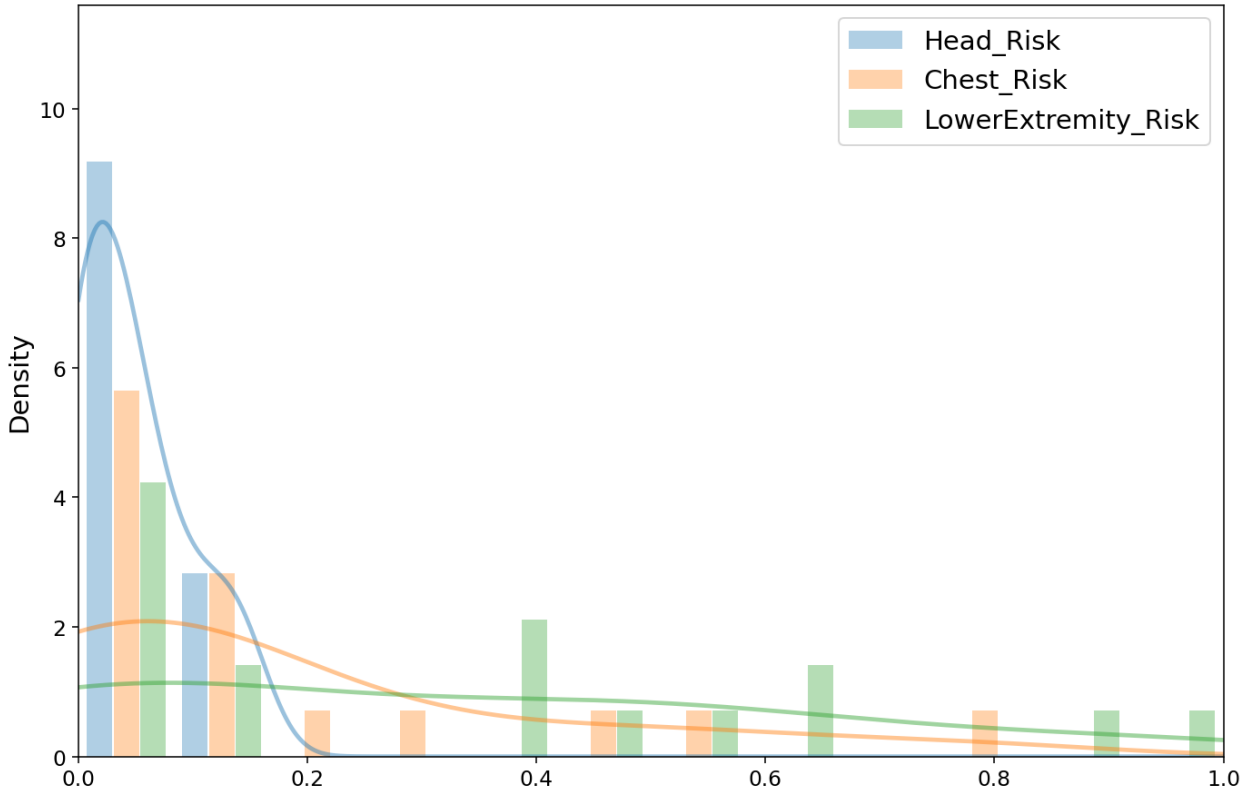
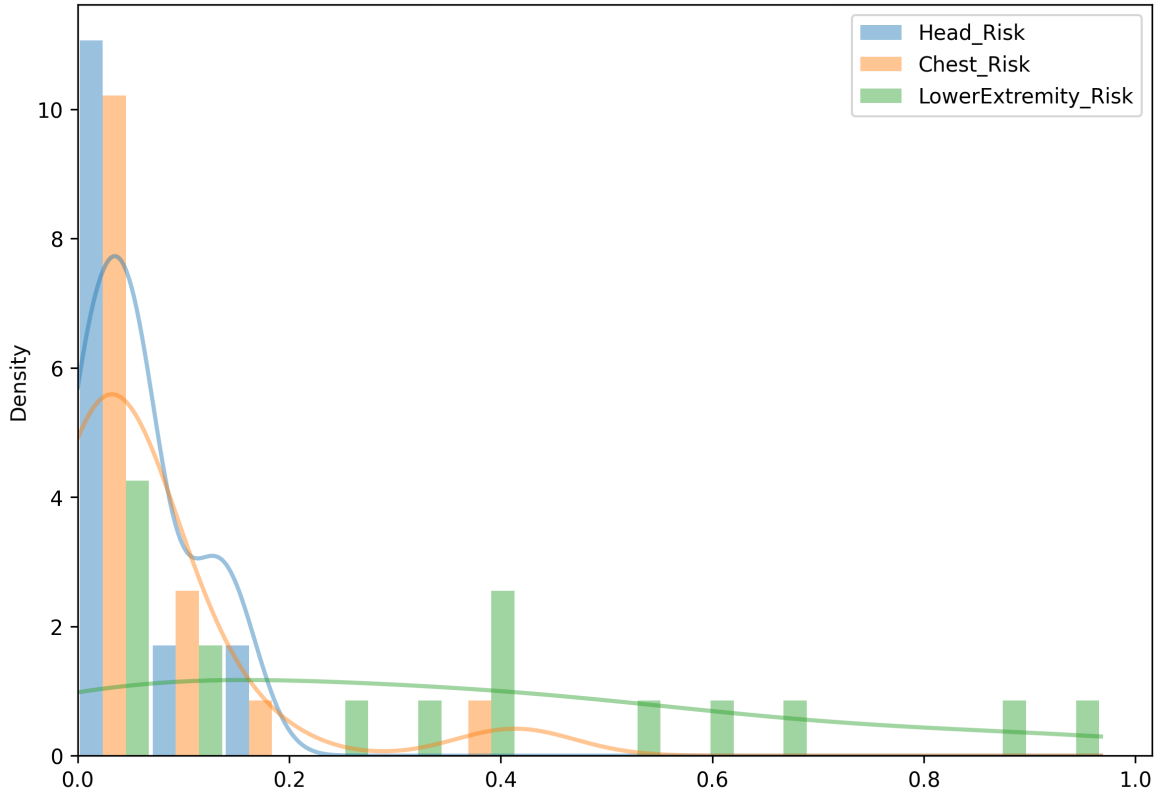
Human Decision versus ADS Decision





	Head	Chest	Lower EXT
Human	0.048 (0.05)	0.175 (0.23)	0.318 (0.32)
ADS	0.056 (0.05)	0.064 (0.10)	0.335 (0.30)

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Conclusion

- Extract field data to generate close-to-reality ADS simulations
- Evaluate injury risks for ADS simulations
- Quantify the injury risk distributions under human driving and ADS decision

Questions?

Contact: Wenbo Sun, Ph.D., sunwbgt@umich.edu

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Supplementary Material

EDR Data (CIREN #108646)

EDR data metrics: speed, braking, acceleration, steering angle, and seatbelt usage

Air Bag Deploy

Type	Position	Stage 1(ms)	Stage 2(ms)
Steering Wheel Hub		13	
Top Instrument Panel		13	

Pre-Crash

Pre-Seconds	Speed (MPH)	Engine Speed (RPM)	Throttle %	Brake Switch Circuit Status
-5.000	68	2560	7	Off
-4.000	68	2560	7	Off
-3.000	65	2304	13	Off
-2.000	71	3328	82	Off
-1.000	52	4608	100	Off

General Data

Version	2.24
Lamp Status	On
CDC	Event# 2 FZEW05
Deploy Status	Deployment
Ignition Cycle - Event"	877
Ignition Cycle - Investigation	878

Driver

Belt	Buckled
Seat	
Pretensioner	Not Reported
Seat Track Forward	Not Reported

Passenger

Belt	Not Reported
Seat	Not Reported
Pretensioner	Not Reported
Seat Track Forward	Not Reported

Crash

Longitudinal Delta V

Time (ms)	Delta V (MPH)
10	.44
20	-1.76
30	-4.39
40	-7.9
50	-12.73
60	-20.62
70	-26.77
80	-32.47
90	-37.3
100	-42.12
110	-45.64
120	-48.71

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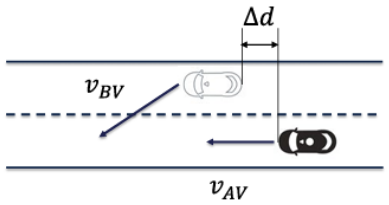
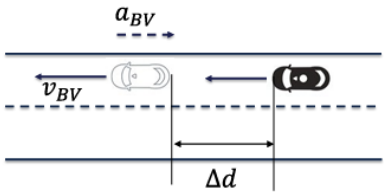
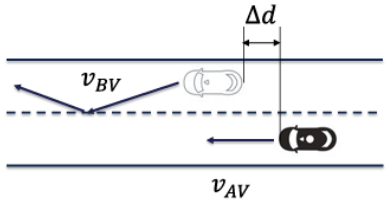
Scenarios in the ADS Simulator



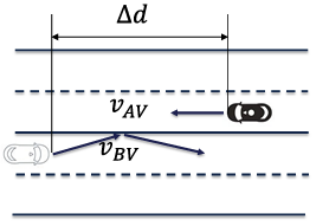
Cut-in



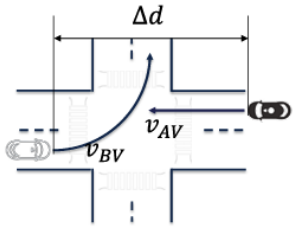
Car-following



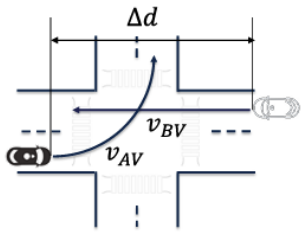
Lane departure
(same direction)



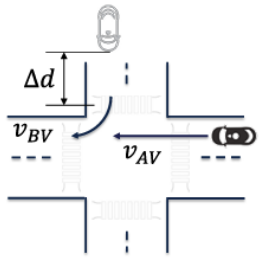
Lane departure
(opposite direction)



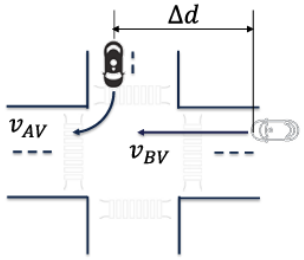
Left turn
(AV goes straight)



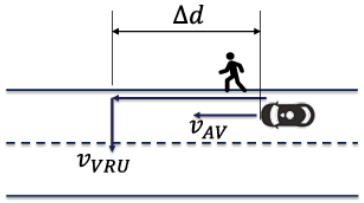
Left turn
(AV turns left)



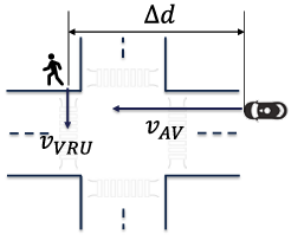
Right turn
(AV goes straight)



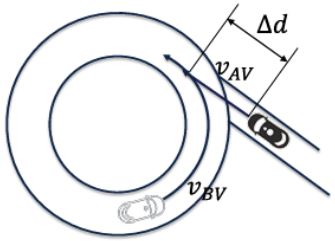
Right turn
(AV turns right)



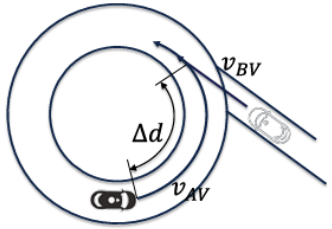
VRU crossing the street
without the crosswalk



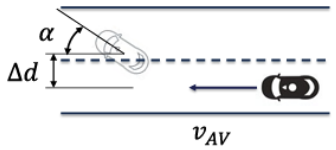
VRU crossing the street
at the crosswalk



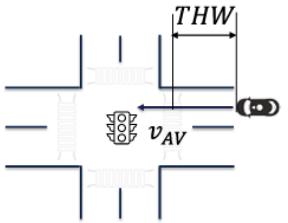
AV merging into
the roundabout



BV merging into
the roundabout



Vehicle encroachment



Traffic signal

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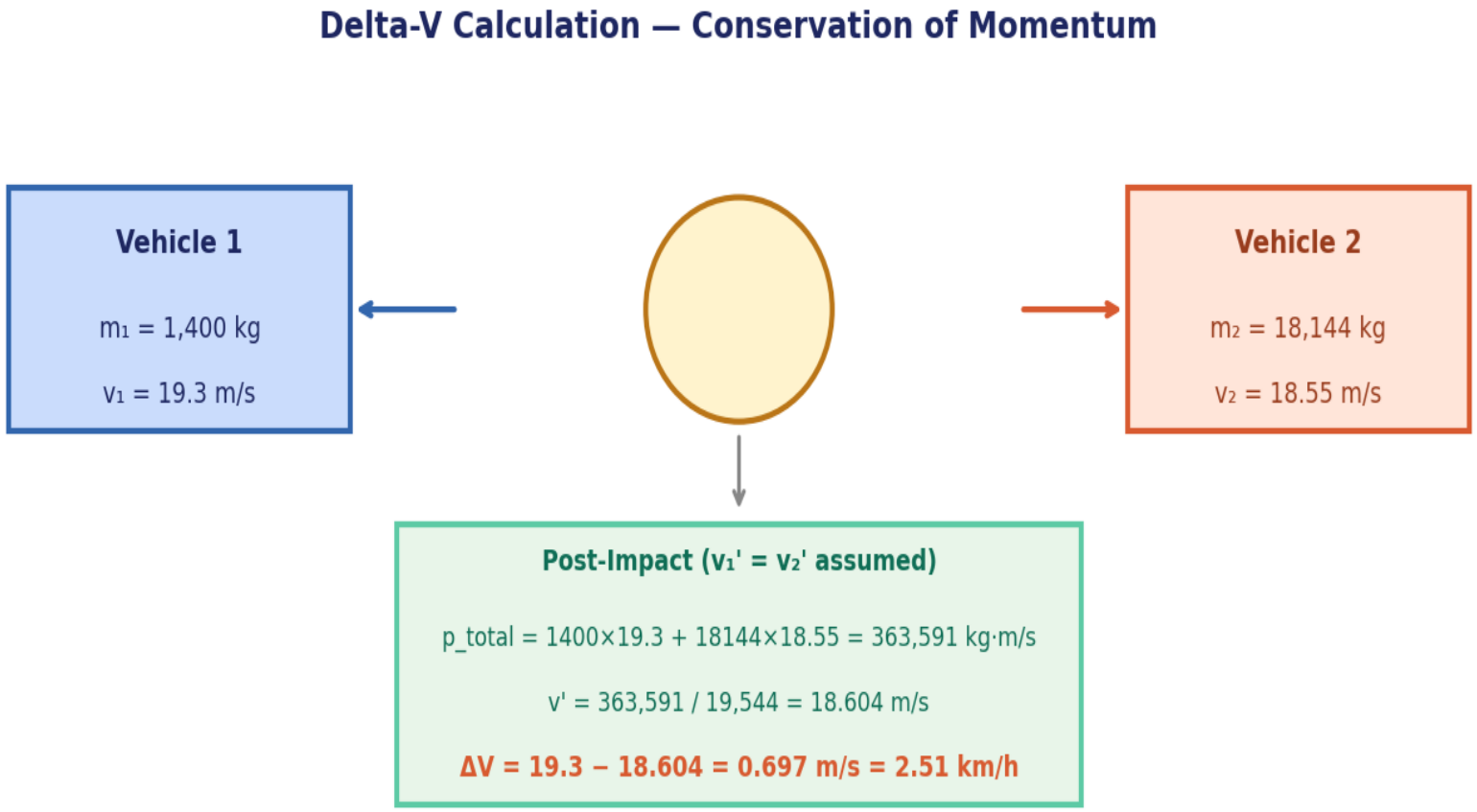
* https://github.com/michigan-traffic-lab/Behavioral-Safety-Assessment

CIREN #100343: Delta-V Calculation (ADS Decision)

Case 100343 — V1 (1,400 kg) rear-ended by V2 (18,144 kg trailer) | Oblique Left impact direction



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CIREN # 100343: Injury Risk Evaluation

Case 100343 | ΔV = 45 km/h | Male, 178 cm, BMI 22.1 | Oblique Left

Head AIS 3+

$z = -10.5901$
$+ 2.3987 \times \ln(45)$
$+ (-0.3892)$ [Age]
$+ (-0.0136 \times 178)$ [Height]
$+ (0.0591 \times 22.1)$ [BMI]
$z = -2.973$
$P = 1/(1+e^{2.973})$

4.9%

Chest AIS 3+

$z = -13.6031$
$+ 2.4905 \times \ln(45)$
$+ 0.4087$ [Age]
$+ (0.0128 \times 178)$ [Height]
$+ (-0.00922 \times 22.1)$ [BMI]
$z = -1.638$
$P = 1/(1+e^{1.638})$

16.3%

Lower Extremity AIS 2+

$z = -12.1951$
$+ 2.5444 \times \ln(45)$
$+ 0.7025$ [Age]
$+ (-0.00014 \times 178)$ [Height]
$+ (0.0425 \times 22.1)$ [BMI]
$z = -0.890$
$P = 1/(1+e^{0.890})$

29.1%

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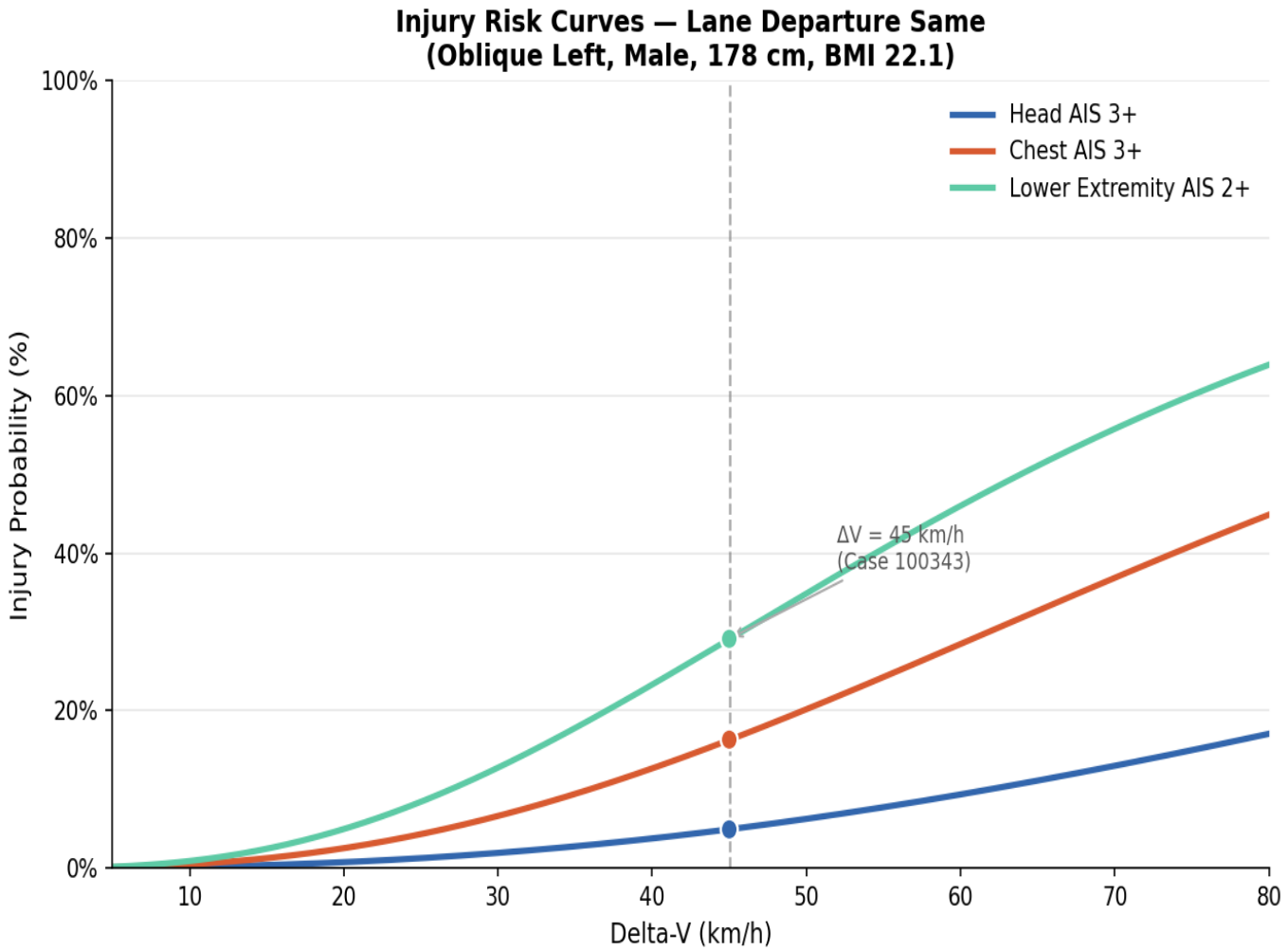
CIREN # 100343: Injury Risk Curves



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EDR Data (CIREN #108646)

EDR data metrics: speed, braking, acceleration, steering angle, and seatbelt usage

Air Bag Deploy

Type	Position	Stage 1(ms)	Stage 2(ms)
Steering Wheel Hub		13	
Top Instrument Panel		13	

Pre-Crash

Pre-Seconds	Speed (MPH)	Engine Speed (RPM)	Throttle %	Brake Switch Circuit Status
-5.000	68	2560	7	Off
-4.000	68	2560	7	Off
-3.000	65	2304	13	Off
-2.000	71	3328	82	Off
-1.000	52	4608	100	Off

General Data

Version	2.24
Lamp Status	On
CDC	Event# 2 FZEW05
Deploy Status	Deployment
Ignition Cycle - Event"	877
Ignition Cycle - Investigation	878

Driver

Belt	Buckled
Seat	
Pretensioner	Not Reported
Seat Track Forward	Not Reported

Passenger

Belt	Not Reported
Seat	Not Reported
Pretensioner	Not Reported
Seat Track Forward	Not Reported

Crash

Longitudinal Delta V

Time (ms)	Delta V (MPH)
10	.44
20	-1.76
30	-4.39
40	-7.9
50	-12.73
60	-20.62
70	-26.77
80	-32.47
90	-37.3
100	-42.12
110	-45.64
120	-48.71

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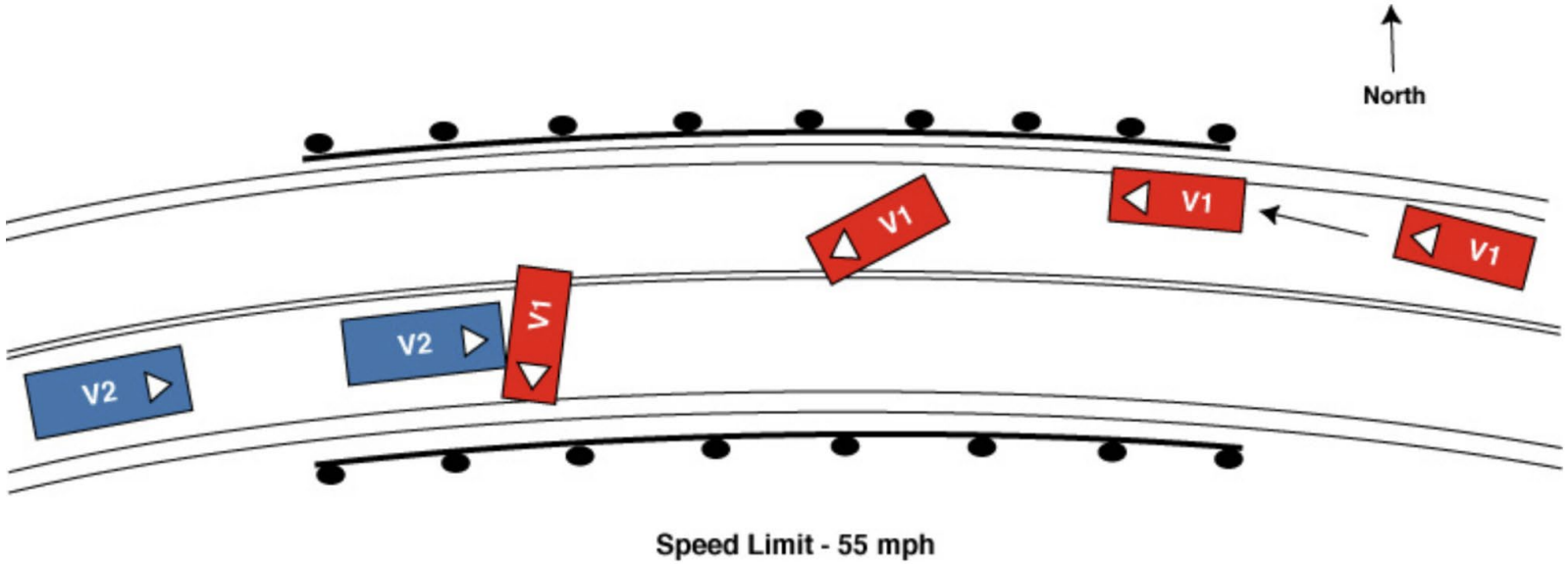
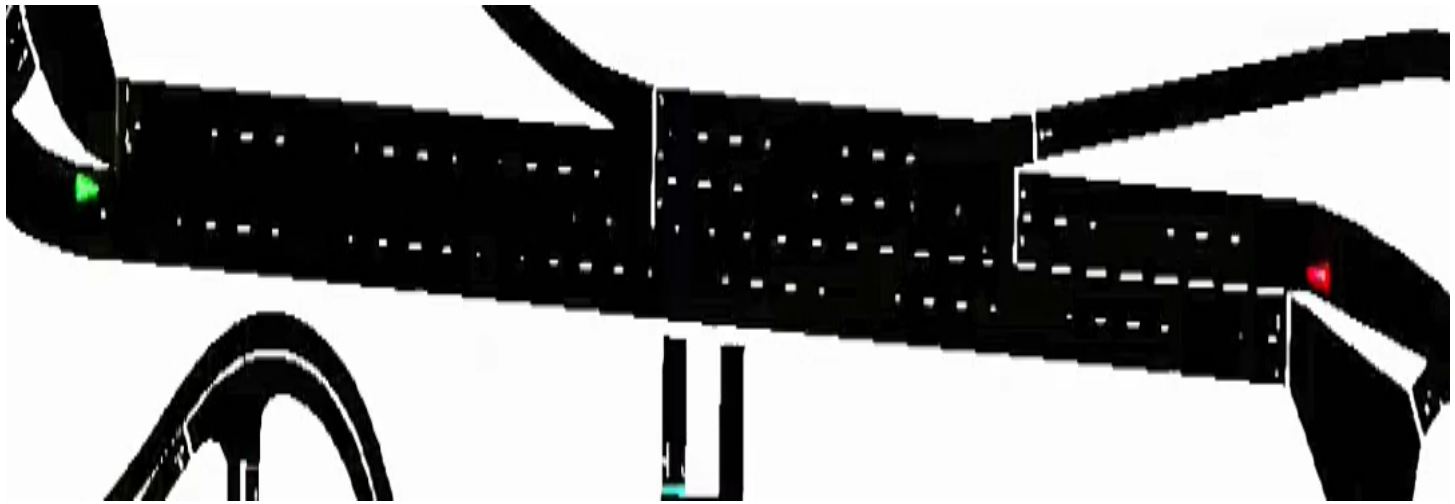
Lane Changing (CIREN #99817)





Red: AV
Green: BV

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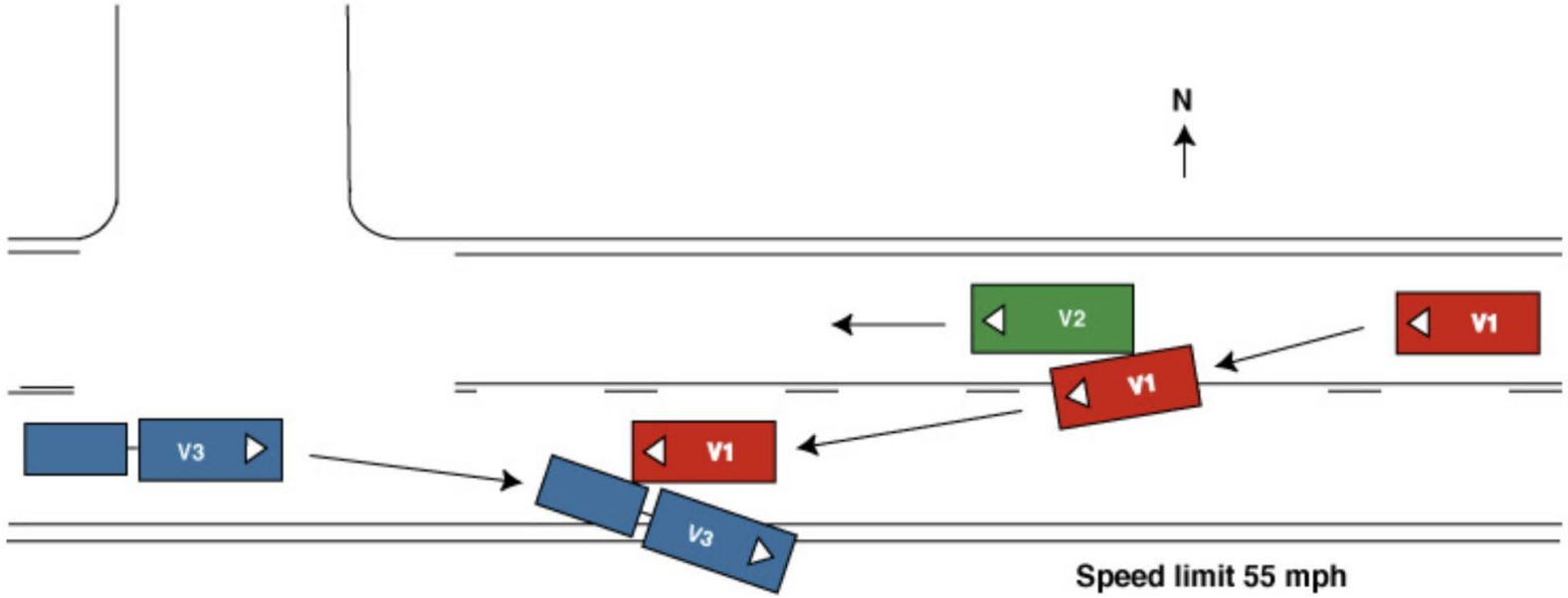
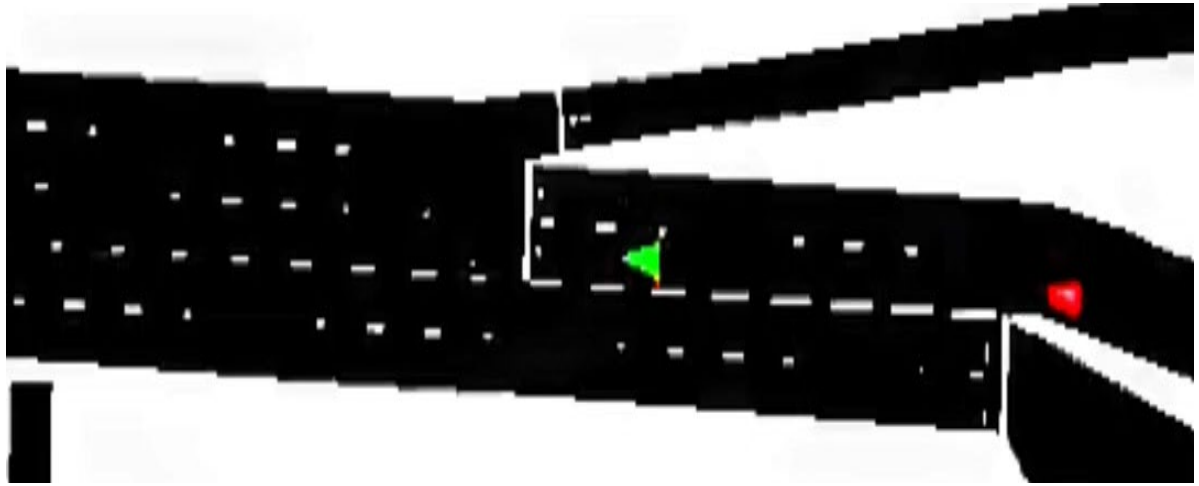
Car Following (CIREN #105203)





Red: AV
Green: BV

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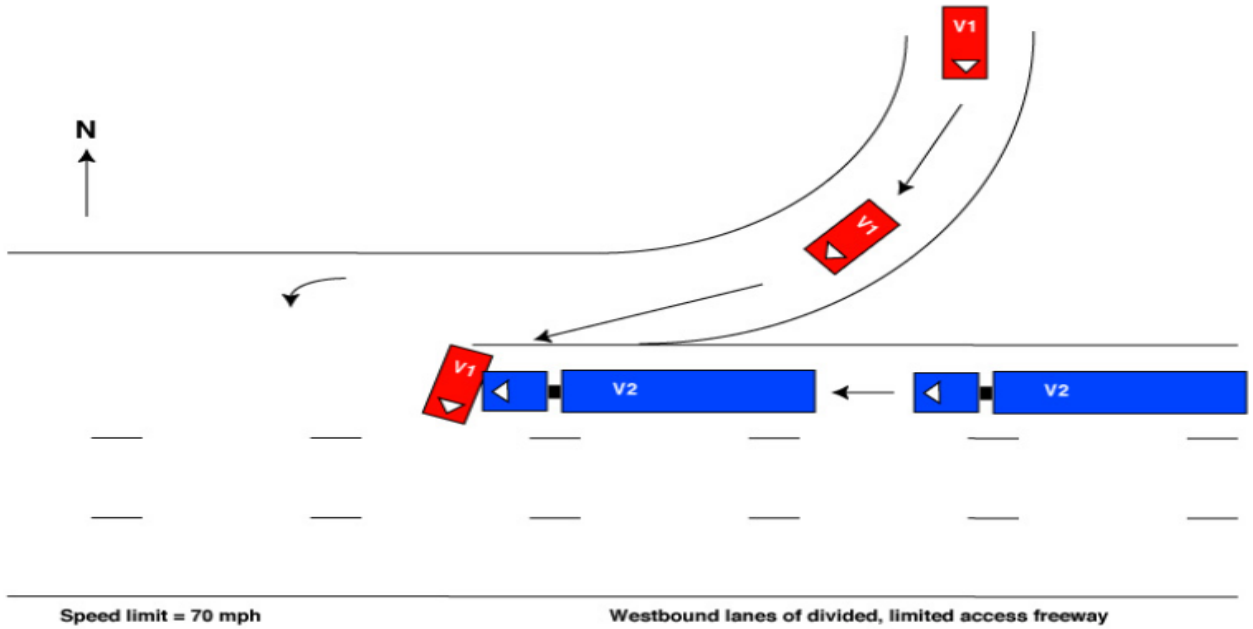
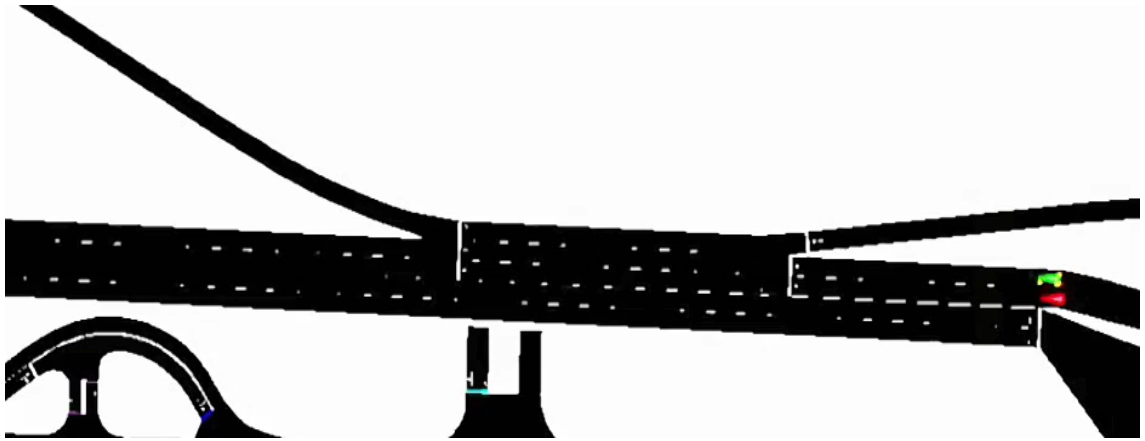
Cut In (CIREN #108909)





Red: AV
Green: BV

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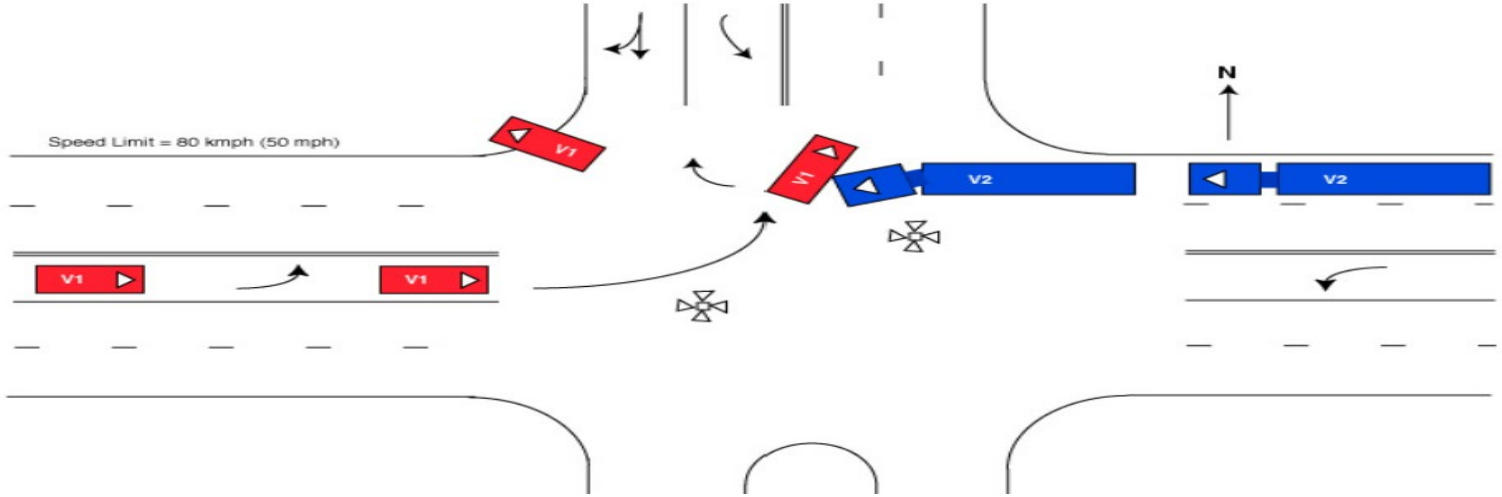
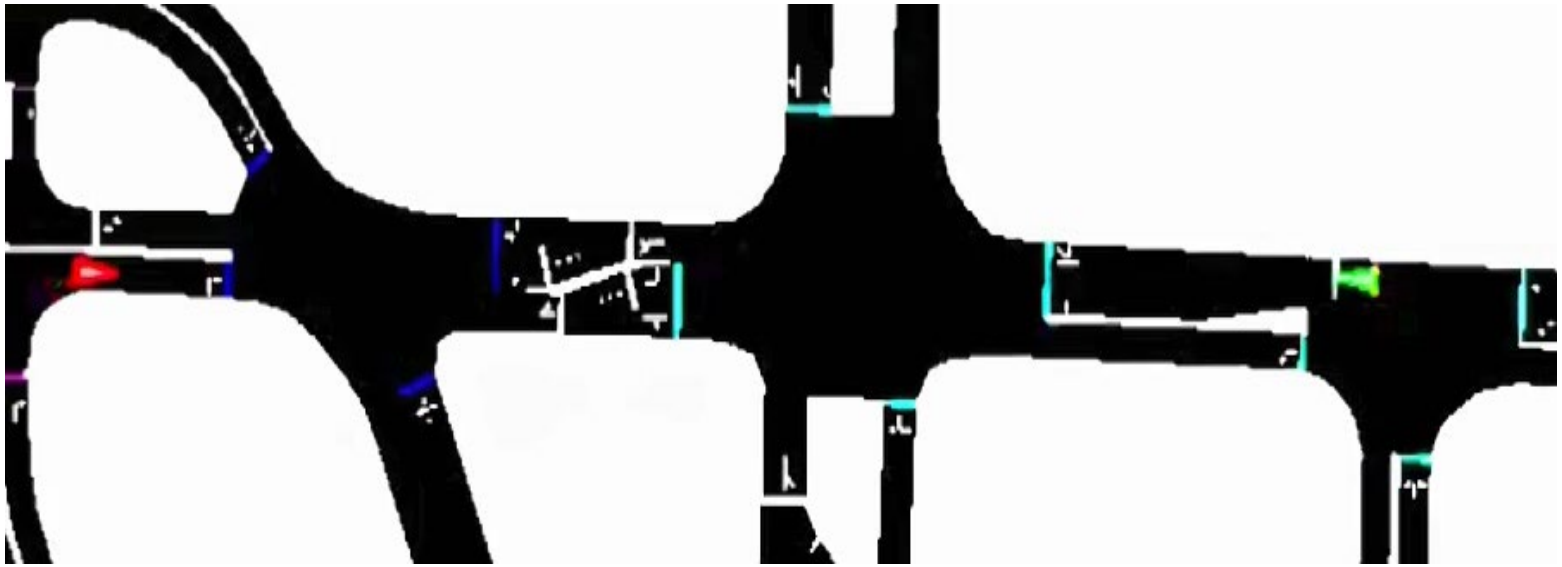
Left Turn (CIREN #109204)





Red: AV
Green: BV

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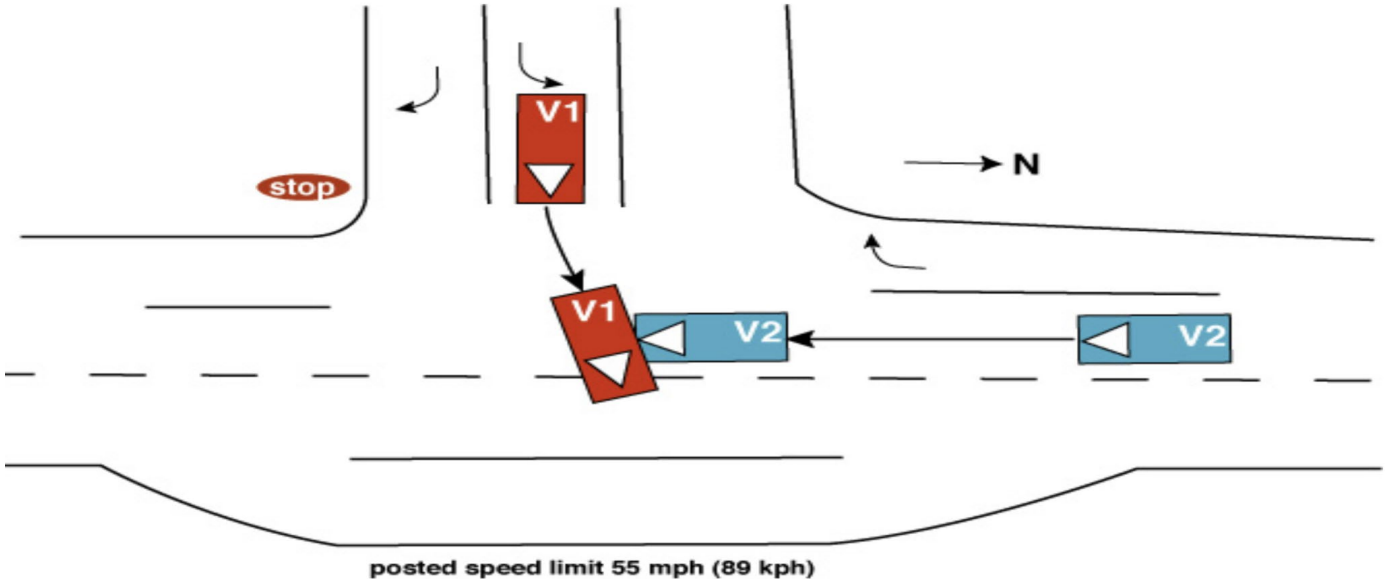
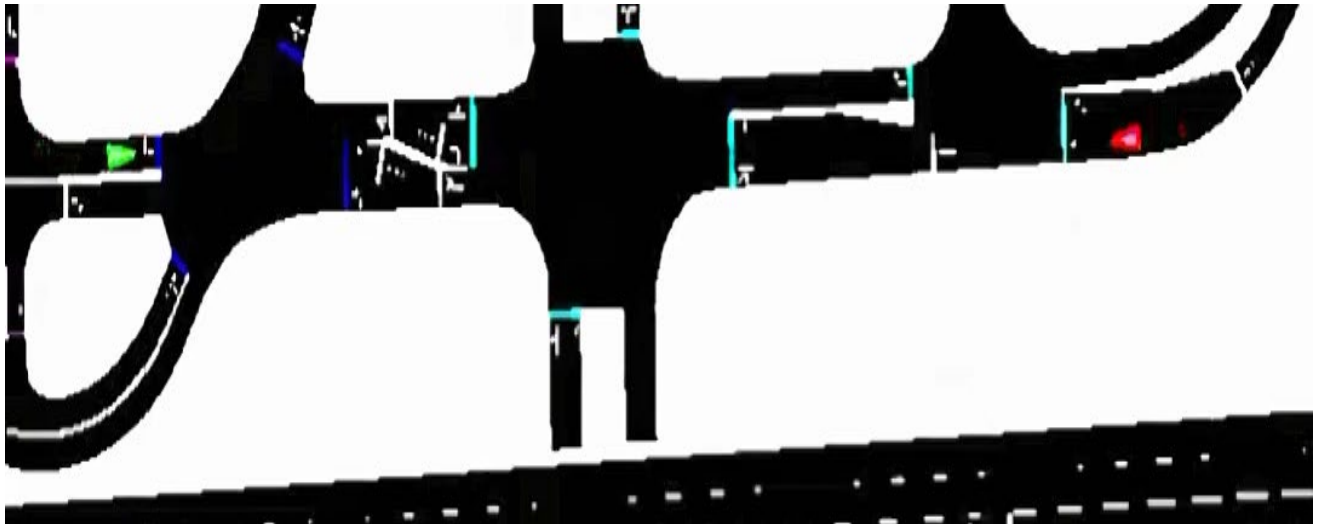
Left Turn (CIREN #100271)





Red: AV
Green: BV

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