Characterisation of Real-World Intersection Traversals from Large-Scale Naturalistic Driving Data in the USA

Katelyn Kleinschmidt, Morgan E. Dean, Rini Sherony, Takashi Hasegawa, Luke E. Riexinger

Abstract This study characterised real-world intersection traversals using naturalistic driving datasets. The real-world intersection traversals were selected from the Second Strategic Highway Research Program (SHRP-2) and the Virginia Traffic Cameras for Advanced Safety Technologies (VT-CAST) 2020 datasets. The VT-CAST dataset contains real-world trajectories from 2,800 hours of vehicle traversals across 126 intersections. A step-by-step approach was taken to create an algorithm that can identify three different intersection traversal trajectories: straight crossing path (SCP); left turn across path opposite direction (LTAP/OD); and left turn across path lateral direction (LTAP/LD). Crashes and near-crashes in SHRP-2 were manually reviewed and characterised into the same three scenarios. For every encounter, the velocity, acceleration, and estimated time to collision (eTTC) were calculated. The average velocities of the traversing vehicles were found to be about 7 m/s for all three intersection traversal scenarios. The average maximum deceleration was at minimum 17 times greater for crash and near-crash scenarios compared to the everyday driving. The VT-CAST dataset allows for a very large quantity of intersection traversals to be recorded and identified. This data on standard driving traversals from VT-CAST and crashes/near-crashes from SHRP-2 may be useful for developing detailed intersection driver behaviour models for I-ADAS development.

Keywords Advanced Driver Assist Systems, crashes, driver behaviour, intersection, real-world data.

I. INTRODUCTION

From 2019 to 2020, 25% of all traffic fatalities in the USA occurred at an intersection [1]. Crossing-path crash scenarios make up one-third of nationally represented police-reported tow-away crashes. The top three most common crossing-path pre-crash scenarios are: straight crossing path (SCP); left turn across path lateral direction (LTAP/LD); and left turn across path opposite direction (LTAP/OD) [2]. The SCP scenario is when both vehicles are traversing straight and the vehicles are travelling on crossing streets. The LTAP/LD scenario is when one vehicle is traversing straight and another vehicle is intending to turn left from a crossing street. The LTAP/OD scenario is when one vehicle is traversing straight and the other vehicle is intending to turn left from the opposite direction as the vehicle traversing straight (Fig. 1). These pre-crash scenarios can lead to near-side crashes – a side-impact crash on the same side as the occupant – or to far-side crashes – a side-impact crash on the opposite side from the occupant – crash modes which are found to lead to a greater risk of serious injury (MAIS3+ injury) compared to the front and rear crash modes at the same delta-V [3]. Therefore, intersection crashes are not only common, they also are more severe than other crash modes.

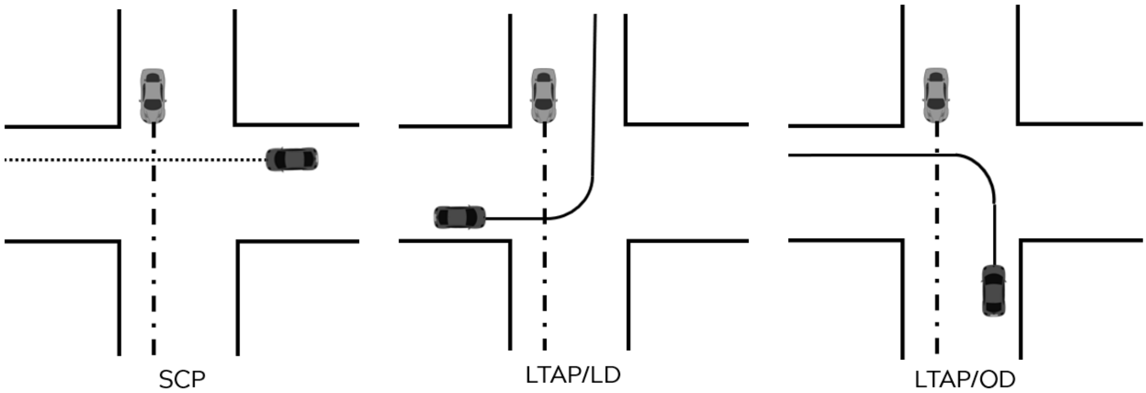

Fig. 1. Example of each of the top three pre-crash scenarios.

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Intersection Advanced Driver Assist Systems (I-ADAS) can assist drivers in preventing or mitigating these crashes under certain circumstances. One way I-ADAS may assist in crash prevention is with automatic emergency braking (AEB), which will automatically apply braking without driver input if the vehicle detects that a crash is imminent. Currently, AEB is an effective method for preventing front-to-rear crashes, with estimated crash reduction benefits up to 56% [4]. There are many different sensor used to detect objects, such as radar, lidar and cameras [5]. Studies have been conducted using ideal detection systems and real-world crashes to predict the percentage of intersection crashes that could have potentially been avoided. Those studies have predicted that a max. of 59% of SCP crashes might be potentially preventable with future development of an ideal AEB system [6]. The studies do have some limitations to them including median values for driving behaviour, two variations of obstruction, and an ideal I-ADAS [6]. It has also been predicted that a maximum of 84% of LTAP/OD crashes might be prevented with an ideal AEB system [7]. I-ADAS with AEB could potentially be a viable option for preventing intersection crashes. With limitations to the studies, the crash preventability will potentially decrease as driver behaviour, weather conditions, and other environmental factors could play a role in the AEB system's effectiveness.

The European New Car Assessment Program (Euro NCAP) has added test protocols for I-ADAS to test the capability of this type of feature [8]. The protocol tests two different scenarios. One is a straight crossing path scenario, and the other is a left turn across path opposite direction scenario [8]. The straight crossing path tests have the target vehicle travelling from the left of the test vehicle on the crossing street. The speeds of each vehicle vary: the test vehicle speed will range from 0 kph to 60 kph and the target vehicle speed will range from 20 kph to 60 kph. There is a total of 30 tests for SCP. The test is designed such that if no deceleration occurs, the centre front of the test vehicle will collide with the side of the target vehicle. The left turn across path opposite direction scenario tests have the target vehicle travelling straight and the test vehicle making a left turn from the opposite direction. The radius of the turn varies based on the speed of the test vehicle. The test vehicle's speed ranges from 10 kph to 20 kph, and the target vehicle's speed ranges from 30 kph to 60 kph. The tests are set up such that the front centre of the test vehicle will impact the front left corner of the target vehicle. The test ends if at least one of the three scenarios occurs: the test vehicle has a velocity of 0 kph without entering into the path of the target vehicle; the test vehicle and target vehicle collide; or the target vehicle has left the path of the test vehicle [8].

The United States New Car Assessment Program (US-NCAP) has also proposed adding I-ADAS with AEB tests into its standard test matrix. The US-NCAP has proposed three different scenarios. The first scenario is a straight crossing-path scenario where both the test vehicle and the target vehicle are traversing straight from crossing roads, with the approach side of the test vehicle changing from being on the right or left side of the target vehicle. There are three different proposed speed combinations, which include both vehicles traveling at 40.2 kph, the test vehicle travelling at 40.2 kph and the target vehicle travelling from 0 kph to 40.2 kph, and the test vehicle travelling from 0 kph to 40.2 kph and the target vehicle traveling at 40.2 kph.

The second scenario is a LTAP/OD test scenario where the test vehicle is travelling straight and the target vehicle is turning left. There are also three different proposed test combinations for this scenario: the test vehicle is travelling at 40.2 kph and the target vehicle is travelling at 24.1 kph, the test vehicle is travelling at 40.2 kph and the target vehicle is travelling from 0 kph to 40.2 kph, and the test vehicle is travelling from 0 kph to 40.2 kph and the target vehicle is travelling at 24.1 kph.

The third scenario is also a LTAP/OD scenario, but the test vehicle is turning left and the target vehicle is travelling straight. There are also three speed combinations for this scenario: the test vehicle is travelling at 24.1 kph and the target vehicle is travelling at 40.2 kph, the test vehicle is travelling at 24.1 kph and the target vehicle is traveling from 0 kph to 40.2 kph, and the test vehicle is travelling from 0 kph to 40.2 kph and the target vehicle is travelling at 40.2 kph. All the tests have two crash-imminent configurations where the vehicles are set up to collide if no deceleration occurs and a near-miss configuration where the vehicles are set up to barely miss each other [9].

While the EU NCAP and the proposed US-NCAP tests evaluate the object detection and decision-making of the system, they do not incorporate any potential actions of the driver. The objective of this study was to characterise real-world intersection traversals using naturalistic driving datasets to provide driver behaviour context to I-ADAS development which could potentially affect crash reduction/mitigation benefits of such systems.

II. METHODS

The real-world intersection traversals were selected from the Second Strategic Highway Research Program (SHRP-2) and the Virginia Traffic Cameras for Advanced Safety Technologies (VT-CAST) 2020 datasets. SHRP-2 is a database that is comprised of radar and camera data from all trips taken by volunteering participants [10]. For this study, only trips that involve a crash or near-crash in an intersection were analysed. SHRP-2 crashes and near-crashes were obtained from the Research of Driver Assist System Dataset [10]. Crashes and near-crashes in SHRP-2 were manually reviewed and characterised into the same three scenarios. The VT-CAST dataset contains real-world trajectories from 1,263 traffic cameras collected in Virginia from December 2019 to December 2020. There are 2,800 hours of vehicle traversals across 126 intersections [11]. The VT-CAST dataset captured normal driving in intersections, and allowed for comparison between nominal driving and driving in a crash and near-crash scenario from SHRP-2. A step-by-step approach was taken to create an algorithm that could identify three different intersection traversal trajectories: straight crossing path (SCP); left turn across path opposite direction (LTAP/OD); and left turn across path lateral direction (LTAP/LD). For every encounter, the velocity, acceleration, and estimated time to collision (eTTC) were calculated.

A. Scenario identification

A process was developed to enable the algorithm to characterise the encounters in VT-CAST. The algorithm was developed in three steps. The first step was to create an ideal intersection with four legs intersecting at 90°. The vehicle trajectories were manually chosen to have the three target scenario types occur. An algorithm was created to parse through the trajectories and categorise the encounters. The next step applied the algorithm to simulated vehicle traversal data in a real intersection geometry. The simulated data added complexity by having 200 vehicles driving through a road system, compared to five vehicles in the ideal intersection. The algorithm was validated by randomly reviewing encounters recorded by the algorithm to check if the encounter was characterized correctly. The final step applied the algorithm to the VT-CAST dataset and improved the algorithm performance. The VT-CAST dataset has an extra layer of challenges because the camera field of view does not necessarily capture the whole intersection. Therefore, the algorithm needed to be robust enough to process partial vehicle trajectories. The algorithm was validated by manually comparing the VT-CAST video with the data collected. An intersection with all 3 scenarios were visible had a total of 36 encounters captured within 3 minutes at a busy intersection. The characterisation precision was calculated for each scenario type: 87.5% for SCP, 85.7% for LTAP/LD, and 100% for LTAP/OD. The algorithm was not able to capture every encounter in the VT-CAST dataset. Due to the differences in infrastructure and the camera field of view, the precision across the entirety of VT-CAST is likely lower. Despite this, tens of thousands of encounters were identified for use in this study because of the large scale of VT-CAST dataset. For example, if the vehicle is only tracked at the very beginning of a left turn it looks like the vehicle is traversing straight instead of making a left and will be characterized as an SCP instead of LTAP/LD. Each step of the process came with its own challenges, which made iterating the algorithm at each step crucial to be able to capture every encounter found in the VT-CAST dataset.

The algorithm determined if the encounter was SCP, LTAP/LD, LTAP/OD, or Other by passing the relative vehicle headings of the conflict vehicle through a decision tree. For an encounter to be SCP, the conflicting vehicle must begin its traversal with a heading of about 90° or 270° and finish its traversal with a similar heading. With the intersection legs being at a 90° angle from each other, the x-coordinate staying constant holds true for a SCP encounter. However, if the intersection legs are not at a 90° angle, the x-coordinate does not stay constant, so the x-coordinate staying constant cannot be a criterion to determine a SCP encounter. For an encounter to be LTAP/LD, the conflicting vehicle must begin its traversal with a heading of about 270°. The conflict vehicle will end its traversal at about 180°. Finally, for an encounter to be LTAP/OD, the conflicting vehicle must begin its traversal with a heading of about 180° and end the traversal with a heading of about 90°. All other encounters, such as LTAP/Turn-into-Path or right turns, were considered an ‘Other’ encounter and were excluded from this study.

B. Case Selection

The algorithm was able to capture 143,643 encounters of crashes, near-crashes, and encounters (Table I). There was a total of 287,286 vehicle trajectories that could be characterised. There were 19 SHRP-2 crashes and 282 near-crashes available. The radar signatures were manually matched to the video. The trajectories from VT-CAST needed to be tracked for more than 1 s to be considered. The encounter, both vehicles near the intersection at the same time, needed to be more than 1 s.

TABLE I
ENCOUNTER COUNT

Encounter Type	SCP	LTAP/LD	LTAP/OD
Crash (SHRP-2)	7	4	8
Near-Crash (SHRP-2)	57	90	135
Encounter (VT-CAST)	35,879	52,957	54,506
TOTAL	35,943	53,051	54,649

C. Characterisation

VT-CAST and SHRP-2 are comprised of many different types of intersection. The following variables were analysed from the intersections: stopping mechanism, intersection shape, minimum and maximum angle between the legs, and lane configuration.

The vehicles in crash or near-crash scenarios were categorised by “fault” (at-fault vehicle), as indicated within the SHRP-2 database. In VT-CAST, each vehicle is near the beginning of the intersection during the start of the vehicle’s trajectory. We defined a physical zone to capture the time range within which the vehicle was in this zone near the start of the intersection. When the vehicle was within this zone, it was determined to be the waiting vehicle. The zone is 10 m in length and is measured from the centre of the closest lane perpendicular to the lane of the vehicle’s trajectory (Fig. 2). Once the vehicle exits this zone, it is considered to be traversing through the intersection.

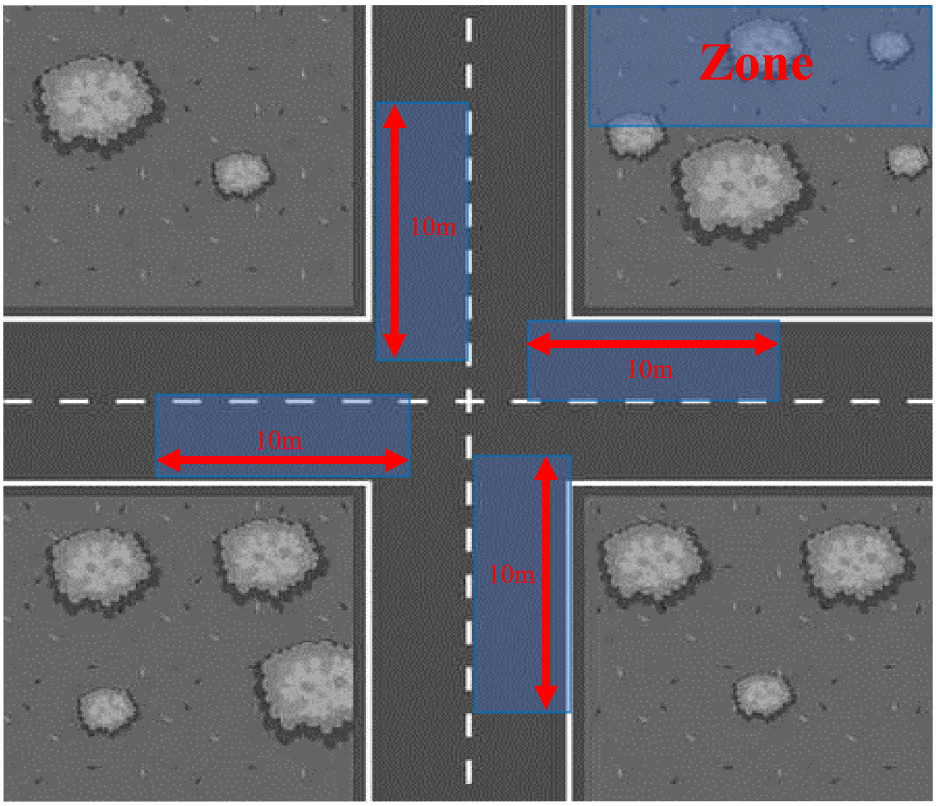

Fig. 2. Visual zones for all four directions of travel in the intersection.

The time range of each vehicle when in the zone and when traversing was determined. The driver behaviours in the intersection were analysed using the time both vehicles were in or near the intersection at the same time (Fig. 3). Only the driver behaviour while the encounter was occurring was evaluated. If the vehicles had extra time in or near the intersection when the vehicle was not in the encounter, this time was disregarded.

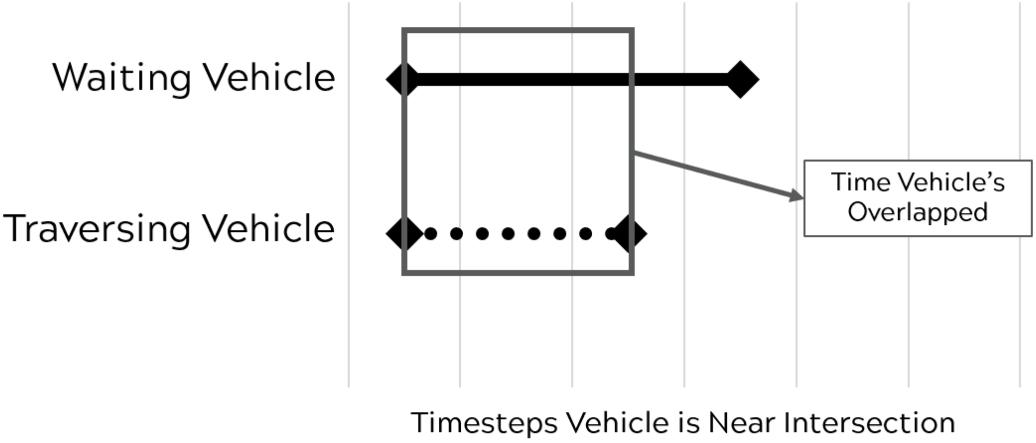

Fig. 3. Analysed time for vehicle trajectory.

The intersect point of the vehicle trajectories for each encounter was needed to calculate the estimated time to collision. Each encounter type needed a slightly different method to find the intersect point. The intersect point for a SCP encounter was calculated by using known path knowledge and path prediction. If the exact intersect point was not seen by the camera, path prediction was used to determine the intersect point. For SCP, the slope of the traversing vehicle's trajectory was determined based on the known trajectory. The waiting vehicle's full trajectory was not always known, so the trajectory was then assumed to be perpendicular to that of the traversing vehicle's trajectory (Fig. 4). Creating two point-slope equations, the intersection point can then be determined and used to calculate the eTTC.

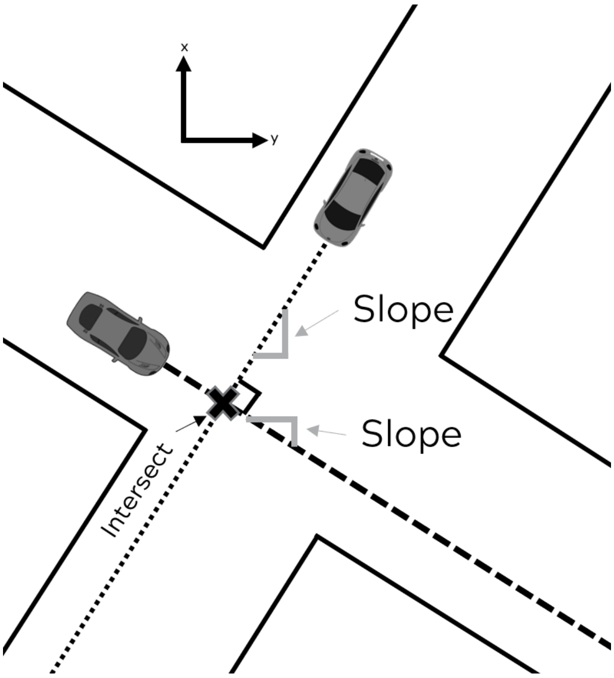

Fig. 4. Visual of eTTC.

The estimated time to the collision for LTAP/LD and LTAP/OD was calculated in a similar way. The eTTC was found by finding the slope of the waiting vehicle's trajectory to then create a predicted path straight forward. The traversing vehicle will pass through the point of the trajected path of the waiting vehicle. This point on the traversal's trajectory was considered the intersect point (Fig. 5 and Fig. 6).

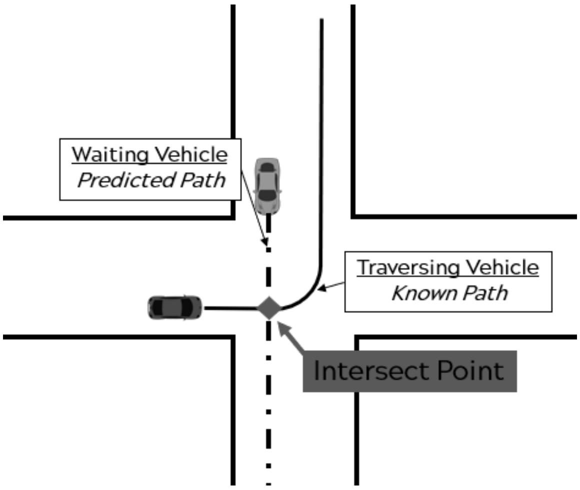

Fig. 5. Methodology for finding the intersect point of the two vehicles' trajectories for LTAP/LD.

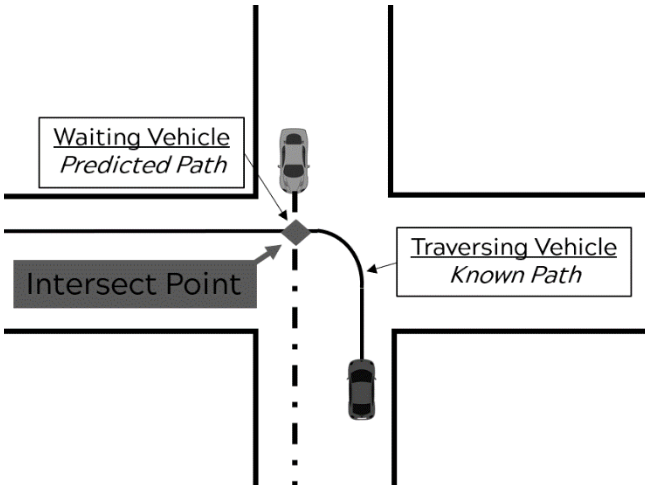

Fig. 6. Methodology for finding the intersect point of the two vehicles' trajectories for LTAP/OD.

The absolute distance from the vehicle's instant position to the intersect point was divided by the absolute instantaneous velocity vector to equate the estimated time to collision (Equation 1):

$$eTTC = \frac{|Distance\ to\ Intersect|}{|Velocity\ Vector|} \quad (1)$$

The maximum acceleration was determined for each vehicle at each time step. The acceleration was determined between each time point by calculating the change in velocity divided by the change in time (Equation 2).

$$acceleration = \frac{v_2 - v_1}{t_2 - t_1} \quad (2)$$

For every vehicle trajectory, the maximum, minimum and average were found for acceleration, deceleration, velocity, and eTTC. Once those values were calculated for every vehicle, the median was calculated based on the type of scenario the vehicles' encounter was categorized as (e.g., SCP at fault crash or LTAP/LD VT-CAST encounter).

III. RESULTS

A. SCP

1) Infrastructure characteristics

Intersections in VT-CAST with SCP encounters were characterised by four different stopping mechanisms: stop signs; traffic lights; mixed; and none. No encounters occurred at intersections that had stop signs as the only stopping mechanism, and no encounters occurred at intersections that had no stopping mechanism in place. In total, 47% of the encounters occurred at intersections with a combination of traffic lights and yield signs as the stopping mechanism, and 53% of the encounters occurred at intersections with only traffic lights. SHRP-2 had about 25% of the SCP encounters occur at an intersection with a traffic light compared to all encounters in SHRP-2 occurring at intersections with a traffic light only 10% of the time. Most (41%) of the SCP encounters in SHRP-2 occurred at intersections with no traffic control. The stopping mechanisms at the intersections are vastly different when comparing the two datasets for SCP encounters. This could be caused by the areas where the VT-CAST cameras are located. The cameras are located on high-volume, state-controlled roads, unlike SHRP-2 vehicles which were recorded everywhere. Overall, the VT-CAST SCP encounters occurred at large intersections with 4-legs and 4-lanes with dedicated left- and right-turn-only lanes and traffic lights. In contrast, majority of SHRP-2 encounters occurred at small intersections that were mainly simple 2-way traffic lanes with no traffic control. The use of data from both VT CAST and SHRP2 which contains significantly different intersection infrastructure is very helpful in capturing in the analysis the diverse intersections that exists in the U.S.

2) Trajectory characteristics

The average velocity was calculated for each vehicle type in the datasets. The waiting vehicles in VT-CAST had a low average velocity of 1.18 m/s. The velocity of the waiting vehicles in VT-CAST was greater than zero due to the velocity of a vehicle starting its traversal through an intersection directly after the vehicle was waiting at a stopping mechanism. On average, the acceleration and deceleration are much higher for the crash and near-crash encounters compared to the VT-CAST vehicles, except for the acceleration of the vehicles at-fault in crash scenarios. The encounters that were not characterised as at-fault or not-at-fault made up approximately 6.3% of the SHRP-2 cases and were disregarded from the results.

TABLE II
SCP CHARACTERISATION

Median	***Crashes***		***Near-Crashes***		***Encounter***	
	Not at Fault	**At Fault**	**Not at Fault**	**At Fault**	**Waiting**	**Traversing**
Average Velocity (m/s)	10.74	13.35	5.03	4.42	1.18	7.19
Average Acceleration (m/s^2)	0.37	0.08	0.69	0.45	0.15	0.28
Maximum Deceleration (m/s^2)	6.04	10.18	7.94	7.86	0.23	0.28

The minimum, median, and maximum eTTC is consistently lower for the crash and near-crash in SHRP-2 compared to VT-CAST encounters (Fig. 7). The VT-CAST eTTC starts to level off around 10 s, with higher eTTCs most likely caused by slower velocities. Due to the small number of crashes, the eTTCs for crashes and near-crashes were plotted together.

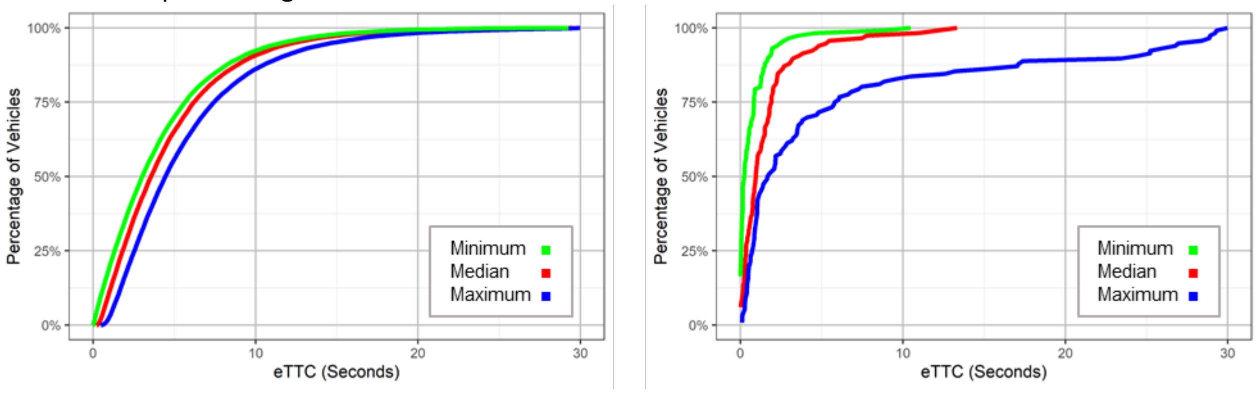

Fig. 7. The cumulative distribution of eTTC maximum, median, and minimum for traversing vehicles in VT-CAST (left), and SHRP-2 (right).

B. LTAP/LD

1) Infrastructure characteristics

In VT-CAST, no LTAP/LD encounters occurred at intersections with stop signs as the only stopping mechanism, and no encounters occurred at intersections with no stopping mechanism in place. In total, 37% of encounters occurred at intersections with traffic lights and stops signs as the stopping mechanism, and 63% at intersections with only traffic lights. The number of lanes of each leg at each intersection was determined. About one-third of all encounters occurred at intersections with four lanes in the direction of travel. The vehicles in SHRP-2 were at an intersection with no traffic control about half of the time. Many SHRP-2 encounters occurred at intersections with a non-divided 2-way traffic roadway.

2) Trajectory characteristics

The average velocity for crashes and near-crashes was higher than the VT-CAST encounters (Table III). In 3% of SHRP-2 cases fault was not defined, therefore these cases were removed from the calculations.

TABLE III
LTAP/LD CHARACTERIZATION

Median	Crashes		Near-Crashes		Encounters	
	Not at Fault	At Fault	Not at Fault	At Fault	Waiting	Traversing
Average Velocity (m/s)	10.74	6.96	8.71	7.85	0.63	7.30
Average Acceleration (m/s^2)	0.20	0.48	0.47	0.58	0.15	0.65
Maximum Deceleration (m/s^2)	17.75	4.93	8.33	7.47	0.28	0.19

The VT-CAST vehicle eTTCs level off around 15 s (Fig. 8). The minimum and median eTTC for VT-CAST have a very close distribution and start to fully converge at about 15 s. The crashes and near-crashes all had a minimum eTTC of less than 5 s (Fig. 9). About 75% of the maximum eTTCs for crashes and near-crashes were less than 2.5 s.

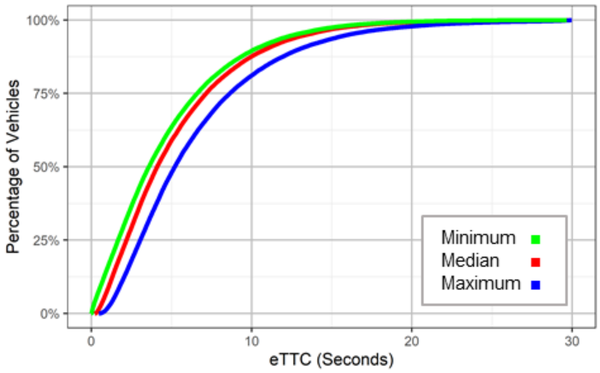

Fig. 8. The cumulative distribution of eTTC maximum, median, and minimum for traversing vehicles in VT-CAST.

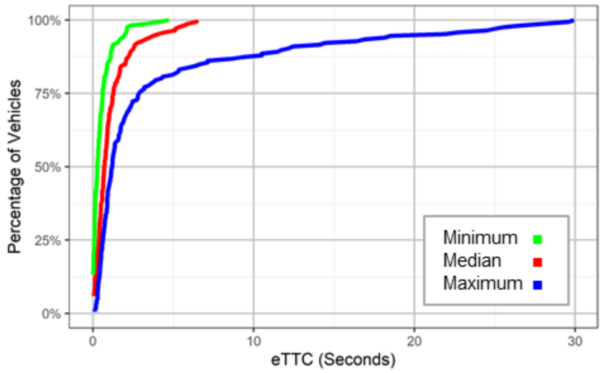

Fig. 9. The cumulative distribution of eTTC maximum, median, and minimum for crash and near-crash encounters in SHRP-2.

C. LTAP/OD

1) Infrastructure characteristics

Of the LTAP/OD encounters in VT-CAST, 39% had a traffic light and a yield sign at the intersection, and 59% of the encounters occurred at intersections that had only traffic lights. About one-third of all LTAP/OD VT-CAST encounters occurred at intersections that had four lanes in the direction of travel. The vehicles in SHRP-2 were at an intersection with no traffic control about half of the time. Many SHRP-2 encounters occurred at intersections with a non-divided 2-way traffic roadway.

2) Trajectory characteristics

The average velocity of the crashes in the LTAP/OD scenario was almost 10 m/s greater than in the other scenario crashes (SCP and LTAP/LD) (Table IV). Similar to the other scenarios, the crash maximum deceleration was high, which was caused by a limitation of the radars that captured the trajectories. About 5.6% of SHRP-2 encounters did not have fault defined and were not included in the calculations.

TABLE IV
LTAP/OD CHARACTERISATION

Median	Crashes		Near-Crashes		Encounters	
	Not at Fault	At Fault	Not at Fault	At Fault	Waiting	Traversing
Average Velocity (m/s)	17.67	17.85	11.98	11.04	0.66	7.20
Average Acceleration (m/s^2)	0.33	0.00	0.36	0.51	0.16	0.61
Maximum Deceleration (m/s^2)	19.08	15.63	8.33	8.86	0.30	0.21

The VT-CAST vehicles have a linear distribution for the minimum, median, and maximum eTTC until about 6 s (Fig. 10). The minimum eTTC for crashes and near-crashes stays close to 0 s for 75% of the vehicles before it starts to level off (Fig. 11). The same goes for the maximum eTTC for crashes and near-crashes, but the maximum eTTC slowly levels off at about 3.5 s.

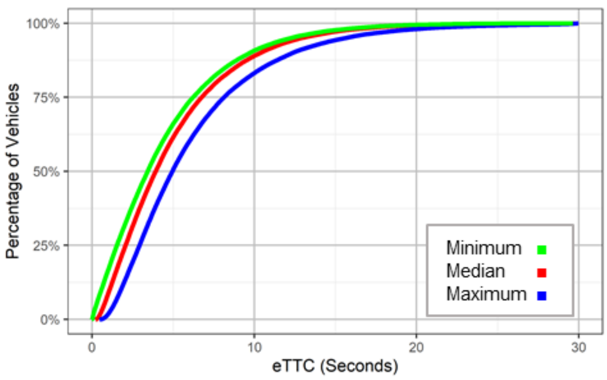

Fig. 10. The cumulative distribution of eTTC maximum, median, and minimum for traversing vehicles in VT-CAST.

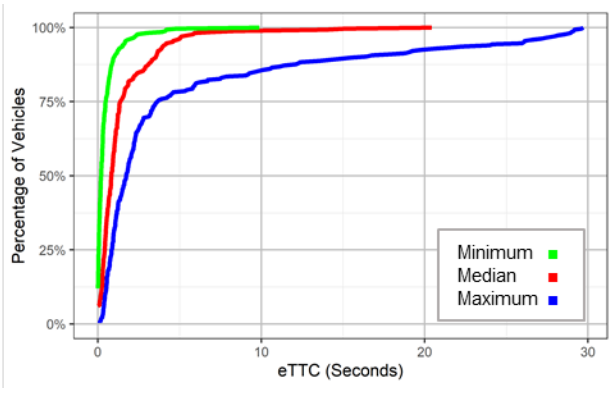

Fig. 11. The cumulative distribution of eTTC maximum, median, and minimum for crash and near-crash encounters in SHRP-2.

IV. Discussion

The driver behaviour characteristics that were generated in this study provide insight as to what drivers do in the top three most frequent intersection scenarios. Most of the normal driving encounters occurred at intersections with traffic light, while most of the crashes and near- crashes occurred at intersections without any type of traffic control for all three scenario types. The infrastructure differences can contribute to the differences seen in the driver behaviour characteristics, such as velocity. The median average velocity for crashes and near-crashes (SHRP2 data) was consistently higher than that of the normal driving encounters (VT CAST data). This could be due to the traffic lights present at the encounters. For example, vehicles at intersections with stop light tend to have a lower velocity with a similar acceleration compared to the vehicles in intersections without a traffic-control device. Speeding is typically closely linked to crashes [11]. Speeding could be the cause for the increased median average velocity in crashes and near-crashes compared to normal encounters in all three scenario types [12].

Currently, the Euro NCAP and proposed US-NCAP only cover SCP and LTAP/OD scenarios. Although LTAP/LD crashes are not as frequent as LTAP/OD and SCP crashes in the US, the LTAP/LD scenarios still pose a risk to drivers, unprotected left turns, and a challenge to I-ADAS [2]. The LTAP/LD encounters can be unprotected lefts where there is no traffic control to tell the driver when to turn and only relies on the driver's perception to make a safe turn. The maximum velocity for the US-NCAP SCP tests (40.2 kph) is 1.5 times higher than the median average velocities found for traversing vehicles in VT-CAST (about 26 kph). However, the distribution of average velocities from in each scenario falls below 54 kph except for LTAP/OD crashes and near-crashes that had on average higher velocities with most of the average velocities being less than 72 kph. Although the US-NCAP tests have a higher velocity than the average encounter in the study, it does not represent all encounters found. The average velocity for the LTAP/OD scenarios for traversing vehicles in VT-CAST was lower than the maximum test speed for the LTAP/OD scenarios for the proposed US-NCAP tests (40.2 kph). However, the median average velocities in crash and near-crash scenarios in SHRP-2 were higher and closely matched the Euro NCAP test speeds (20–60 kph). The maximum Euro NCAP test speed (60 kph) is greater than all the median average velocities found for each scenario except LTAP/OD crashes and near-crashes. The NCAP test scenarios also only has roads with a 90-degree difference between the legs and no obstructed view. In this study, it has been found that the road infrastructure isn't as perfect as this and can affect driver behaviour. The combination of drivers driving faster in imperfect intersections could pose a problem for AEB systems that depend on its perception system to detect hazards in time to activate and prevent or mitigate the imminent crash.

TABLE V
SUMMARY TABLE

	Euro NCAP	*US-NCAP (Proposed)*	*SHRP-2 (Crash & Near Crashes)*	*VT-CAST (Only Traversing)*
Intersection Type	4-Legged	4-Legged	Many	99% 4-Legged
SCP Max. Median Velocity	60 kph	40.2 kph	48.06 kph (13.35 m/s)	25.88 kph (7.19 m/s)
LTAP/LD Max. Median Velocity	N/A	N/A	38.66 kph (10.74 m/s)	26.28 kph (7.3 m/s)
LTAP/OD Max. Median Velocity	60 kph	40.2 kph	64.26 kph (17.85 m/s)	25.92 kph (7.2 m/s)

The analysis of intersection driving data can provide insights into real-world intersection normal driving encounters, crashes, and near-crashes. Since the information from VT-CAST and SHRP 2 is a good representation of real world driving behaviours on the road (distance, speed, heading, etc.), this data is relevant for the development of I-ADAS systems. In addition to generating I-ADAS activation criteria, the estimated parameters from the encounters could allow for a driver behaviour prediction model to be developed. The driver behaviour model may be able to predict the longitudinal and lateral behaviours of drivers based on the data collected and characterized in this study to improve interactions with other vehicles on the road.

Limitations

The SHRP-2 dataset uses radar data to collect information about other vehicles in the roadway. The radar has a limited field of view, therefore the target vehicle for the SCP and LTAP/LD scenarios was recorded for only a short amount of time. The whole traversal is not known, but the known trajectories are long enough to assess driver behaviours in crash and near-crash scenarios. The radars are also limited by the inaccuracies in detecting another vehicle’s speed, which caused some of the accelerations to be higher than the vehicles’ capabilities. The VT-CAST dataset was limited by the camera quality of the traffic cameras from which it was collected, as well as by the angles of those cameras. In some cases, the camera was not angled to capture the whole intersection, which meant only partial trajectories were recorded. Similar to SHRP-2, the vehicles were filtered based on the length of time the camera was able to capture the vehicle’s trajectory.

V. CONCLUSIONS

The driver behaviour characteristics for drivers driving through an intersection were found to be different for vehicles in a crash or near-crash in the SHRP-2 dataset compared to the vehicles driving through an intersection in the VT-CAST dataset. The biggest difference was in the maximum deceleration between the crashes and near-crashes and the normal driving encounters. For most crash and near-crash scenarios, the vehicle at-fault had a higher average velocity compared to the vehicle not-at-fault. The estimated time to collision also showed differences between normal driving in VT-CAST and the crash and near-crash scenarios in SHRP-2. The estimated time to collision was lower (shorter), as expected, for the crashes and near-crashes vs. normal driving.

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