Preliminary Study of the Response of Forward Collision Warning Systems to Motorcycles

Vorläufige Studie über Kollisionswarnsysteme mit Blick auf Motorräder

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Abstract

Existing and proposed near-future New Car Assessment Program (NCAP) activities are focused on evaluating the abilities of vehicle based crash avoidance technologies to avoid car-car, car-pedestrian and car-bicycle crashes but do not explicitly address issues of car-motorcycle crashes. Motorcycles represent a substantial portion of the motor vehicle fleet worldwide, and currently account for 14% of US traffic fatalities. By extension, the technologies for detecting potential conflicts between cars and motorcycles may currently exist and could provide useful improvements to motorcycle and overall traffic safety.

The goal of this preliminary project was to survey example current production vehicles equipped with Forward Collision Warning (FCW) systems to determine how well these systems function when the Principal Other Vehicle (POV) is an L3 mid-sized motorcycle.

To accomplish this, the protocols and two of the three test scenarios described in the US National Highway Traffic Safety Administration's (NHTSA) Forward Collision Warning System Confirmation Test (February 2013) were used. An 800cc Sport Touring motorcycle was substituted for the mid-sized passenger vehicle for use as the POV. In the first scenario, a subject vehicle (SV) approaches a stopped POV in the same lane of travel. In the second scenario the SV, traveling at a constant speed, approaches the POV moving at constant speed which is slower than the SV. The test vehicles were equipped with the same sensors, GPS and data acquisition systems used in the US NCAP FCW tests.

Preliminary results indicate that stopped motorcycles may not be consistently identified as potential collision partners by contemporary production FCW systems. In some cases no alert was provided; in others the timing of the alert was later than for those tests for which the POV was a mid-sized passenger car.

It may be hypothesized that as drivers become comfortable with, and rely more on ADAS technologies, they will become less attentive to the driving task, and that a possible consequence of broad ADAS implementation may be an increase in car-motorcycle accidents, even as car-car accidents decrease. Therefore motorcycles or their representations should be included in future ADAS test procedure development and retroactively introduced into existing ones.

Preliminary Study of the Response of Forward Collision Warning Systems to Motorcycles

Overview

Existing and proposed near-future New Car Assessment Program (NCAP) activities are focused on evaluating the abilities of vehicle based crash avoidance technologies to avoid car-car, car-pedestrian and car-bicycle crashes but do not explicitly address issues of car-motorcycle crashes. Motorcycles represent a substantial portion of the motor vehicle fleet worldwide, and currently account for 14% of US traffic fatalities. By extension, the technologies for detecting potential conflicts between cars and motorcycles may currently exist and could provide useful improvements to motorcycle and overall traffic safety.

Test procedures and equipment for use in evaluating the performance of Automatic Emergency Braking (AEB) systems have been, or are being, developed for scenarios involving a passenger vehicle in potential conflict with another passenger vehicle, a pedestrian or a bicyclist. Scenarios involving a motorcycle are not being explicitly addressed, even though current technologies for detecting potential conflicts between passenger vehicles and motorcycles exist and could provide useful improvements to motorcycle safety. In many ways these AEB systems are an outgrowth or further development of Forward Collision Warning (FCW) systems currently in production.

When evaluating AEB systems, either as part of system development or as confirmation of a production system, there is a need to have a collision "partner" that presents, to the systems being evaluated:

- characteristics that are suitably representative of the real world objects they are intended to represent;and
- no hazard to the test vehicle, personnel, etc.

Test procedures generally refer to this collision partner device as the Principal Other Vehicle (POV), and they may be generally referred to informally as "targets".

With respect to rear end collisions, both NHTSA and Euro NCAP have test target systems in use for evaluating AEB systems in rear end collisions (Refs 1, 2). Pedestrian targets which have been developed in the US and Europe (Refs 3, 4) are being deployed in Euro NCAP testing, and studied by NHTSA (Ref 5). In addition considerable effort has gone into development of a cyclist target and test equipment for the evaluation of cyclist-AEB systems (Ref 6), and automobile-type targets for applications to other than rear end collisions are in the final stages of development (Ref 7).

If an FCW or AEB system functions correctly for automobile, pedestrian and bicyclist targets, then it might be assumed that it will function as well for a motorcyclist, but there is little published data to address this. The goal of this preliminary project was to survey example current production vehicles equipped with Forward Collision Warning (FCW) systems to determine how well these systems function when the Principal Other Vehicle (POV) is a mid-sized motorcycle.

The protocols and two of the three test scenarios described in NHTSA's Forward Collision Warning System Confirmation Test (February 2013, Ref 8) were used to accomplish this. An 800cc Sport Touring motorcycle was substituted for the mid-sized passenger vehicle for use as the POV. In the first scenario, a subject vehicle (SV) approaches, from behind, a stopped POV in the same lane of travel. In the second scenario the SV, traveling at a constant speed, approaches, from behind, the POV moving at constant speed which is slower than that of the SV. The test vehicles were equipped with the same, or equivalent, sensors, GPS and data acquisition systems used in US NCAP FCW tests. For comparison, the same subject vehicles, systems and protocols were used to evaluate system performance with a mid-sized passenger vehicle as the POV.

Preliminary results for the stopped POV scenario indicate that motorcycles may not be consistently identified as potential collision partners by contemporary production FCW systems. In some trials no alert was provided; in others, the timing of the alerts was later than for the corresponding tests where the POV was a mid-sized passenger car. For the slower moving POV scenario, the results for the motorcycle and passenger car POV were generally in agreement.

As drivers become comfortable with, and rely more on Advanced Driver Assistance Systems (ADAS), they may become less attentive to the driving task. So, an unintended consequence of broad ADAS implementation may be an increase in the frequency of car-motorcycle accidents even as car-car accidents decrease. It is important therefore that consideration of motorcycles be included in future ADAS test procedure and equipment development, and retroactively introduced into existing ones.

Evaluation procedures and criteria

The current investigation used an adaptation of the procedures that are currently in use for evaluating FCW systems as part of the NHTSA New Car Assessment Program (NCAP) (Ref 1). To adapt these procedures;

- A mid-sized motorcycle was substituted for a mid-sized passenger car for the POV.
- The current investigation included Tests 1 and 3 of the NHTSA NCAP testprocedures, as follows:
    - Test 1. Subject Vehicle (SV) Encounters Stopped Principal Other Vehicle on a Straight Road

  - Test 3. Subject Vehicle Encounters Slower Principal Other Vehicle

  The NHTSA NCAP Test procedures include a scenario (Test 2) in which SV encounters a decelerating POV. This was not run for the motorcycle because a suitable controller for repeatably controlling motorcycle deceleration was not available at the time.

- The timing and pass/fail criteria used for the NHTSA NCAP tests are based on passenger vehicle properties, not motorcycles, as the POV. Whether or not these criteria are appropriate for motorcycles is not considered herein. The criteria applied in this study are those of the NHTSA NCAP procedure.

Test 3 trials were performed with SV automatic transmission in ‘‘Drive’’. If the SV FCW system provided a warning timing adjustment for the driver, only the most “conservative” (earliest warning) setting was used.

An overview of each of the test procedures follows.

Test 1. Subject Vehicle Encounters Stopped Principal Other Vehicle on a Straight Road

This test evaluated the ability of the FCW function to detect a stopped lead vehicle, as depicted in Figure 1.

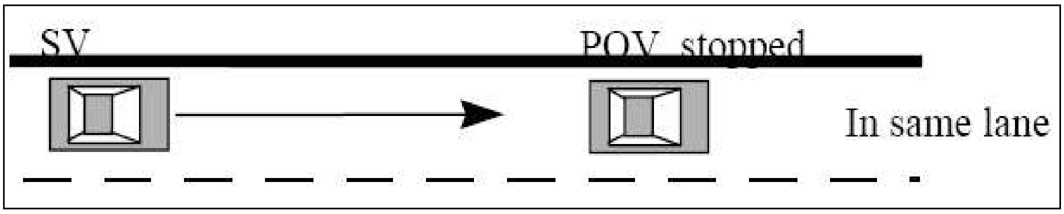

Figure 1. Depiction of Test 1

a. Alert Criteria

In order to pass the test, the FCW alert must be issued when the time-to-collision (TTC) is at least 2.1 seconds. In accordance with Ref 8, the TTC for this test was calculated by considering the speeds of the subject vehicle (SV) and the lead vehicle (POV) at the time of the FCW alert. This is when the SV and POV speeds are nominally equal to 45 and 0 mph (72.4 and 0 kph), respectively). Nominally, the Test 1 series comprised seven individual trials. The FCW system must satisfy the TTC alert criteria for at least five of the seven test trials.

b. Procedure

The POV was parked in the center of a travel lane. Its longitudinal axis was oriented parallel to the roadway edge, and facing the same direction as the SV, so the SV approached the rear of the POV.

The SV was driven at a nominal speed of 45 mph (72.4 kph) in the center of the lane of travel, toward the parked POV. The test began when the SV was 492 ft (150 m) from the POV and ended when either of the following occurred:

- The required FCW alert occurred.
- The TTC to the POV fell to less than 90 percent of the minimum allowable range (i.e., TTC = 1.9 sec) for the onset of the required FCW alert.

The SV driver then steered and/or braked to keep the SV from striking the POV.

For an individual test trial to be valid, the following was required throughout the test:

- The SV vehicle speed could not deviate from the nominal speed by more than 1.0 mph (1.6 kph) for a period of three seconds prior to (1) the required FCW alert or (2) before the range fell to less than 90 percent of the minimum allowable range for onset of the required FCW alert.
- The SV driver could not apply any force to the brake pedal before the required FCW alert occurred, or before the range fell to less than 90 percent of the minimum allowable range for onset of the required FCW alert.
- The lateral distance between the centerline of the SV, relative to the centerline of the POV, in road coordinates, could not exceed 2.0 ft (0.6 m).
- The yaw rate of the SV could not exceed ±1 deg/sec during the test.

Test 3. Subject Vehicle Encounters Slower Principal Other Vehicle

This test examined the ability of the FCW system to recognize a slower lead vehicle being driven with a constant speed and issue a timely alert. As shown in Figure 2, the scenario used a closing speed of 25.0 mph (40.2 kph).

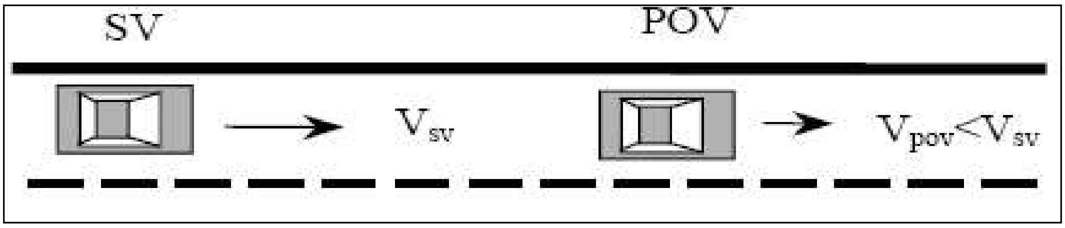

Figure 2. Depiction of Test 3

a. Alert Criteria

In order to pass the test, the FCW alert must be issued when TTC is at least 2.0 seconds. The TTC for this test, a prediction of the time it would take for the SV to collide with the POV, was calculated by considering the speeds of the SV and POV at the time of the FCW alert. Nominally, the Test 3 series comprised seven individual trials. The FCW system must satisfy the TTC alert criteria for at least five of the seven test trials.

b. Procedure

Throughout the test, the POV was driven at a constant 20.0 mph (32.2 kph) in the center of the lane of travel.

The SV was driven at 45.0 mph (72.4 kph), in the center lane of travel, toward the slow-moving POV.

The test began when the headway from the SV to the POV was 329 ft (100 m) and ended when either of the following occurred:

- The required FCW alert occurred.
- The TTC to the POV fell to less than 90% of the minimum allowable range (i.e., TTC = 1.8 sec) for the onset of the required FCW alert.

The SV driver then steered and/or braked to keep the SV from striking the POV.

For an individual test trial to be valid, the following was required throughout the test:

- The SV vehicle speed could not deviate from the nominal speed by more than 1.0 mph (1.6 kph) for a period of 3 seconds prior to (1) the required FCW alert, or (2) before the range fell to less than 90 percent of the minimum allowable range for onset of the required FCW alert.
- Speed of the POV could not deviate from the nominal speed by more than 1.0 mph (1.6 kph) during the test.

- The lateral distance between the centerline of the SV, relative to the centerline of the POV, in road coordinates, could not exceed 2.0 ft (0.6 m).
- The yaw rates of the SV and POV could not exceed ±1 deg/sec during the test.
- SV driver could not apply any force to the brake pedal before the required FCW alert occurred, or before the range fell to less than 90 percent of the minimum allowable range for onset of the required FCW alert.

Principal Other Vehicles

A stock 2006 Honda VFR 800 sport touring motorcycle, as shown in Figure 3, was used as the Principal Other Vehicle (POV). All equipment necessary for use on public roads was installed. Vehicle loading consisted of the rider plus equipment and instrumentation. A 2000 Honda Accord, as shown in Figure 4, was used as the comparison POV.

Figure 3. Honda VFR800 POV

Figure 4. Honda Accord POV

FCW Equipped Subject Vehicles

Eight subject vehicle's FCWs were evaluated in this study. The SVs were all new (less than 500 mi), model year 2016 production vehicles available in the US. The FCW systems installed in the vehicles were from at least four different suppliers, and used different implementations of camera and radar sensors. Table 1 lists the FCW sensor types for each vehicle. It includes columns indicating whether the owner's manual for the vehicle addresses whether or not the system might detect motorcycles and whether the FCW alerts are a component of an AEB system.

Table 1. Subject Vehicle Characteristics

SV	Sensor Type(s)	Motorcycle Considered in Owner's Manual	AEB Function Provided
1	Camera, Radar	Yes	Yes
2	Camera, Radar	Yes	Yes
3	Camera	No	Yes
4	Camera, Radar	No	Yes
5	Camera, Radar	Yes	Yes
6	Camera, Radar	Yes	Yes
7	Camera, Radar	Yes	Yes
8	Camera, Radar	Yes	Yes

Instrumentation

Table 2 lists the sensors, signal conditioning and data acquisition equipment used for these evaluations. Figures 5 and 6 show the test instrumentation and equipment installed in the passenger car POV and motorcycle POV.

Table 2. Test Instrumentation and Equipment

Type	Output	Range	Accuracy, Other Primary Specs	Mfr, Model
Differential Global Positioning System	Position, Velocity	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots	Horizontal Position: ±1 cm Vertical Position: ±2 cm Velocity: 0.05 km/h	Trimble GPS Receiver, 5700 (base station and in SV)
Multi-Axis Inertial Sensing System	Position; Longitudinal, Lateral, and Vertical Accels; Lateral, Longitudinal and Vertical Velocities; Roll, Pitch, Yaw Rates; Roll, Pitch, Yaw Angles	Latitude: ±90 deg Longitude: ±180 deg Altitude: 0-18 km Velocity: 0-1000 knots Accel: ±100 m/s2 Angular Rate: ±100 deg/s Angular Disp: ±180 deg	Position: ±2 cm Velocity: 0.05 km/h Accel: ≤ 0.01% of full range Angular Rate: ≤ 0.01% of full range Roll/Pitch Angle: ±0.03 deg Heading Angle: ±0.1 deg	Oxford Technical Solutions (OXTS) xNAV 550 in motorcycle, Inertial+ in SV
Real-Time Calculation of Position and Velocity Relative to POV	Distance and Velocity to POV	Lateral Lane Dist: ±30 m Lateral Lane Velocity: ±20 m/sec Longitudinal Range to POV: ±200 m Longitudinal Range Rate: ±50 m/sec	Lateral Distance to Lane Marking: ±2 cm Lateral Velocity to Lane Marking: ±0.02m/sec Longitudinal Range: ±3 cm Longitudinal Range Rate: ±0.02 m/sec	Oxford Technical Solutions (OXTS), RT-Range
Data Acquisition System [Includes amplification, anti-aliasing, and analog to digital conversion.]	Record Time; Position; Velocity; Distance to lane markings; Headway distance; Closing Velocity; Lateral, Longitudinal, and Vertical Accels; Roll, Yaw, and Pitch Rates; Roll, Yaw and Pitch Angles.	Sufficient to meet or exceed individual sensors	Sound digitized at 10 kHz, all other channels digitized at 100 Hz. Accuracy is sufficient to meet or exceed individual sensors	SoMat, eDaq ECPU processor
				SoMat, High level Board EHLS
Microphone	Sound (to measure time at alert)	Frequency Response: 80 Hz – 20 kHz	Signal-to-noise: 64 dB, 1 kHz at 1 Pa	Audio-Technica AT899
Light Sensor	Light intensity (to measure time at alert)	Spectral Bandwidth: 440-800 nm	Rise time < 10 msec	DRI designed and developed Light Sensor

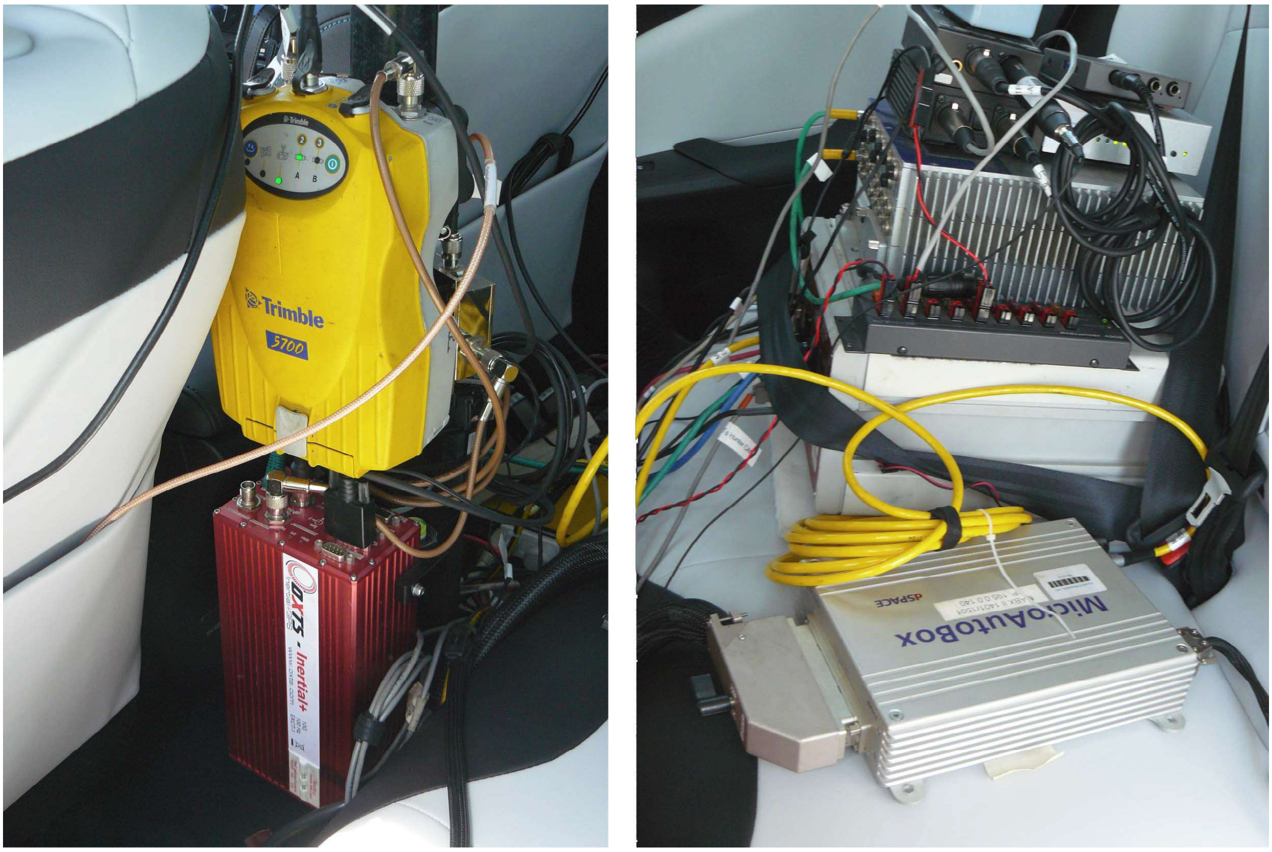

Figure 5. Instrumentation and Data Acquisition Installed in Subject Vehicle

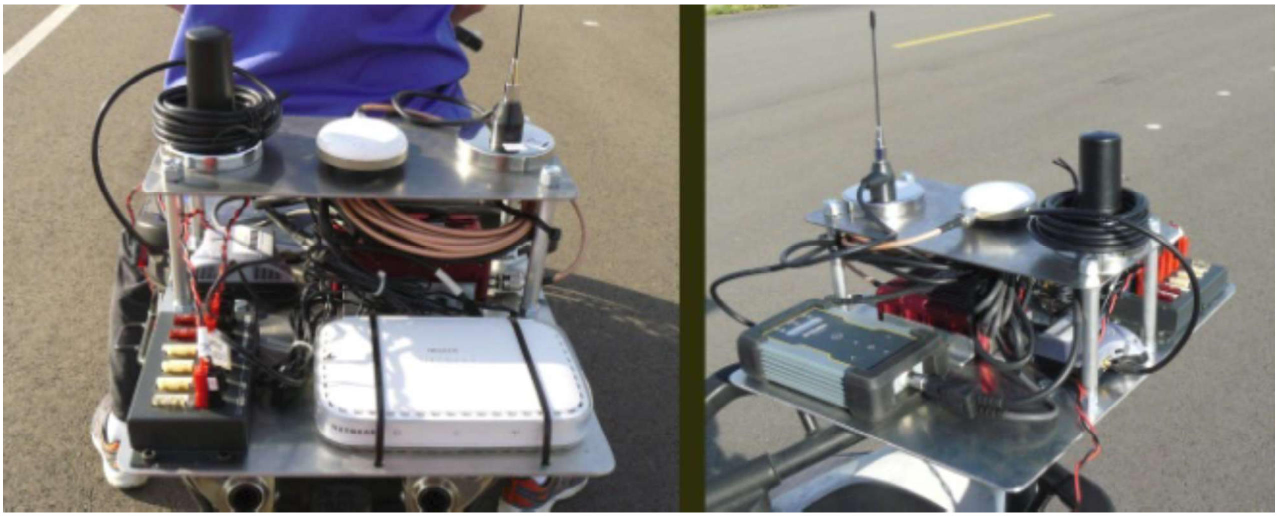

Figure 6. Instrumentation Installed on Motorcycle POV

For systems that implement auditory alerts it is important to accurately identify the onset of the auditory alert. Part of the pre-test instrumentation verification process was to determine the tonal frequency of the auditory alert through use of the PSD (Power Spectral Density) function in Matlab™. This was accomplished in order to identify the center frequency around which a band-pass filter is applied to subsequent auditory alert data so that the onset of such alerts could be determined. The bandpass filter used for these warning signals types was a phaseless, forward-reverse pass, elliptical (Cauer) digital filter, with filter parameters as listed in Table 3.

Table 3. Auditory Warning Filter Parameters

Warning Type	Filter Order	Peak-to-Peak Ripple	Minimum Stop Band Attenuation	Pass-Band Frequency Range
Auditory	5th	3 dB	60 dB	Identified Center Frequency ± 5%

Evaluation results

The evaluation results for the two POVs (i.e., passenger car and motorcycle) in the two test scenarios are described below. Note that the timing and pass/fail criteria used for the NHTSA NCAP tests are based on studies done with passenger vehicles as the POV. Equivalent pass/fail criteria do not exist for motorcycle POVs at this point in time. Nevertheless, for purposes of this preliminary evaluation, and in order to provide a comparison, the terms “pass” and “fail” are used herein for both the motorcycle and passenger car POVs. With respect to the alert timing, an important metric is the Time to Collision (TTC) margin. For the stopped POV the NHTSA NCAP criterion is that the alert be provided to the driver at least 2.1 seconds prior to collision, and for the slower moving POV the criterion is that the alert be provided to the driver at least 2.0 seconds before collision. “TTC margin”, as used below, is a measure of how close to the allowable timing criteria the alert occurred. A negative value indicates that an alert was not provided within the specified timing window, and positive values indicate the amount of time before the criterion time that the alert occurred. For example, for the stopped POV test scenario, if the alert occurred at a TTC of 2.36 seconds, the TTC margin was 0.26 seconds (i.e., 2.36 – 2.10), and if the alert occurred at a TTC of 1.92 seconds the TTC margin was -0.18 (i.e., 1.92 – 2.10).

Stopped POV Scenario

Table 4 summarizes the results for all valid trials for the stationary Motorcycle POV scenario. Of the eight subject vehicles only SV2 and SV6 met the NHTSA pass criteria that the FCW system must satisfy the TTC alert criteria for at least five of the seven test trials. Only SV2 satisfied the TTC alert criteria for all valid runs. Five of the vehicles did not satisfy the criteria for all valid runs, as a result of late TTC alert, not providing an alert, or a combination of the two. Two of the vehicles (SV7 and SV8) never provided any alert. Of the 50 valid test trials, 36 (72%) resulted in an inadequate TTC alert.

Table 4. Summary of Results for Stationary Motorcycle POV

SV	Valid Trials	Pass	Late	No warning	Overall
1	7	0	7	0	No Pass
2	5	5	0	0	Pass
3	7	0	7	0	No Pass
4	7	4	3	0	No Pass
5	7	0	5	2	No Pass
6	7	5	0	2	Pass
7	6	0	0	6	No Pass
8	4	0	0	4	No Pass
Total	50	14	22	14	

By way of comparison, Table 5 summarizes the results for all valid trials for the stationary passenger car POV scenario. All eight of the subject vehicles met the NHTSA criteria that the FCW system satisfies the TTC alert criteria for at least five of the seven test trials. Of the 56 valid test trials, three (5.4%) resulted in an inadequate TTC alert.

Table 5. Summary of Results for Stationary Passenger Car POV

SV	Valid Trials	Pass	Late	No warning	Overall
1	7	7	0	0	Pass
2	7	7	0	0	Pass
3	7	7	0	0	Pass
4	7	7	0	0	Pass
5	7	5	2	0	Pass
6	7	7	0	0	Pass
7	7	6	0	1	Pass
8	7	7	0	0	Pass
Total	56	53	2	1	

Figure 7 shows the results for the stationary POV scenario for both the motorcycle and passenger car POVs graphically.

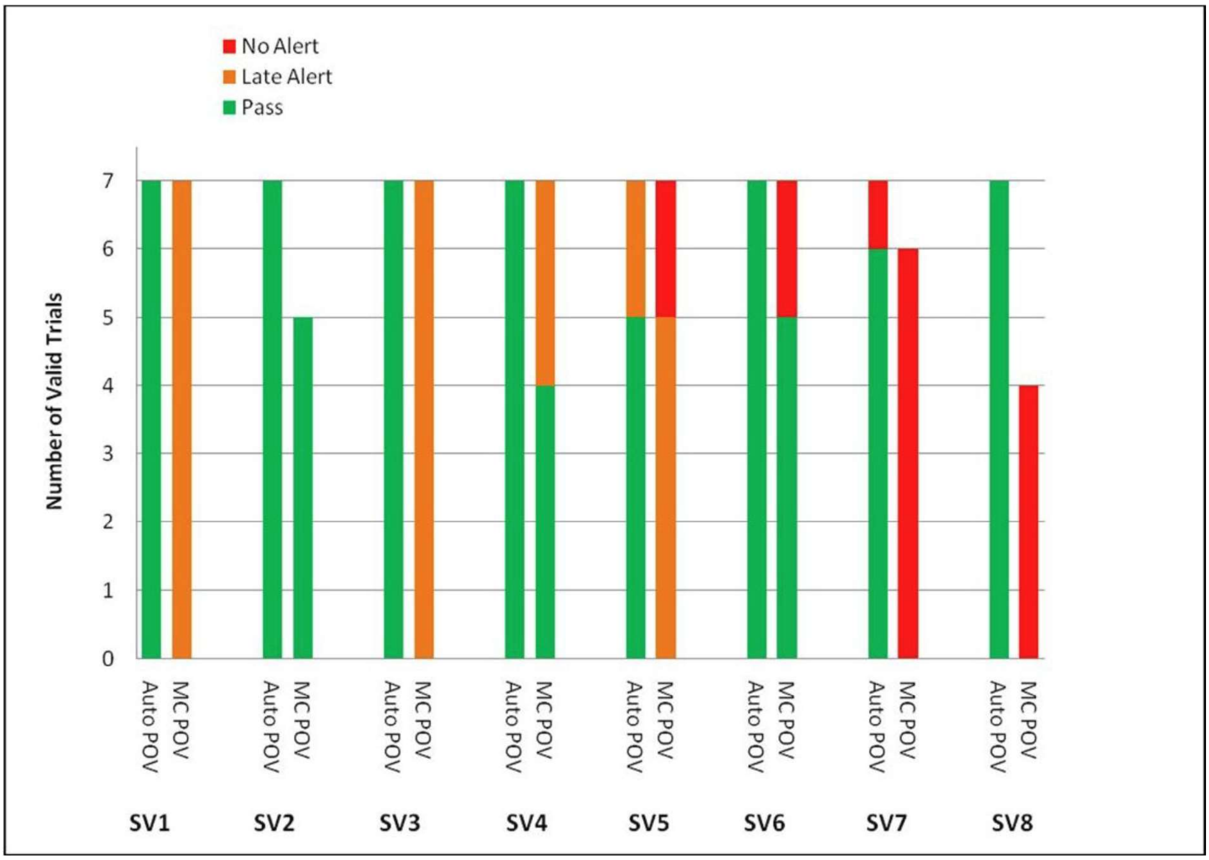

Figure 7. Summary of Valid Trials for Stationary POV

Figure 8 shows the TTC margins for the stopped POV scenario. In this figure, the average values for each SV-POV combination are indicated by the bar; the upper error bar indicates the maximum value, and the lower error bar indicates the minimum value. These error bars are provided to illustrate the range of results for each case. Note that data for trials in which no alert was provided cannot be represented in this figure, in particular, no data for the motorcycle POV are shown for SVs 7 and 8 as no alerts were provided in any of the trials for these SVs.

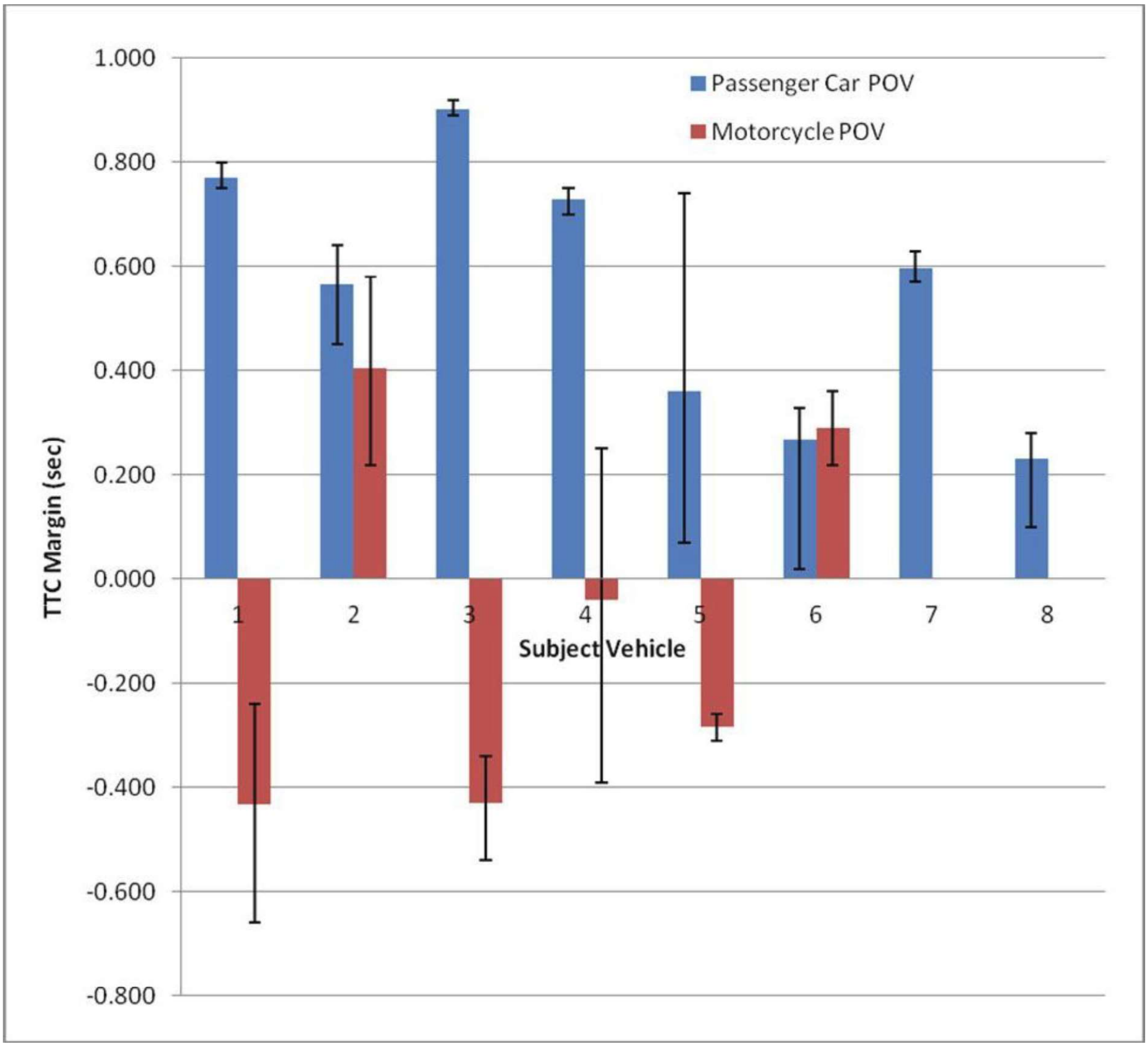

Figure 8. TTC Margins for the Stopped POV Scenario (when the alert occurred)

Slower Moving POV Scenario

Table 6 summarizes the results for all valid trials for the slower moving motorcycle POV scenario. The results indicate that five of the six subject vehicles studied met the NHTSA criteria that the FCW system satisfies the TTC alert criteria for at least five of seven test trials. (The sixth vehicle only completed six valid trials). SVs 4 and 7 were not tested with this scenario due to technical difficulties. Of the 40 valid test trials, 3 (7.5%) resulted in an inadequate TTC alert.

Table 6. Summary of Results for Slower POV, Motorcycle

SV	Valid Trials	Pass	Late	No warning	Overall
1	7	7	0	0	Pass
2	5	5	0	0	Pass
3	7	7	0	0	Pass
4					
5	7	7	0	0	Pass
6	8	8	0	0	Pass
7					
8	6	3	0	3	No Pass
Total	40	37	0	3	

Table 7 summarizes the results for all valid trials for the slower moving passenger car POV scenario. All eight of the subject vehicles met the NHTSA criteria that the FCW system satisfies the TTC alert criteria for at least five of the seven test trials. Of the 56 valid test trials, only 1 (1.8%) resulted in an inadequate TTC alert.

Table 7. Summary of Results for Slower POV, Accord

SV	Valid Trials	Pass	Late	No warning	Overall
1	7	7	0	0	Pass
2	7	7	0	0	Pass
3	7	7	0	0	Pass
4	7	7	0	0	Pass
5	7	7	0	0	Pass
6	7	7	0	0	Pass
7	7	7	0	0	Pass
8	7	6	1	0	Pass
Total	56	55	1	0	

Figure 9 shows the summarized results for the slower moving POV, for both POVs graphically.

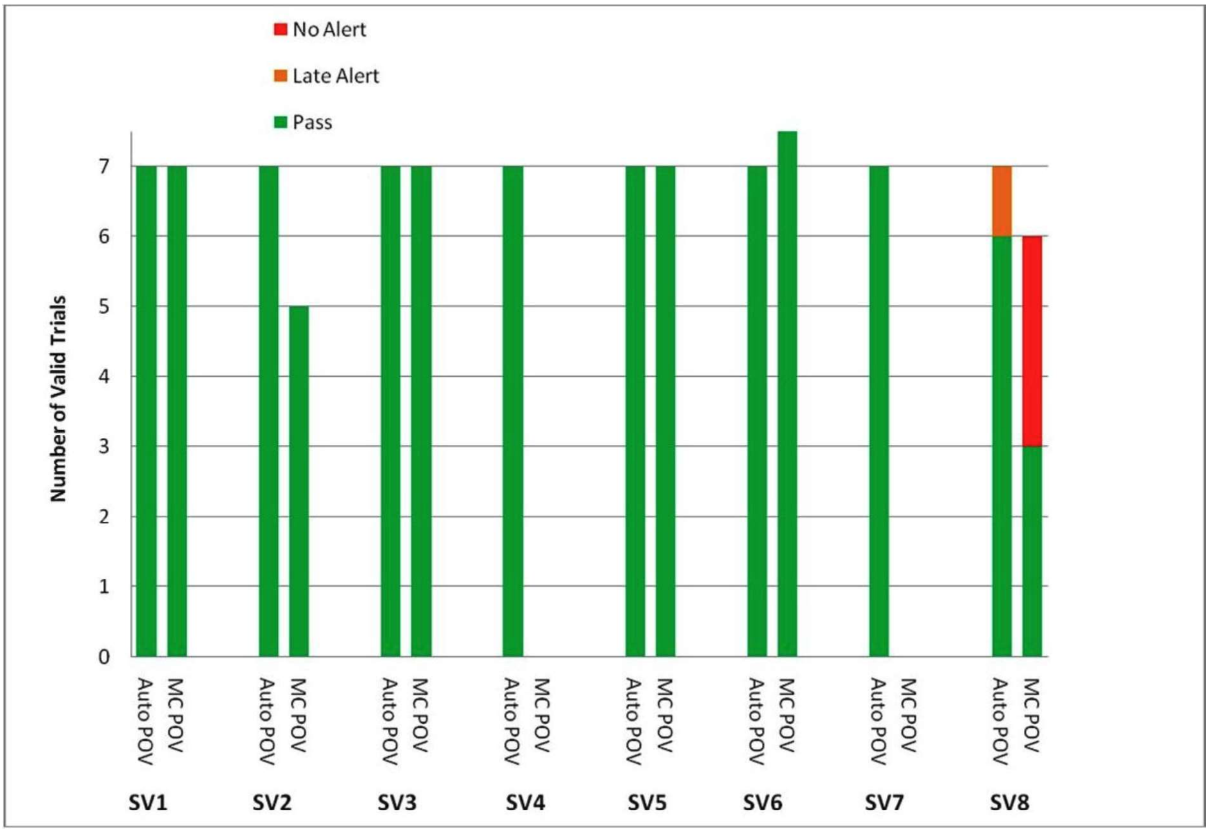

Figure 9. Summary of Valid Trials for Slower Moving POV

Figure 10 shows the TTC margins for the slower moving POV scenario. In this figure, the average values for each SV-POV combination are indicated by the bar; the upper error bar indicates the maximum value, and the lower error bar indicates the minimum value. These error bars are provided to illustrate the range of results for each case. Note that data for trials in which no alert was provided cannot be represented in this figure.

Figure 11 shows the combined results for all conditions, i.e., stationary POV and slower moving POV, expressed as a percentage of total valid trials. For the passenger vehicle POV, 3.6% of all valid runs did not meet the alert criteria, whereas for the motorcycle POV 41% of all valid runs did not meet the alert criteria.

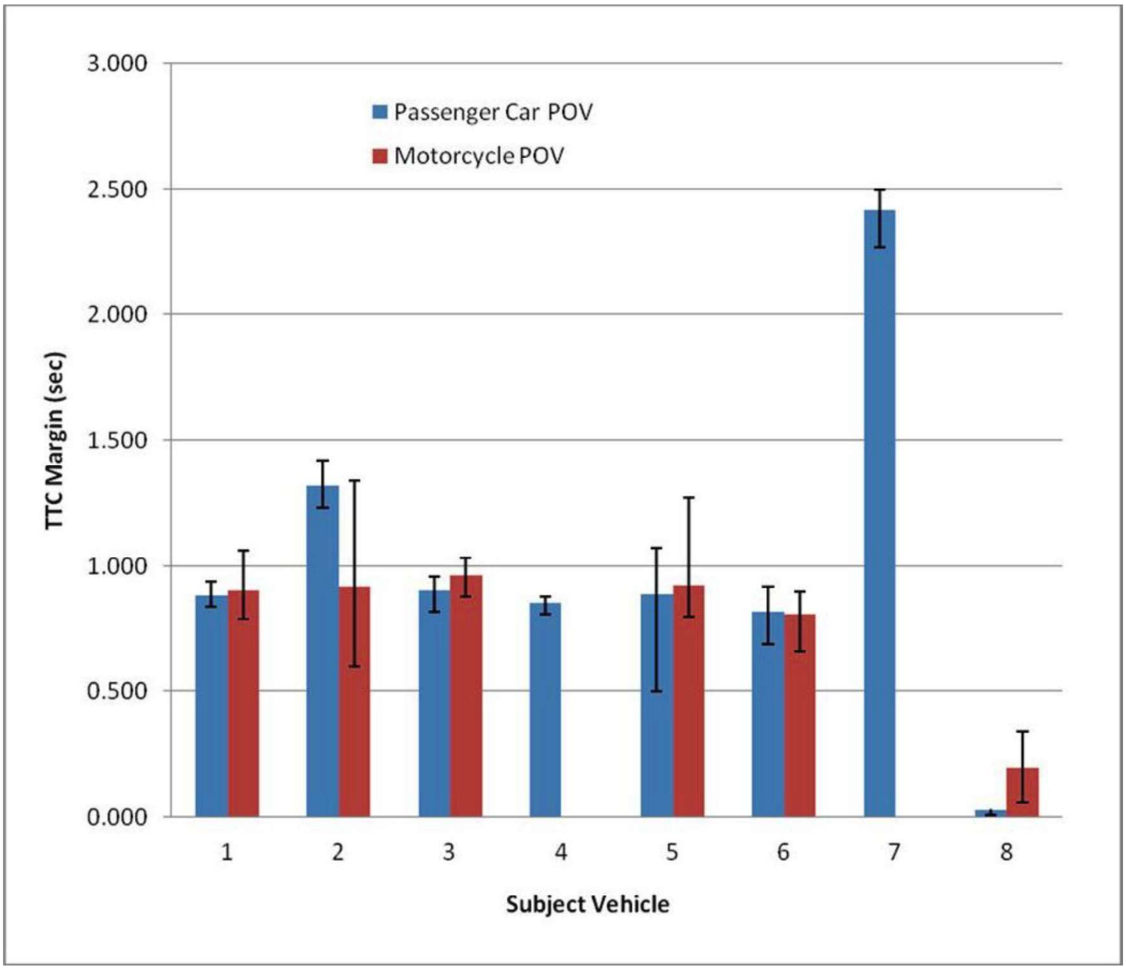

Figure 10. TTC Margins for the Slower Moving POV Scenario

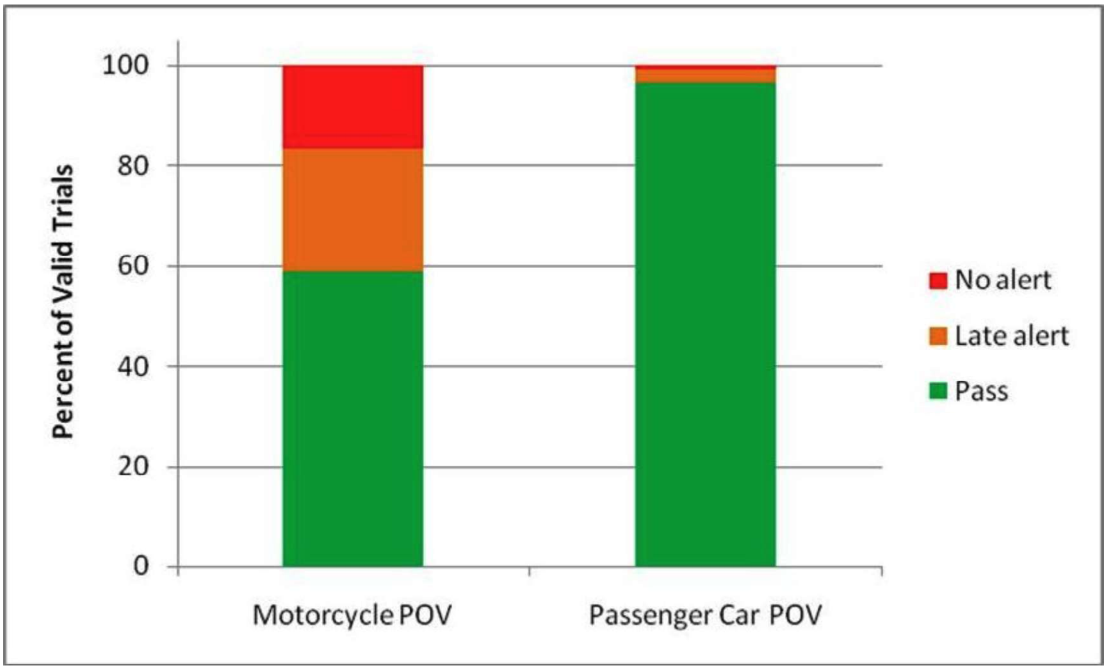

Figure 11. Combined Results for Stationary and Slower Moving POV as a Percentage of Valid Trials Completed

Discussion

It should be emphasized that the results of this evaluation are preliminary. They were accomplished with a single, stock example motorcycle and a small sample of subject vehicles. Further evaluations should be accomplished with additional motorcycle types, a broader range of subject vehicle FCW/AEB system types and evaluation conditions such as lighting conditions and vehicle speeds before definitive conclusions can be drawn.

The combined preliminary results over all valid trials and both evaluation scenarios indicate that the motorcycle POV was not adequately detected in 41% of the trials, compared to 3.6% for the automobile POV. In nearly 17% of the motorcycle POV trials, no alert was presented to the driver of the SV, compared to less than 1% for the automobile POV.

Of the two scenarios, the successful detection of the stopped motorcycle appears to be more difficult than detection of the slower moving motorcycle POV, where the results were mostly comparable to those of the passenger vehicle POV. For the stopped motorcycle POV, in 44% of the valid trials the alert was provided late, and in 24% there was no alert provided.

In-depth motorcycle crash investigations have clearly shown that the vast majority of other vehicle (OV) to motorcycle accidents occur in front of the OV driver. Data from the Motorcycle In-Depth Accident Study (MAIDS) (8) conducted in Europe has shown that 60% of all OV to motorcycle occur in a 120 degree arc in front of the OV driver (see Figure 12). The US Hurt Study (9) reported a similar finding in that 77% of all OV to motorcycle accidents occurred within a 60 degree arc directly in front of the OV driver.

Data from the MAIDS has shown that 2.4% of all collisions (n=22) involved an OV impacting into the rear of the motorcycle. In almost all of these cases, the motorcycle was stopped at the time of the collision, typically at an intersection.

Perhaps one of the more interesting findings of the MAIDS study was that 37% of all OV to motorcycle accidents involved an OV driver perception failure, meaning that the OV driver may have failed to see the motorcycle prior to the precipitating event that caused the crash. As noted above, the frequency of these types of motorcycle accidents may increase as drivers depend more and more upon ADAS systems.

Over the last 10-15 years passenger vehicle occupant deaths in the United States have decreased substantially, while over the same time span, motorcyclist deaths have remained more-or-less constant. As a result, motorcyclist fatalities now account for approximately 14% of all US traffic fatalities (NHTSA Traffic Safety Facts, Ref 11). At least some of the reduction in the frequency of overall road traffic deaths may be attributed to electronic control systems such as Electronic Stability Control (ESC), and a number of studies have concluded that ESC is highly effective in reducing single-vehicle crashes in cars and SUVs. FCW systems are becoming more common and along with them AEB systems, and we may expect that passenger vehicle occupant deaths will continue to decline as more of these systems make their way onto the roadways.

Detection of motorcycles by other vehicle drivers is a constant challenge in the current riding and driving environment. As drivers become comfortable with, and rely more on ADAS technologies, they may become less attentive to the driving task and thus be less vigilant at detecting motorcycles on the roadway. If ADAS systems are unable to correctly identify motorcycles, a possible consequence of broad ADAS implementation may be an increase in car-motorcycle accidents even as car-car accidents decrease.

In the longer term it is possible that Vehicle-to-Vehicle (V2V) communications between motorcycles and other road users offer possibilities for a benefit to motorcyclist safety. While there is currently activity in that technical area, market penetration of such technologies at a level that would afford measurable effects on motorcyclist safety are likely to be at least a decade away.

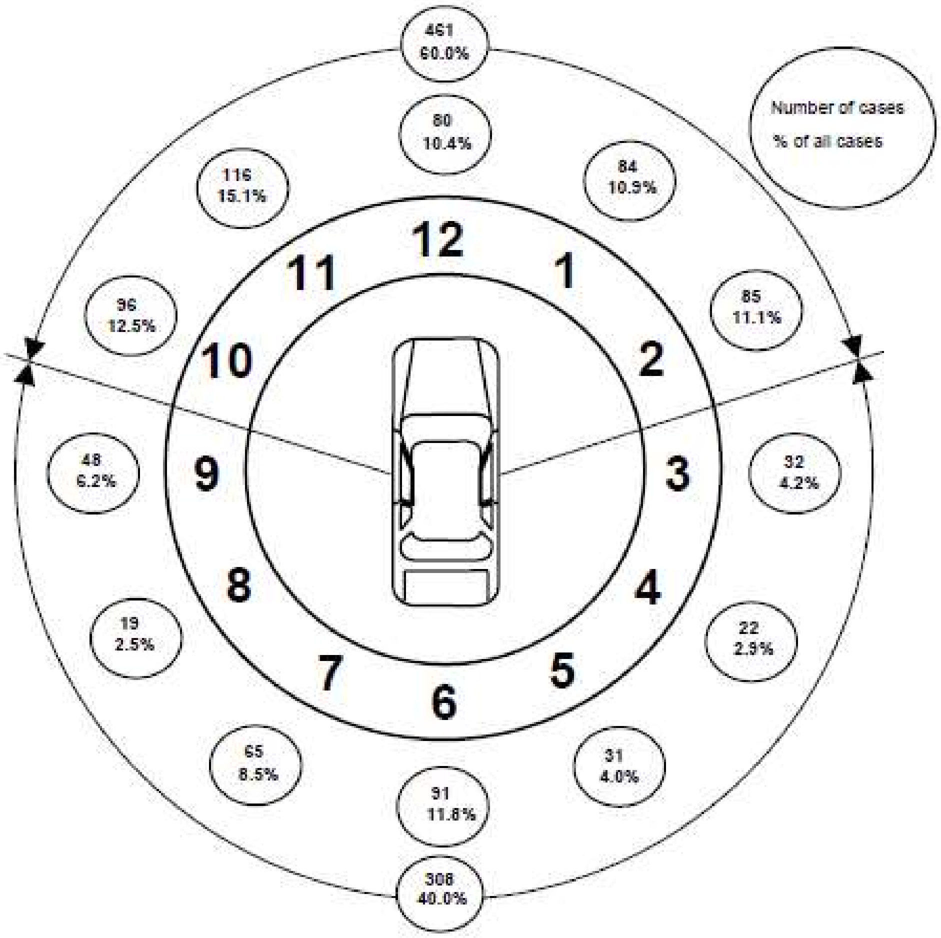

Figure 12. Other vehicle line of sight to the PTW (Ref 7)

The preliminary findings of this study indicate that in order for the safety benefits of ADAS systems to extend to motorcycles, such systems need to more reliably detect motorcycles in potential crash scenarios. One way to encourage and verify this would be to include motorcycles or their representations in ADAS test procedures. Suggested steps for future efforts include:

- identify the response properties of a range of actual motorcycles (including riders) to sensing technologies, including radar, camera, lidar, etc.;
- develop crashable motorcycle targets and delivery systems (Ref 7);
- identify and rank the most commonly occurring motorcycle-car accident scenarios and develop specific test scenarios to address those;
- include these targets and motorcycle specific scenarios in future test procedures; and
- retroactively introduce these into existing test procedures.

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