ADAS TESTING IN CANADA: COULD PARTIAL AUTOMATION MAKE OUR ROADS SAFER?

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Paper Number 19-0339

ABSTRACT

As part of an ongoing effort to further improve the safety of its road transportation system, Transport Canada (TC) has been evaluating Advanced Driver Assistance Systems (ADAS) for a number of years now. The main objective of this paper is to determine the potential of ADAS technology in reducing fatalities and injuries on Canadian roadways while using proven international test protocols and certified test equipment. The findings will be used to provide science-based evidence in support of future regulatory, research and policy development.

Results from this study clearly demonstrated that Automatic Emergency Braking (AEB) and Pedestrian AEB (P-AEB) technologies can provide significant improvements in terms of collision mitigation which can directly result in reduced road fatalities and injuries. These findings are also in line with those of studies based on real-World data predicting significant reductions in rear-end collisions due to AEB deployment.

Nonetheless, this ADAS program also exposed an important number of flaws and performance variability. While the best AEB and P-AEB systems were able to fully avoid collisions with vehicles and pedestrians at speeds up to 60 kilometers per hour (km/h), others were challenged at speeds below 10 km/h. Also, a few P-AEB systems were never able to avoid a collision with a pedestrian despite manufacturers' claims of pedestrian avoidance capabilities. Scenarios replicating AEB activation in moving traffic showed that most systems unnecessarily came to a full stop rather than match the speed of vehicles they detected on their path, potentially generating higher safety concerns than those they were designed to prevent in high density traffic. Finally, due to variability in test results and overall unpredictable system behaviour, it was not possible to gather enough data to confidently assess the potential safety benefits associated with Lane Support Systems (LSS).

AEB, P-AEB and LSS are essential components of automated driving systems which will need to reliably brake and steer at all time to safely avoid other road users. That level of performance is not yet evident from the extensive testing carried out within this project. Substantial progress is therefore needed to reach the level of detection, braking and steering performance that will be required to make commercial automated driving systems a reality.

INTRODUCTION

At the time of writing, Transport Canada (TC) had just released its latest motor vehicle collision statistics report which is generated every year from the National Collision Database (NCDB). The NCDB contains detailed information from all police-reported motor vehicle collisions that occur on Canadian roads. According to this report, fatalities, severe injuries and total injuries were at an all-time low in 2017. TC started collecting these data in the early 70's when fatalities were almost 4 times greater than what they are today despite a much lower count in licensed drivers and registered vehicles. Thankfully, with the advent of effective safety policies and technological advancement, amongst things, Canadian motorists have been witnessing a continued improvement in road safety for nearly five consecutive decades. However, even if statistics showed a downward trend in casualties for 2017, 1,841 people still lost their lives due to traffic-related collisions across the nation while 154,866 suffered injuries [1].

As part of a constant effort to further improve the safety of its road transportation system, TC has been evaluating crash avoidance technologies and Advanced Driver Assistance Systems (ADAS) for several years now. In short, ADAS technologies are the building blocks of full automation and include a wide variety of active safety features that can assist drivers in: applying the brakes automatically if an imminent crash is detected; keeping a vehicle on its traveling lane; detecting vehicles in a blind spot; or keeping a safe distance from vehicles ahead. Some of the World-leading safety experts believe that the greatest gains in highway safety in the coming years will result from a widespread application of crash avoidance technologies [2] [3].

An in-depth analysis of the latest statistics extracted from the NCDB revealed that the most frequent occurrences in which current driver assistance technologies could offer either full or partial mitigation measures was rear-end collisions (25% of collisions with casualties) while those offering the best potential for saving lives correspond to road departures (17% of fatalities) and collisions involving vulnerable road users (17% of fatalities). The latter being composed of pedestrian (15% of fatalities) and cyclists (2% of fatalities). 746 of the collisions involving fatalities (44%) and 85,993 of those involving personal injuries (74%) took place in urban settings while the remainder occurred in rural areas.

While several ADAS technologies are currently being evaluated by TC, this study will specifically focus on the assessment of Automatic Emergency Braking (AEB), Pedestrian AEB (P-AEB) and Lane Support Systems (LSS). These particular technologies were intensively investigated as they were deemed able to offer substantial safety benefits in the high risk areas previously identified. The findings of this study will be used to provide science-based evidence in support of future research, regulatory and policy development.

METHODS

The crash avoidance technologies investigated in this study use sensors such as radars, lidars, ultrasonic or cameras to scan the road ahead or surrounding a vehicle and detect potential conflicting situations. In order to properly evaluate each system, these conflicts need to be reproduced with high repeatability in controlled environments. The following sections will describe the protocols, equipment and methodology used to perform these evaluations.

Systems Tested

AEB and P-AEB systems are designed to prevent crashes or reduce their severity by braking automatically when an imminent collision is detected and the driver fails to react on time, or at all. They are characterized by 3 different functionalities: Forward Collision Warning (FCW) which warns a driver when a conflicting situation is detected; Crash Imminent Braking (CIB) which applies the brakes automatically if a driver fails to respond to the warning on time; and Dynamic Brake Support (DBS) which provides supplemental braking power if a driver does respond to the warning on time but does not brake hard enough.

LSS incorporates a group of technologies designed to assist drivers in keeping their vehicles on their traveling lane. They include Lane Departure Warning (LDW), Lane Keeping Assist (LKA), Lane Centering Systems (LCS), Emergency Lane Keeping (ELK), and others. The current evaluation will focus on LDW and LKA.

Test Vehicles

During the course of this program, approximately 100,000 km of combined on-road and track testing were conducted by TC and its contracting partner PMG Technologies on 36 different ADAS-equipped vehicles. Caution was taken to assemble a test fleet that was as diverse as representative of the real-world Canadian fleet. The vehicles selected ranged from model year (MY) 2012 to 2018 and were sourced from every manufacturers selling light passenger vehicles in Canada under 24 different brands. With the exception of a 2017 Volvo XC90 and a 2016 Tesla Model S, which were graciously lent by Volvo Canada and Environment and Climate Change Canada (ECCC), the test vehicles where acquired by TC. No details about the programs were communicated throughout the procurement process to ensure that the vehicles remained comparable to those available commercially. Table 1 provides the detailed list of vehicles used in this study.

Table 1.
Transport Canada ADAS Test Vehicle Fleet

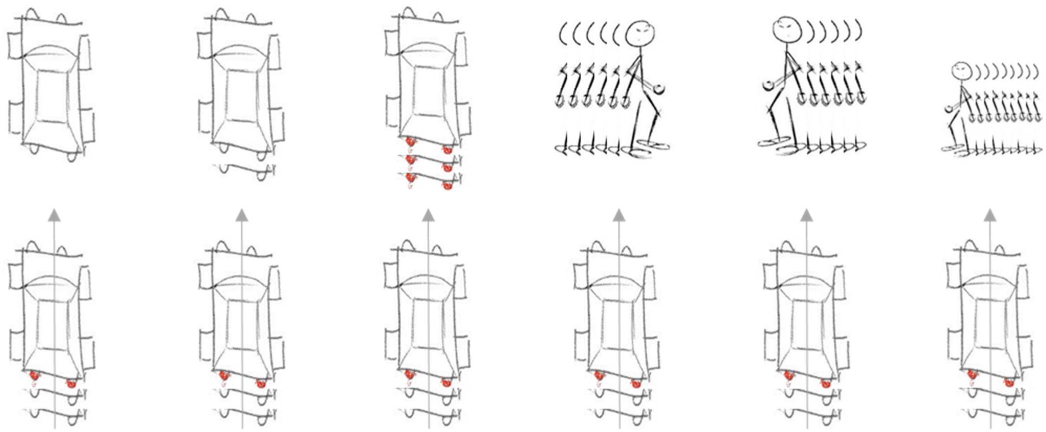
Manufacturer	Test Vehicles
Ford Motor Company	Ford Focus, Lincoln MKX, Ford Fusion
General Motors	Chevrolet Impala, GMC Acadia
Toyota Motor Corporation	Toyota Prius PHEV (2), Toyota Corolla and Toyota Highlander
FCA	Jeep Grand Cherokee, Chrysler 200, Fiat 500X, Chrysler Pacifica
Honda Motor Company	Honda CRV, Honda Civic
Hyundai Kia Auto Group	Hyundai Genesis, Hyundai Elantra and Kia Sportage
Nissan Motor Co	Infiniti Q50 and Mitsubishi Outlander, Nissan Rogue
Volkswagen Group	Audi A3, Volkswagen Golf
Mazda	Mazda 6
Subaru Corporation	Subaru Legacy, Subaru Outback, Subaru Impreza, Subaru Crosstrek
Daimler	Mercedes-Benz C400, Mercedes-Benz E300
BMW Group	BMW i3
Tesla	Tesla Model S
Jaguar Land Rover	Land Rover Discovery Sport
Volvo	Volvo S60, Volvo XC90, Volvo XC60

Test Procedures and Protocols

For comparison and validation purposes, the work carried out in this study was based primarily on test procedures developed by the National Highway Traffic Safety Administration (NHTSA) [4] [5], the International Organization for Standardization (ISO) [6] [7], the European New Car Assessment Program (Euro NCAP) [8] [9] [10], as well as the Insurance Institute for Highway Safety (IIHS) [11] [12].

Table 2 shows the test scenarios used for both the AEB and P-AEB evaluations. A total of 4 scenarios were used to evaluate the CIB and DBS variants of AEB in static and dynamic modes: a moving car approaching a stopped car (A1) representing a car stopped at a red light, at a stop sign or in traffic; a fast car approaching a slow car (B1 / B2); and an emergency stop where two cars are traveling at the same speed in close proximity and the lead car brakes suddenly (C1). 4 scenarios were also used for P-AEB testing: a running adult crossing the path of a car far-side (CPFA-50) with a theoretical impact point located at 50% of the width of the car (median); a walking adult crossing the path of a car near-side (CPNA-25 / CPNA-75) with a theoretical impact point located at 25% / 75% of the width of the car (passenger side / driver side); and a child running from behind two near-side road-side obstructing vehicles (CPNC-50) with a theoretical impact point on the median. The target and vehicle speeds required for each scenario are provided in Table 2 while more details can be found in the above-mentioned test procedures.

Table 2.
AEB and P-AEB Test Scenarios

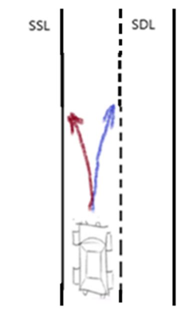
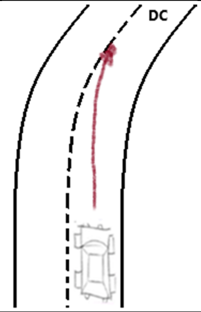
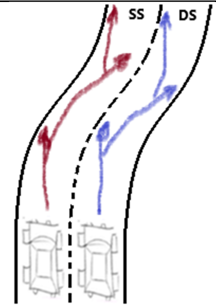


Test Scenario	STATIC A1	DYNAMIC B1 / B2	DYNAMIC C1	PED CPFA-50	PED CPNA-25/75	PED CPNC-50
Target Speed (km/h)	0	16 / 32	56	8	5	5
Vehicle Speed (km/h)	0-50	40 / 72	56	0-50	0-50	0-50

There are over 1 million kilometers (km) of roads in Canada with varied state of maintenance and quality [13]. These include 17,000 km of expressway and a total of 415,600 km of paved roads. A mixture of road segments from TC's Motor Vehicle Test Center (MVTC) which were judged representative of this vast road network were selected for the LSS evaluation. 3 different scenarios were used to evaluate the 10 different systems included in this study. The first was a drifting scenario in a straight line where a vehicle would drift towards a shoulder lane (SSL) or towards a dotted center lane (SDL) [10]. The second scenario was a vehicle entering a 493 meters (m) radius curve towards a dotted center lane (DC) [7]. The third scenario was an S-Curve course that forced the vehicle to react to a left and right lane marking consecutively (based on Scenario #1 and #2). In the Doted S-Curve scenario, the vehicle encounters the dotted line first (DS) while in the Solid S-Curve scenario, it encounters the solid line first (SS). All 3 scenarios are illustrated in Table 3.

The surface type for both Straight Line and the S-Curve scenarios was asphalt with white dotted center lines and solid yellow shoulder lanes. The Curve scenario was performed on a concrete section of a high-speed track with the same paint configuration. The road markings were mapped using an Oxford Technical Solutions (OxTS) RT 4002 system and imported into an RT-Range system to have a 2D representation of the test bed. The outer edges of the vehicles' tires were also measured and digitalized into the system to increase precision. This method allowed testing under various weather condition while always providing vehicle's position with respect to the lane markings.

Table 3.
LSS Scenarios

Scenario #1	Scenario #2	Scenario #3
		
Straight Solid Line (SSL) and Straight Dotted Line (SDL)	Dotted Curve (DC), 493 m radius	Dotted S-Curve (DS) and Solid S-Curve (SS), 1,219 m radius
Entering Gate at 72 km/h		

Test Equipment

The targets used for the AEB evaluation included the Euro NCAP Vehicle Target (EVT), the NHTSA Strikeable Surrogate Vehicle (SSV) and the Euro NCAP Global Vehicle Target (GVT) coupled to the Guided Soft Target (GST) system from Anthony Best Dynamics (ABD). The P-AEB evaluation used the Euro NCAP pedestrian targets (50^{th} percentile adult male (EPTa) and 7-year-old child (EPTc)) paired with the Soft Pedestrian Target (SPT-20) system from ABD. All of these systems were used in accordance with the test protocols previously described. Figure 1 shows the evolution of the test targets used in the Crash Avoidance program. From left to right: TC/PMG's inaugural "pendulum" vehicle surrogate target (not included in analysis), the EVT, the SSV, the EVT in winter testing condition, the GVT and to complete, the full family of pedestrian dummies.

Figure 1: Surrogate Targets used in AEB and P-AEB Evaluation Programs

The test vehicles where instrumented with RT4002 Inertial GPS Navigation Systems and RT-Range from OxTS to measure vehicle position and heading, vehicle speed and angular velocities (yaw, roll, and pitch rate), linear acceleration (longitudinal, lateral and vertical), distance to target and relative velocity. The accuracy of the GPS was augmented through the use of a portable GPS Base Station. To increase accuracy and repeatability of crucial longitudinal test parameters (i.e.: throttle input, braking input, velocity, headway), test and target tow vehicles were fitted with Combined Brake and Accelerator Robots (CBAR) from ABD. All lateral test parameters were controlled by the test drivers.

Test Methodology

The methodology used for the AEB evaluation was based on both the CIB and DBS procedures designed by NHTSA [4] [5] with the only exception that static tests (A1) were performed at speeds within the range of 10 km per hour (km/h) to 50 km/h (to allow comparison with Euro NCAP) rather than only at 40 km/h. In order to reduce the number of tests required to complete each vehicle's assessment and preserve the test equipment's integrity the following strategy was followed: the vehicle was driven at an initial speed of 20 km/h; if there was no impact, the speed was then increased in increments of 10 km/h up to the maximum speed of 50 km/h; if an impact occurred, the speed was reduced by 5 km/h. A series of tests was considered valid if no impacts were observed in at least 5 out of 7 tests. If 3 impacts occurred before reaching 5 out of 7 tests without impact, the vehicle speed was reduced by 5 km/h. The goal was to determine the maximum avoidance speed of the systems. The test speed chart used for the static AEB scenario and all 4 P-AEB scenarios is shown in Figure 2.

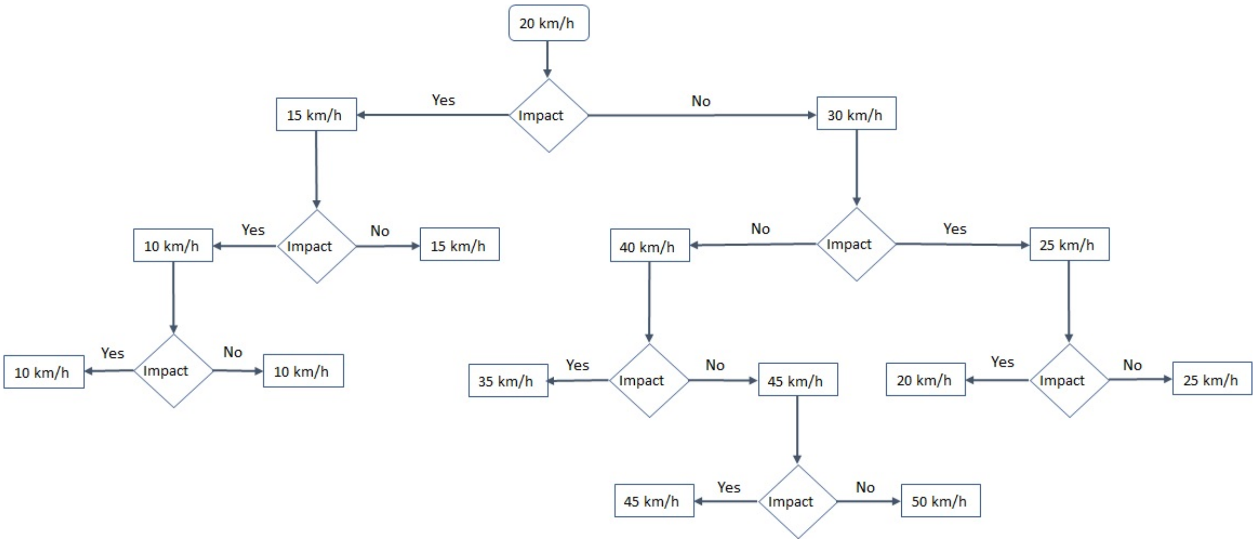


Figure 2: Test Speed Chart for Static AEB and P-AEB Evaluation Programs

The procedure used for the LSS evaluation was based on existing American and European test protocols and was designed to capture the LSS behaviours of 10 vehicles from TC's test fleet. It consisted of 5 repetitions of each test scenario (Table 3) with cruise control "on" and with cruise control "off". If the results with and without cruise control were similar, the tests were only performed 3 times in the "off" configuration. Vehicles were tested with LKA system active and inactive. Haptic signals were collected via an accelerometer on the steering wheel and audio signals via a sound probe.

The data collected during the LSS testing included: environmental conditions; offset from lane marking at warning; distance travelled from the entrance gate at warning; ambient temperature; wind speed; wind direction; the type of warning (visual, audio, haptic); test speed; and state of cruise control (on/off). The warnings were produced visually for most of the vehicles tested.

In the winter of 2019, TC started assessing the performance of LSS on snow covered roads (Figure 3). The method consisted of: creating tire tracks to produce a contrast with the surrounding environment after a snow fall; and try to engage the LSS while driving on this portion of road. 4 vehicles were tested and none of them were able to fully engage and recognize the road path. This type of condition is typical of Canadian roads in winter.

Scenario 2 Segment	Scenario 1 and 3 Segment	Winter conditions

Figure 3: Road Surfaces for LSS Testing

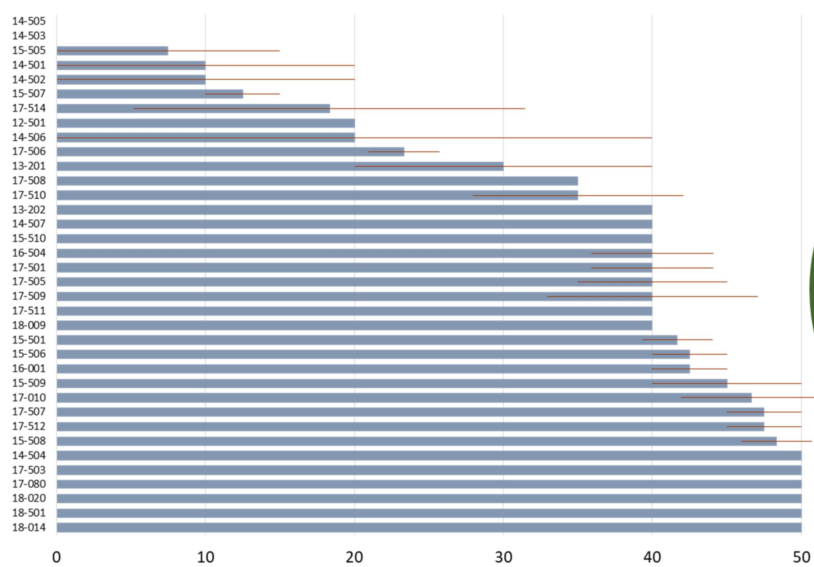
RESULTS

This study includes the comparative analysis of 7,710 individual crash avoidance tests obtained from 36 specimen vehicles equipped with automatic emergency braking, pedestrian automatic emergency braking and lane support systems. Over 100,000 km of combined on-road and track testing were conducted with these vehicles in a wide range of climate conditions replicating the Canadian landscape in the best possible way (standard conditions, direct sun, darkness, rain, fog, ice, and snow).

Automatic Emergency Braking (AEB) Test Results

All AEB systems tested during this evaluation were evaluated for both their CIB and DBS variants. The complete test matrix included 4 test scenarios (A1, B1, B2, C1) to be tested at a potential of up to 5 different speeds in static configuration and at one single speed in each of the dynamic scenarios. All 3 targets (EVT, SSV, GVT) were typically used for standard or rainy conditions when possible. The EVT was the only target used during the winter testing portion of the program and only the static test scenario (A1) was conducted on dry, ice and snow surfaces. The speed reductions and maximum avoidance speed presented in the Tables and Figures below consist of an average of 5 out of 7 tests as previously described.

AEB Maximum Avoidance Speed. Figure 4 shows the maximum avoidance speed achieved by each of the test vehicles in this evaluation. Some of the best systems were able to fully avoid a rear-end collision at speeds in excess of 60 km/h while others were challenged by speeds below 10 km/h. This exercise demonstrated that all systems were not designed equally and that some were not even capable of avoiding a collision at all in static scenarios. 2 of the test vehicles could not avoid a collision at any speed while 6 of them were able to avoid a collision at 50 km/h. In general, the evaluation of the CIB and DBS variant of the systems would produce similar results but for a few specimens, the level of performance measured in the DBS configuration far exceeded the level of performance measured in the CIB configuration (Table 4). For instance, one of the 2 vehicles that could not avoid a rear-end collision at any speed in the CIB configuration was able to avoid a collision at 50 km/h in the DBS configuration.



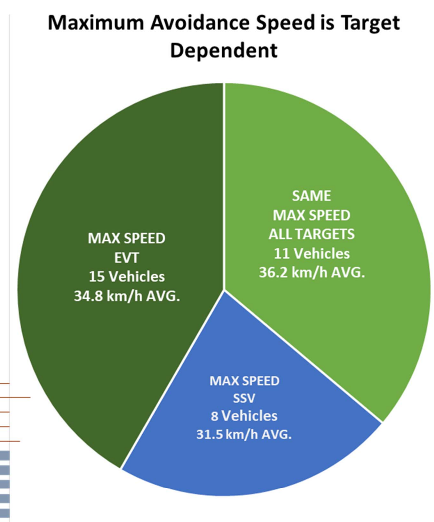


Figure 4: Maximum Avoidance Speed of 36 AEB Systems, CIB Configuration (km/h)

The maximum avoidance speed measured for each of the test vehicles as proven to be target dependent. The maximum avoidance speed was highest when tested with the EVT for 15 vehicles while 8 vehicles reached higher avoidance speeds when tested with the SSV. This could potentially be explained by the fact that a large amount of manufacturers had indicated that their systems were developed using the EVT. For 11 of the systems tested, the test target had no influence on the maximum avoidance speed and 2 vehicles had similar results with at least 2 out of the 3 targets. The test to test variation is also illustrated by the error bars on the chart of Figure 4.

AEB Maximum Speed Reduction. Table 5 lists the speed reductions achieved by each of the AEB systems in their CIB configuration. The results were organized in a way to provide a good visual representation of the overall test fleet performance. Results are presented in increments of 5 km/h for each target and a scale of green tones was created to rank the level of speed reduction achieved for every target speed. This scale would attribute the color light grey for a speed reduction of 0 km/h (severe impact) or test speeds that were not conducted due to repeated impacts at lower speeds, the color light green for a low speed impact and the color dark green for a full avoidance or 100% of the expected speed reduction. The dark grey zones indicate scenarios that were not conducted. The results were then organized in chromatic order with the darker shades from top to bottom. A simple look at this table provides a good overview of what can generally be expected from AEB technology in terms of speed reduction and associated safety benefits as its deployment in the field is in constant progression. To sum up, the greener, the better.

The overall results suggest that 7 or 8 test samples that found themselves at the bottom of the chart did not seem to perform as well as the average of the rest of the fleet. However, when comparing these results against established performance criteria, 24 out of the 36 AEB systems evaluated achieved a level of performance sufficient to meet all the requirements set forth in NHTSA's CIB test procedure, as shown in Table 6. Concurrently, only 2 of the systems did not meet the minimum performance requirement used for the voluntary memorandum of understanding (MOU) signed between IIHS, NHTSA and the car industry for a commitment to make AEB a standard feature by 2022 in the United States (U.S.). This minimum requirement consists of a subset of NHTSA's requirement for the static test with the option of achieving a speed reduction of 15.8 km/h in either a 20 km/h or 40 km/h test or achieving a speed reduction of 7.9 km/h in both tests. Again, one of these two specimens was found to meet NHTSA's minimal performance requirements when evaluated in the DBS configuration.

As many manufacturers indicated that their system would perform better in scenarios where a target is in motion, it was expected that the level of performance would be greater for the dynamic scenarios. The chromatic scale used in Table 5 demonstrates this quite eloquently as very few areas of the 16-40 (B1), 32-72 (B2) and 56-56 (C1) columns are labelled in light grey. However, amber and red shaded cells do appear in the B1 and B2 columns. As many of the systems did bring the vehicles to a full stop instead of modulating their speed to that of the target they detected on their path, these amber and red shaded areas represent excessive speed reductions or over-braking. For every speed reduction that exceeded 24 km/h in the B1 scenarios or 40 km/h in the B2 scenarios (with a slight tolerance for both cases) a scale of amber to red tones was created. The color amber is associated with mild excessive deceleration and the color red is associated with severe excessive deceleration or a full stop. This representation is not absolutely perfect as it includes cases were vehicles did not produce excessive braking because of their system design but simply because they crashed with a target, or a vehicle if this was to be transposed in the real world. Nevertheless, this demonstrates a scenario where, if in high density traffic, AEB systems could potentially generate safety concerns which are greater than those they can prevent.

Table 4.
Vehicles with better Maximum Avoidance Speed in DBS than CIB (km/h)

Vehicle	EVT (A1)		SSV (A1)	
	CIB	DBS	CIB	DBS
14-505	0	50	0	50
16-504	40	50	30	50
17-506	25	50	20	50

AEB Performance Criteria. Table 6 provides a list of performance requirements used for the assessment of AEB systems. All requirements presented in this table are in accordance with those of NHTSA's CIB test procedure. One additional requirement for the static test scenario (A1) was also included to allow for direct results comparison with the Euro NCAP test protocol [8].

Table 5.
Speed Reductions Provided by 36 AEB Systems, CIB Configuration (km/h)

Test Vehicle	EVT A1							B1	B2	C1	SSV A1							B1	B2	C1	GVT A1							B1	B2	C1
	20	25	30	35	40	45	50	16 40	32 72	56 56	20	25	30	35	40	45	50	16 40	32 72	56 56	20	25	30	35	40	45	50	16 40	32 72	56 56
18-020	19	-	29	-	39	44	48	28	45	55	19	-	29	-	39	-	49	29	47	56	21	-	30	-	39	44	50	34	44	56
17-503	19	-	30	-	40	-	49	36	58	56	20	-	30	-	39	-	49	38	64	55	20	-	30	-	40	-	50	35	55	56
17-504	-	-	29	-	38	-	48	37	48	55	18	-	29	-	38	-	48	37	51	55										
17-507	19	-	29	-	39	-	49	40	48	50	20	-	29	-	39	41	33	34	57	47	-	-	-	-	-	41	-	-	-	-
18-501	-	-	-	-	39	-	49	37	65	46	-	-	-	-	39	-	49	37	48	48	-	-	-	-	-	-	-	37	48	51
18-014	19	-	29	-	39	44	48	39	51	55	19	-	29	-	39	-	49	-	-	-	20	-	30	-	39	-	50	-	-	-
17-010	20	-	30	-	39	44	47	35	48	52	20	-	30	-	40	-	43	39	55	54	20	-	30	-	40	-	-	37	48	53
13-201	20	-	30	-	40	-	50	40	71	48	20	-	30	-	40	-	50	40	72	45										
15-509	-	-	-	-	39	-	49	39	56	55	19	-	29	-	39	45	49	39	63	56	-	-	-	-	-	45	-	-	-	-
15-501	-	-	-	35	34	44	46	20	67	46	-	-	-	-	37	40	38	23	57	46	19	-	-	-	40	40	41	30	49	38
14-504	20	23	27	-	40	-	50	37	64	42	-	-	-	35	40	-	49	35	61	35										
16-504	20	-	30	-	40	44	34	29	41	53	-	-	30	34	34	-	-	30	29	38	19	-	30	35	36	-	-	37	26	33
17-501	-	-	-	-	39	33	41	40	66	56	15	-	30	-	39	43	41	29	40	52	19	-	30	35	38	43	-	30	45	47
17-505	20	-	29	-	40	45	45	38	48	49	13	-	30	33	33	-	-	34	25	40										
15-508	10	-	30	-	40	45	48	40	70	48	19	22	25	33	33	-	48	37	65	48	-	-	30	-	38	-	42	37	45	50
17-512	13	-	30	-	40	45	44	36	61	24	-	25	30	-	40	32	31	36	60	17	-	-	-	-	-	32	-	-	-	-
15-506	-	-	-	-	38	45	43	40	67	33	-	-	28	25	26	16	-	40	72	33										
17-511	20	-	30	-	39	39	30	40	65	29	-	-	30	-	40	39	32	32	45	21	20	-	27	27	39	39	-	40	36	23
14-507	16	17	14	-	32	-	23	25	43	22	14	20	27	35	40	45	24	27	32	27	-	-	-	-	-	45	-	-	-	-
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16-001	19	25	28	35	40	38	-	37	45	53	19	25	-	35	-	44	38	23	37	40	-	-	-	-	-	44	-	-	-	-
17-510	20	25	30	-	36	34	-	19	49	56	-	25	30	32	33	-	-	32	48	49	-	25	19	-	31	-	9	28	37	56
17-509	20	-	30	35	32	-	-	40	70	56	20	-	30	-	40	-	50	39	67	56	-	-	29	33	29	-	-	40	49	46
13-202	20	-	30	35	30	-	-	36	44	35	20	-	30	29	27	-	-	40	40	40										
17-514	20	-	30	17	11	-	-	36	42	51	20	24	21	-	-	-	-	39	67	42	-	-	-	-	-	-	-	40	53	41
15-510	-	-	30	22	21	-	-	40	28	29	-	23	26	20	21	-	-	-	-	-										
14-506	19	25	19	-	16	-	-	32	27	17	-	24	19	-	16	-	-	40	20	18										
17-506	20	23	15	-	-	-	-	22	14	13	20	17	13	-	-	-	-	10	11	13	-	25	17	-	-	-	-	-	-	-
17-508	-	-	-	-	-	-	-	33	17	-	-	-	29	33	26	-	-	18	13	6										
14-501	-	18	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-										
14-502	17	12	11	3	4	-	-	18	31	-	-	-	-	-	-	-	-	31	33	-										
14-503	10	4	9	9	7	-	5	13	8	12	-	-	-	-	-	-	-	30	63	11										
14-505	5	-	-	-	6	-	-	14	16	17	2	-	-	-	-	-	-	11	11	19										
15-505	14	11	11	-	11	-	-	11	6	14	11	-	-	12	12	-	-	10	8	-										
15-507	6	7	17	-	-	-	-	36	26	24	16	24	17	-	-	-	-	24	24	21										
12-501	17	11	-	-	-	-	-	-	-	14	12	8	4	-	-	-	-	40	-	-										

Table 6.
Crash Imminent Braking (CIB) Performance Requirements

Minimum Performance Requirements for CIB Assessment					
Scenario	A1		B1	B2	C1
Target (km/h)	0	0	16	32	56
Vehicle (km/h)	0-50	40	40	72	56
Minimum Speed Reduction Requirement	No Impact At least 5/7 valid test trials	>15.8 km/h At least 5/7 valid test trials	No Impact At least 5/7 valid test trials	>15.8 km/h At least 5/7 valid test trials	>16.9 km/h At least 5/7 valid test trials

Pedestrian Automatic Emergency Braking (P-AEB) Test Results

The P-AEB analysis included a total of 19 systems ranging from MY 2016 to 2018. Similarly to the AEB evaluation, the test matrix included 4 different test scenarios (CPFA-50, CPNA-25, CPNA-75, CPNC-50) to be tested between 10 km/h and 50 km/h. The 50th percentile adult articulated pedestrian dummy was used for the first 3 scenarios mentioned, while the 7-year-old articulated child dummy was used for the CPNC-50. Unlike the AEB evaluation, the systems were not typically tested for both their CIB and DBS variants. However, two specimens which did not perform to expectations in the CIB configuration were re-tested in the DBS configuration and showed significant improvement. The speed reductions and maximum avoidance speed presented in the Tables and Figures below consist of an average of 5 out of 7 tests as previously described.

P-AEB Maximum Avoidance Speed. The maximum avoidance speeds measured during the P-AEB evaluation were seen in the CPNA-75. For this scenario, as the theoretical point of impact was past the median line of the vehicle and that there was no obstruction, it seemed easier for the systems to detect potential conflicts. Similarly to what was experienced during the AEB evaluation, some systems were challenged by speeds below 10 km/h while others were able to fully avoid a collision with a pedestrian at speeds in excess of 60 km/h. 4 of the test vehicles evaluated could not avoid a collision at any speed while 4 of them were able to avoid a collision at 50 km/h. In general, comparing the AEB and P-AEB results showed a good correlation. The top 3 performing test samples of the P-AEB evaluation are the same as the top 3 performers of the AEB evaluation.

An analysis comparing TC's results to those of Euro NCAP showed variability in 3 out of 4 sample vehicles. The speed reductions observed with TC's sample TC17-503 where higher than those measured in the Euro NCAP test for a similar model (one MY older and lower model trim). Samples TC18-020 and TC18-501 showed good correlation except for TC18-501 that could never detect a running adult in the CPFA-50 test. The previous evaluation of a different sample from the same manufacturer (TC15-509) showed the same phenomenon even if both vehicles measured up to expectations in all 3 other P-AEB test scenarios. Finally, sample TC17-512 never detected a pedestrian in any of all 4 test scenarios in TC's tests but performed well in Euro NCAP's tests.

Table 7.
TC/Euro NCAP P-AEB Maximum Avoidance Speed in km/h

	TC17-503		TC17-512		TC18-020		TC18-501	
Scenario	Euro NCAP	TC	Euro NCAP	TC	Euro NCAP	TC	Euro NCAP	TC
CPNC-50	30	40	30	No response	40	45	35	35
CPFA-50	20	50	20	No response	60	50*	50	No response
CPNA-25	40	55	35	No response	60	50*	60	50*
CPNA-75	40	60	40	No response	60	50*	60	50*

* Maximum test speed performed

P-AEB Maximum Speed Reduction. Table 8 lists the speed reductions achieved by each of the P-AEB systems in their CIB configuration. The chromatic scale previously described in the AEB section was also used to present the P-AEB results. While there was good correlation in maximum avoidance speeds between the car-to-car and pedestrian AEB results, a comparison between the two speed reduction tables clearly demonstrates that current AEB systems perform better in car-to-car scenarios then in pedestrian scenarios. This may not necessarily be a surprise as detecting moving pedestrians and predict their position in time and space is a far more complex and challenging task than detecting a larger vehicle in a straight line. Since pedestrian and vulnerable road users represent a large portion of road fatalities, this shows that P-AEB should be identified as a primary area of research were innovation and technological advancement could produce important safety improvements. The chromatic organization of the table demonstrates that the CPNA-75 scenario produced the highest speed reductions while the CPNC-50 scenario with the child dummy and obstruction had proven to be the most challenging of all scenarios. Finally, and of concerning note, the P-AEB program also demonstrated that 4 out of 19 test specimens evaluated did not provide any mitigation in any of the 4 test scenarios despite the manufacturers' claim of pedestrian avoidance capabilities.

Table 8.
Speed Reduction Provided by 19 Pedestrian AEB Systems (km/h)

Test Vehicle	CPNA-75							CPNA-25							CPFA-50							CPNC-50						
	20	25	30	35	40	45	50	20	25	30	35	40	45	50	20	25	30	35	40	45	50	20	25	30	35	40	45	50
18-020	-	-	-	-	-	-	50	20	-	-	-	-	-	50	-	-	30	-	40	-	50	20	-	30	-	40	35	28
17-503	20	-	30	-	40	-	42	17	-	30	-	40	-	49	19	-	30	-	40	41	48	-	-	-	-	38	37	27
17-504	-	-	30	-	40	-	50	20	-	30	-	40	-	50	20	-	30	-	40	-	50	-	-	30	35	24	29	33
18-501	-	-	-	-	-	-	50	20	-	30	-	40	-	50	-	-	-	-	-	-	-	19	-	29	35	13	-	-
15-509	-	-	30	-	-	-	50	10	-	30	-	38	37	-	-	-	-	-	-	-	-	20	12	-	-	-	-	-
17-010	20	-	30	-	40	38	26	19	-	30	32	21	-	-	20	25	30	35	23	26	-	-	25	8	-	-	-	-
17-509	-	-	-	-	36	21	-	20	25	14	-	-	-	-	16	23	17	-	-	-	-	20	-	25	18	-	-	-
15-501	-	-	-	-	-	37	24	1	4	-	-	-	-	-	12	12	9	-	-	-	-	10	-	-	-	-	-	-
17-505	15	-	30	29	19	-	-	7	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
17-506	20	-	30	14	-	-	-	13	-	-	-	-	-	-	20	21	30	12	-	-	-	20	18	13	-	-	-	-
17-508	20	21	24	-	-	-	-	11	11	-	-	-	-	-	17	15	24	-	-	-	-	18	9	-	-	-	-	-
17-507	20	25	14	-	-	-	-	5	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
18-014	-	-	21	-	15	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17-501	-	-	-	26	11	-	-	8	-	-	-	-	-	-	4	-	-	-	-	-	-	1	-	-	-	-	-	-
16-504	5	-	-	-	-	-	-	13	10	18	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
16-001	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17-514	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18-009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15-505	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Fleet Averaged AEB and P-AEB Test Results. Figure 5 provides a general overview of the averaged speed reduction results observed during this study for all AEB and P-AEB scenarios in the CIB configuration, all targets combined. The intention was to provide a visual representation of the overall potential safety benefits associated with AEB and P-AEB, based on this scientific assessment. The break-down of speed reductions was in the range of: 15 km/h for pedestrian scenarios; 27 km/h for static AEB scenarios; and 43 km/h for dynamic AEB scenarios. The test to test variability is also illustrated by the error bars for each data set. The graph shows fleet average excessive braking in the range of 8-12 km/h and 4-5 km/h in the B1 and B2 scenarios, respectively, depending on the target. The red boxes represent the NHTSA performance requirements while the green box represents the requirements of the MOU between the car industry, IIHS and NHTSA, both described previously. These show that the averaged industry standard currently far exceeds the minimum performance requirements set by these two safety agencies.

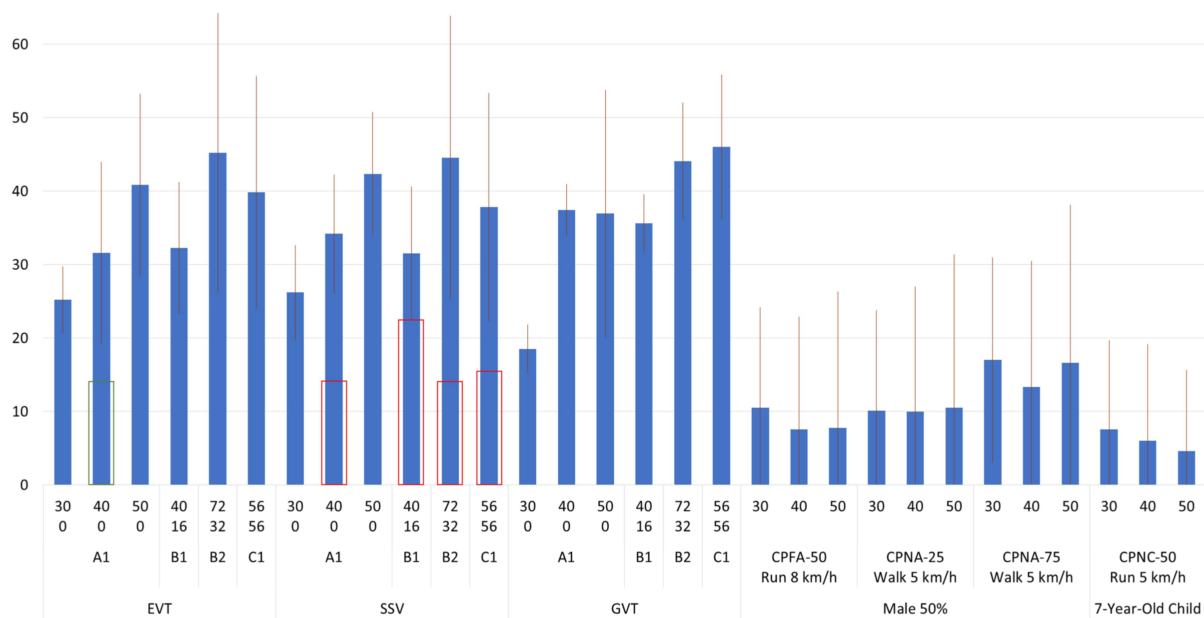

Figure 5: Averaged Speed Reductions of 36 AEB Systems and 19 P-AEB Systems (km/h)

Lane Support System (LSS) Test Results

The procedure used for the LSS evaluation was based on existing U.S. and European test protocols and was designed to capture the LSS behavior of 10 vehicles from TC's test fleet. Results from some of the test samples varied in functionalities and some systems operated differently under similar testing conditions. Some vehicles were equipped with systems that only provided warnings, while others provided warnings and correction or lane-centering capabilities. Other vehicles were equipped with LKA systems that auto-corrected without warning the driver.

<u>Lane Departure Warning (LDW) System.</u> All vehicles were not tested with the lane departure correction system activated. 4 out of 10 were tested in LDW only. The main focus was to evaluate the signals provided to the driver. The procedure was adapted to include the vehicles with lane correction capabilities. 4 vehicles were tested in the LDW mode and the results are presented in Table 9. 5 tests were done with the cruise control "on" in order to activate the LKA and to assist with the speed control. 3 tests were completed without cruise control. Vehicles with only the LDW functions activated resulted in at least a visual signal for all tests.

Table 9.
Lane Departure Warning

		SSL			**SDL**			**DC**		
Specimen	Cruise	Visual	Audio	Haptic	Visual	Audio	Haptic	Visual	Audio	Haptic
17-512	On	5/5	1/5	5/5	5/5	0/5	5/5	5/5	0/5	5/5
	Off	3/3	2/3	3/3	3/3	0/3	3/3	3/3	0/3	3/3
17-511	On	5/5	0/5	5/5	3/5	0/5	0/5	3/5	0/5	3/5
	Off	3/3	0/3	3/3	0/3	0/3	0/3	3/3	0/3	3/3
17-010	On	5/5	5/5	0/5	5/5	4/5	0/5	5/5	5/5	0/5
	Off	3/3	3/3	0/3	3/3	3/3	0/3	3/3	3/3	0/3
15-508	On	5/5	0/5	5/5	5/5	0/5	5/5	5/5	0/5	5/5
	Off	3/3	0/3	3/3	3/3	0/3	3/3	3/3	0/3	3/3

<u>Lane Keeping Assist (LKA) System.</u> Using the same tests scenarios to test the LKA functions yielded different results as can be seen in Table 10. 2 out of 8 vehicles tested stayed in their traveling lane during the 3 tests scenarios without generating warnings. This "background" system corrected for the driver to keep the vehicle in the lane and did not generated alerts unless crossing the lane. In our test, the two vehicles drove in the lane and remained between the lane markings. 4 out of 8 vehicles used their LKA system and warned the driver when approaching lane markings by using audio and visual alerts for each test. The vehicles corrected, but always warned the driver. This approach was interesting as the system tried to keep the vehicle on track, but also warned the driver if the vehicle was drifting away from the center lane. Warnings generated by number of tests are presented in the Tables below.

Table 10.
Lane Keeping Assist

		SSL			**SDL**			**DC**		
Specimen	Cruise	Visual	Audio	Haptic	Visual	Audio	Haptic	Visual	Audio	Haptic
17-503	On	On	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
	Off	Off	3/3	0/3	3/3	0/3	0/3	3/3	0/3	0/3
17-512	On	On	1/3	0/3	1/3	0/5	0/5	0/5	0/4	0/4
18-009	Off	Off	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
	On	On	5/5	0/5	0/5	5/5	0/5	0/5	5/5	0/5
18-020	Off	Off	3/3	0/3	0/3	3/3	0/3	0/3	3/3	0/3
	On	On	5/5	0/5	0/5	5/5	0/5	0/5	5/5	2/5
17-010	Off	Off	3/3	0/3	0/3	3/3	0/3	0/3	3/3	1/3
	On	On	5/5	6/5	5/5	5/5	4/5	0/5	5/5	3/3
17-503	Off	Off	3/3	3/3	0/3	3/3	2/3	0/3	3/3	3/3
18-501	On	On	2/5	2/5	0/5	5/5	5/5	0/5	3/5	3/5
	Off	Off	0/3	0/3	0/3	3/3	3/3	0/3	2/3	2/3
17-514*	On	On	5/5	0/5	0/5	5/5	0/5	0/5	5/5	5/5
	Off	Off	3/3	0/3	0/3	3/3	0/3	0/3	3/3	3/3
17-501	On	On	5/5	5/5	0/5	4/5	4/5	0/5	1/5	1/5
	Off	Off	3/3	3/3	0/3	3/3	3/3	0/3	0/3	0/3

*LKA does not correct every time, works randomly

The other observation noted for this test is a combination of lane keeping and warning systems. 2 out of 8 vehicles produced warnings and made corrections. It was interesting to see that for consecutive and repeatable test conditions, different results were observed. One of the two vehicles had issues engaging the LKA in certain tests, resulting only in audio warnings. One vehicle did not perform the same during the SSL and SDL which could be related to lane marking quality. It could be attributed to the sensitivity to recognize the "road" like lanes or simply put, a calibration difference for this system.

For scenario #3 (S-Curve) presented in Table 11, the tests were performed starting in the right lane, moving to a dotted line first and again starting in the left lane moving towards the edge of the road first. The goal of this test was to challenge the robustness of the system in having more than 1 signal input, a left input followed by a right input. In the case of pure warning only, the driver made the correction to the steering wheel to follow the path. The length of the course was 800 meters or 40 seconds in duration. The vehicle encountered an S-shaped road with a radius of curvature of 1,219 m. Some LKA systems prompted the driver to touch the steering wheel before the end of the procedure, with the first warning appearing before the end of the course. For 26 out of 40 tests conducted, the LKA helped the driver staying in the lane and 14 out of 40 tests warned of lane departure (LDW).

Looking at all combinations of the two tests, from the right and the left lane, cruise control operational or not as well as LKA system activated, 7 out of 10 vehicles reacted the same way in terms of alerting the driver. With the LKA off, visual alerts in conjunction with a vibratory alert was produced 6 times out of 8. With the LKA on, 2 vehicles

Table 11.
Scenario #3 with LKA "off" – Warning only

		SS			**DS**		
Specimen	Cruise	Visual	Audio	Haptic	Visual	Audio	Haptic
15-508	On	5/5	0/5	5/5	5/5	0/5	5/5
	Off	3/3	0/3	3/3	3/3	0/3	3/3
17-514	On	5/5	0/5	0/5	5/5	0/5	0/5
	Off	3/3	0/3	0/3	3/3	0/3	0/3
17-503	Off	3/3	0/3	3/3	0/3	0/3	3/3
17-512	On	5/5	4/5	5/5	5/5	0/5	5/5
	Off	3/3	3/3	3/3	3/3	0/3	3/3
17-511	On	5/5	0/5	5/5	5/5	0/5	5/5
	Off	3/3	0/3	3/3	3/3	0/3	3/3

Table 12.
Scenario #3 with LKA activated

		SS			**DS**		
Specimen	Cruise	Visual	Audio	Haptic	Visual	Audio	Haptic
17-514	On	0/5	0/5	0/5	5/5	0/5	0/5
	Off	0/3	0/3	0/3	3/3	0/3	0/3
18-501	On	5/5	5/5	0/5	2/5	2/5	0/5
	Off	3/3	3/3	0/3	3/3	3/3	3/3
17-010	On	5/5	5/5	0/5	5/5	5/5	0/5
	Off	3/3	3/3	0/3	3/3	3/3	0/3
17-503	On	0/5	0/5	0/5	4/5	1/5	0/5
17-512	On	0/3	0/3	0/3	0/3	0/3	0/3
	Off	0/2	0/2	0/2	0/3	0/3	0/3
18-009	On	5/5	0/5	0/5	5/5	0/5	0/5
	Off	3/3	0/3	0/3	3/3	0/3	0/3
18-020	On	5/5	0/5	0/5	5/5	0/5	0/5
	Off	3/3	0/3	0/3	3/3	0/3	0/3
17-501	On	5/5	5/5	0/5	3/5	3/5	0/5
	Off	3/3	3/3	0/3	3/3	3/3	0/3

out of 6 warned the driver with both a visual and audible signal. 3 vehicles only warned visually and 1 vehicle did not warn the driver and simply maintained its lane for the duration of the test. Two vehicles were not consistent with their warnings while the LKA was engaged and the number of alerts varied depending on whether the test was performed from a dotted line to a solid lane and vice-versa.

A difference in system reaction was observed during scenario #3, a test that represented real road conditions. It was interesting to capture the limits of the system under more challenging situations. Table 11 showed warning only and Table 12 with LKA activated mode during scenario #3.

DISCUSSION

The specific objectives of this study were as follows: evaluate the performance of ADAS to determine their potential in reducing fatalities and injuries on Canadian roadways; determine the limitations of ADAS to identify potential risks to road safety; provide scientific evidence to help shape future regulatory, research and policy development surrounding automated and connected vehicle technologies; assess and develop test methods and procedures; and evaluate the suitability of surrogate vehicle and pedestrian targets for future research and regulatory programs. To address these objectives, 7,710 individual crash avoidance tests obtained from 36 ADAS-equipped vehicles were conducted at the MVTC. While the effects of all test parameters are included in this discussion, the focus of the study banks on results obtained on-track and in standard conditions. An in-depth analysis of these results follows.

AEB. AEB systems were evaluated for their CIB and DBS variants according to 4 different test scenarios with 3 different targets replicating the characteristics of a real vehicle. The test results suggested that all systems were not designed equally. Important performance variability were observed across the fleet and some systems were not even capable of avoiding collisions in static scenarios. However, when comparing results against established performance criteria set forth by internationally recognized road safety organizations, 24 out of 36 AEB systems achieved a fully satisfactory level of performance. Concurrently, only 2 of the systems did not meet the minimum performance requirement used for the voluntary MOU signed between IIHS, NHTSA and the car industry for a commitment to make AEB a standard feature by 2022 in the U.S.

Overall, the evaluation of the CIB and DBS variant of the systems did produce similar results but for a few specimens, the level of performance measured in the DBS configuration far exceeded the level of performance measured in the CIB configuration. For instance, one of 2 vehicles that could not avoid a rear-end collision at any speed in the CIB configuration was able to avoid a collision at 50 km/h in the DBS configuration. The maximum avoidance speed measured for each of the test vehicles was found to be mostly target dependent. While 11 test specimens produced the same results independently of which target they were evaluated with, 15 vehicles could avoid the target at a higher speeds when tested with the EVT target.

A chromatic scale of the results obtained during the AEB evaluation was developed to provide an overall visual perspective of what can be expected from AEB technology in terms of safety benefits as its deployment in the field is in constant progression. The chart created clearly demonstrates that AEB technology can provide significant improvements in terms of collision mitigation which can directly result in reduced road casualties.

P-AEB. 19 P-AEB systems were evaluated according to 4 different test scenarios simulating some of the most common real-life situation involving collision between vehicle and adult or child pedestrians. The maximum avoidance speeds of the P-AEB evaluation were observed for the CPNA-75 condition. For this scenario, as the theoretical point of impact was past the median line of the vehicle and that there was no obstruction, it seemed easier for the systems to detect potential conflicts. Similarly to what was experienced during the AEB evaluation, some systems were challenged at speeds below 10 km/h while others were able to fully avoid a collision with a pedestrian at speeds in excess of 60 km/h. Overall, the speed reductions observed during the AEB evaluation of the systems were more important than those observed during the P-AEB evaluation. This may not necessarily be a surprise as detecting moving pedestrians and predict their position in time and space is a far more complex and challenging task than detecting a larger vehicle in a straight line.

An analysis comparing TC's results to those of Euro NCAP showed variability in 3 out of 4 sample vehicles. It also showed that one of the sample vehicle never detected a pedestrian in any of all 4 test scenarios in TC's tests while it performed well in the Euro NCAP tests.

Finally, and of concerning note, the P-AEB testing program demonstrated that 4 out of 19 test specimens did not provide any mitigation in any of the 4 test scenarios despite the manufacturers' claim of pedestrian detection capabilities. Since vulnerable road users and more specifically pedestrians account for a large portion of road fatalities, this shows that P-AEB should be identified as a primary area of research were innovation and technological advancement could produce important safety improvements.

LSS. As more advanced LSS testing methods are being developed using steering robots, such as described in the *Euro NCAP Lane Support Systems* test protocol [10], the testing procedure developed for this program demonstrated some limitations. The work presented here consists of an exploratory approach aiming at evaluating the status of commercially available LSS under realistic conditions. The operational limitations of 10 LSS systems were evaluated on a mixture of roads at the MVTC according to 3 different scenarios.

4 out of 4 vehicles tested with LDW produced visual warnings for SSL, SDL and DC. For that same sequence, 1 vehicle constantly produced visual and audio warnings while the others generated a combination of visual and haptic or visual and audio warnings. Only 1 vehicle generated haptic, audio and visual warnings for the SS test only. With LKA activated, 2 out of 8 vehicles stayed on their traveling lane for the SSL, SDL and DC scenarios without generating warnings. The system operated in the background and did not communicate with the driver. 3 out of 8 vehicles generated audio and visual alerts. The SS scenario was more consistent than the DS scenario as only 2 vehicles reacted differently from SS and DS. Scenario #3 was performed only with LKA activated and simulated real-world driving of an S-Curve. Only one vehicle generated a haptic signal during the DS test with the cruise control "off". This test was more challenging as 4 out of 8 vehicles did not reproduce the same warnings going into the SS or DS test. It may be attributed to lane markings as differences with respect to line types were observed in other scenarios. LSS was only constant for visual warnings and not for the enhancement of haptic and audio signals.

While the preferred strategy used to warn drivers of lane crossing for the systems tested during this evaluation was through visual signals, supplemental haptic and audio signals were inconsistent from vehicle to vehicle. At times, test drivers felt bombarded with alarms and signals without exactly knowing how they should be interpreted. System sensitivity to lane markings also seemed to be an issue for a subset of sample test vehicles. Ideally, more data and a comprehensive human factor assessment would be required in order to articulate an accurate estimate of potential safety benefits associated with LSS technologies.

Findings. As the deployment of ADAS is in constant progression, TC will continue to monitor the evolution and performance of new systems introduced on the global markets. As mentioned previously, despite being in its relative infancy, ADAS safety benefits are already recognized by several international consumers, insurance and safety organizations [2] [3]. Results from this study clearly demonstrated that AEB and P-AEB technologies can provide significant improvements in terms of collision mitigation which can directly result in reduction of road fatalities and injuries. An in-depth analysis of these results showed that while driving at speeds typical of an urban environment, the vehicle fleet evaluated in this study could provide average speed reductions of: 15 km/h in pedestrian scenarios; 27 km/h in static scenarios; and 43 km/h in dynamic scenarios. Furthermore, 66% of all tests conducted during the AEB evaluation resulted in a full avoidance. While it is not expected that such a ratio would translate to real-world conditions it seems that the findings of this study are in line with those of other studies that predicted that AEB technology could potentially reduce rear-end collisions by 38% to 50% [14] [15].

Some limitations of AEB and P-AEB systems were also exposed during this evaluation. While most systems demonstrated a satisfactory level of performance when compared against established performance criteria, the overall results suggested important performance variability across the entire fleet. Scenarios replicating AEB activation in moving traffic showed that excessive braking was generated by most systems. While the speed reduction required for the *fast vehicle approaching a slow vehicle* scenarios should ideally match the speed of the vehicle ahead and not crash into it (i.e., 16 km/h and 32 km/h), most of the test specimens rather came to a full stop. This represented speed reductions of 40 km/h and 72 km/h, respectively. This excessive deceleration is concerning as it shows a situation where AEB systems could generate higher safety risks than those they can prevent in high density traffic. Only a few of the latest, pricier and more technologically advanced specimens behaved appropriately in these tests. Of equally concerning nature, 4 out of 19 vehicles evaluated for P-AEB were never able to avoid a collision with a pedestrian.

While a full analysis on the effects of weather conditions on AEB and P-AEB as not yet been completed due to insufficient data, it is worth mentioning that decreased performance was observed in both rain and winter conditions. More data is also required in order to articulate a comprehensive assessment of LSS technologies and their associated safety benefits due to variability in test results and generalized unpredictable system behavior.

CONCLUSION

The concept of mitigating the severity of a collision or avoiding it altogether being the best possible way to reduce traffic-related fatalities and injuries on motorways is certainly something that resonates well with most motorists. Modern ADAS technologies hold the promise of doing just that. They could potentially, or will, save thousands of lives around the world in years to come while we await a driverless and collision free future. This is assuming that they are used within the scope of their limitations and functionalities, and that it is understood that for the time being, in the vast majority of situations, they are only designed to assist drivers and not replace them.

Since its inception, TC's crash avoidance program has been investigating some of the most prominent ADAS technologies currently available on the market and evaluating how they can benefit Canadians. Results from this study clearly demonstrated that AEB and P-AEB technologies can provide significant improvements in terms of collision mitigation which can directly result in reduced road fatalities and injuries. These findings are also in line with those of studies based on real-World data predicting significant reductions in rear-end collisions due to AEB deployment.

Nonetheless, this research program also exposed an important number of flaws and performance variability. While the best AEB and P-AEB systems were able to fully avoid collisions with vehicles and pedestrians at speeds up to 60 km/h, others were challenged at speeds below 10 km/h. A few P-AEB systems were never able to avoid a collision with a pedestrian despite manufacturers' claims of pedestrian detection capabilities. Scenarios replicating AEB activation in moving traffic showed that most systems unnecessarily came to a full stop rather than match the speed of vehicles they detected on their path, potentially generating higher safety concerns than those they were designed to prevent. Finally, due to variability in test results and general unpredictable system behaviour, it was not possible to gather enough data to confidently assess the potential safety benefits associated with LSS.

AEB, P-AEB and LSS are essential components of automated driving systems which will need to reliably brake and steer at all time to safely avoid other road users. That level of performance is not yet evident from the extensive testing carried out within this project. Substantial progress is therefore needed to reach the level of detection, braking and steering performance that will be required to make commercial automated driving systems a reality.

ACKNOWLEDGMENTS

Motor Vehicle Safety (TC), Human Factors (TC), ecoTECHNOLOGIE for Vehicles (TC), Compliance (TC), Collision Investigations (TC), Defects and Recalls (TC), Transportation Division (ECCC), Emissions Research and Measurements Section (ECCC), PMG Technologies, Volvo Canada

DISCLAIMER

The contents of this report reflect the views and interpretation of the authors, who are responsible for the results, the information, and their accuracies herein. The contents do not necessarily represent, or otherwise reflect, the official opinion, position or policies of Transport Canada or the Government of Canada.

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