



OCTOBER 2025

PERFORMANCE OF PEDESTRIAN AUTOMATIC EMERGENCY BRAKING SYSTEMS:

Nighttime Effectiveness and
High-Visibility Clothing Evaluation

[NewsRoom.AAA.com](https://www.aaa.com/newsroom)





(this page intentionally left blank)



ABSTRACT

Pedestrian Automatic Emergency Braking (PAEB) is an Advanced Driver Assistance System (ADAS) feature designed to detect and respond to potential collisions with pedestrians. By utilizing onboard sensors and processing, PAEB systems can automatically apply the brakes when a collision with a pedestrian is deemed imminent and the driver does not react in time. This technology is intended to prevent or mitigate vehicle-to-pedestrian collisions whenever possible. While advancements have improved PAEB performance in standardized test scenarios, challenges may remain in real-world conditions, such as in low-light environments [1] and when pedestrians wear high-visibility clothing commonly used by first responders and roadway workers [2].

This study evaluated the performance of 2024 and 2025 model year PAEB systems in a controlled closed-course environment, using a perpendicular crossing scenario at 40 km/h and an industry-standard adult pedestrian target. Each system was assessed during both daytime and nighttime conditions, with the pedestrian target dressed in its standard non-reflective clothing as well as an American National Standards Institute (ANSI) Class 3 high-visibility clothing ensemble. Test procedures were designed to mirror those used in AAA's 2019 PAEB study to enable direct comparison of those results for the nighttime condition.

The primary objectives were to determine whether nighttime PAEB performance has improved since 2019 and to assess the influence of ANSI Class 3 high-visibility clothing on system effectiveness under both day and night conditions. Results indicate that while detection and response have improved in general since the previous study, system performance continues to vary by vehicle, particularly at night and when pedestrians are outfitted in ANSI Class 3 high-visibility clothing. These findings underscore the need for continued development and evaluation of PAEB technologies to ensure reliable pedestrian protection in real-world scenarios.

This research was conducted in partnership with the Automobile Club of Southern California's Automotive Research Center.

Research Questions:

1. How has nighttime pedestrian detection performance of the evaluated PAEB systems changed compared to similar tests conducted in 2019?
2. How does outfitting the pedestrian target with an ANSI Class 3 ensemble affect the performance of the evaluated PAEB systems during both day and night testing in the same scenario?

Key Findings:

1. Nighttime PAEB impact avoidance improved overall from 0% in 2019 to 60% in 2025, but detection and response were inconsistent by model.
2. ANSI Class 3 high-visibility clothing had no negative effect on daytime PAEB performance and sometimes improved detection, but nighttime responses varied by vehicle, ranging from improved avoidance to complete loss of detection.



GLOSSARY

Advanced Driver Assistance Systems (ADAS): A suite of vehicle technologies designed to automate, adapt, or enhance vehicle systems for safety and improved driving. Common features include automatic emergency braking, lane keeping assistance, and adaptive cruise control.

ANSI Class 3 High-Visibility Clothing: Apparel meeting the American National Standards Institute (ANSI) requirements for high-visibility clothing, including a fluorescent shirt and pants with retroreflective material. Commonly worn by roadway workers and first responders.

Automatic Emergency Braking (AEB): A safety system that detects an impending collision and automatically applies the brakes to prevent or mitigate the impact if the driver does not respond in time.

Baseline Condition: The reference scenario, typically involving the pedestrian target in standard non-reflective clothing, used for comparison with other test variables (such as high-visibility apparel).

Closed-Course Environment: A test area isolated from public traffic and environmental variables, allowing for controlled evaluation of vehicle systems under repeatable conditions.

Forward Collision Warning (FCW): A system that alerts the driver if a frontal collision with a vehicle, pedestrian, or other object is imminent, providing a warning before automatic braking is initiated.

Mitigation: A test outcome where the system reduces the speed of impact or the severity of a collision, even if the pedestrian is not completely avoided.

Pedestrian Automatic Emergency Braking (PAEB): A specific type of AEB that detects pedestrians in or near the vehicle's path and can automatically apply the brakes to avoid or lessen the severity of a collision.

Perpendicular Crossing Scenario: A test setup in which a pedestrian target crosses the vehicle's path at a 90-degree angle, simulating a common urban or suburban pedestrian encounter.

Run-Level Results: The outcome and recorded data from a single iteration of a test scenario (i.e., one vehicle run against the pedestrian target under defined conditions).

Time-to-Collision (TTC): The calculated time remaining before a collision occurs, assuming constant speeds and trajectories for both vehicle and target.



CONTENTS

I.	Introduction	7
II.	Background	8
III.	Vehicle Selection & Preparation	9
	A. ADAS Requirements	9
	B. Test Vehicle Selection Process	9
	C. Test Vehicles	9
	D. Test Vehicle Preparation	9
IV.	Test Equipment and Resources	10
	A. Data Acquisition Equipment	10
	1) Oxford Technical Solutions (OxTS) RT3000 V3 with RT-Range S Hunter Capabilities	10
	2) Electret Microphone with MAX4466 Amplifier	10
	3) Futek LAU220 Pedal Force Sensor	11
	4) DEWESoft CAM-120 Cameras with CAM-BOX2 Distribution Box	11
	5) DEWESoft CAN-2 Interface	11
	6) Data Logging Equipment	11
	B. Test Target Equipment	12
	1) ABD LaunchPad™ 80 (LP80)	12
	2) 4activePA-adult Articulating Pedestrian Target	13
	C. Test Facility	13
V.	Inquiry #1: How has nighttime pedestrian detection performance of the evaluated PAEB systems changed compared to similar tests conducted in 2019?	14
	A. Objective	14
	B. Methodology	14
	C. Test Results	16
	1) Honda Accord	16
	2) Toyota Camry	17
	3) Chevrolet Malibu	17
	4) Tesla Model 3	18
VI.	Inquiry #2: How does outfitting the pedestrian target with an ANSI Class 3 ensemble affect the performance of the evaluated PAEB systems during both day and night testing in the same scenario?	19
	A. Objective	19
	B. Methodology	19



C. Test Results.....	20
1) Honda Accord	20
2) Toyota Camry	22
3) Chevrolet Malibu	23
4) Tesla Model 3	24
VII. Discussion	25
A. How has nighttime pedestrian detection performance of the evaluated PAEB systems changed compared to similar tests conducted in 2019?	25
B. How does outfitting the pedestrian target with an ANSI Class 3 ensemble affect the performance of the evaluated PAEB systems during both day and night testing in the same scenario?	27
VIII. Key Findings	30
IX. Recommendations	30
X. References	31
XI. Approvals	32



I. INTRODUCTION

Pedestrian safety remains a critical concern in the United States. Preliminary data from the State Highway Safety Offices of all U.S. states suggests that in 2023 an estimated 7,318 pedestrians were killed in motor vehicle crashes. This is a 5.4% decrease from the 7,737 pedestrian fatalities reported in 2022. However, this figure is still 14.1% higher than the 6,412 pedestrian deaths recorded in 2019. A significant proportion of these fatalities occur under low-light conditions. Specifically, approximately 77% of pedestrian deaths happened at night in 2023 [3]. Early data for the first half of 2024 indicates 3,304 pedestrian fatalities, a 2.6% decrease compared to the same period in 2023. This is still 12% higher than in 2019 and 48% higher than in 2014 [4]. For reference, the U. S. population only increased about 7% from 2014 to 2024 [5].

In 2019, AAA conducted a comprehensive evaluation of PAEB systems across various scenarios, including daytime and nighttime conditions. The study revealed that while some systems performed adequately during daylight, their effectiveness plummeted in low-light environments. The research found the evaluated pedestrian detection systems to be completely ineffective during nighttime conditions, rendering them unreliable when needed most.

Since that time, there have been advancements in sensor technology and processing algorithms, potentially enhancing the performance of PAEB systems. However, questions remain regarding their effectiveness under challenging real-world conditions, such as low-light environments and scenarios involving pedestrians wearing high-visibility clothing. Recent research suggests that reflective clothing may confound ADAS systems, potentially reducing their effectiveness [2].

To assess the current state of PAEB technology, AAA conducted primary research in a closed-course environment, evaluating the performance of 2024 and 2025 model year vehicles equipped with PAEB systems. The study focused on a perpendicular crossing scenario at 40 kph, utilizing a 4active articulating adult pedestrian target dressed in both its standard clothing and an ANSI Class 3 high-visibility clothing ensemble. Tests were conducted during both daytime and nighttime conditions, with procedures designed to mirror those from the 2019 evaluation.

The primary objectives of this research are to determine how the nighttime pedestrian detection performance of the evaluated PAEB systems has changed since 2019 and to assess the impact of ANSI Class 3 clothing on system effectiveness during both day and night testing. The following report presents the study methodology, detailed results, key findings, and recommendations based on the evaluation of these systems under varied lighting and pedestrian apparel conditions.



Figure 1. PAEB can save lives. Image Source: AAA

II. BACKGROUND

PAEB systems are a subset of ADAS intended to reduce the frequency and severity of vehicle-to-pedestrian collisions. These systems employ a variety of sensors, often cameras and radar, to identify pedestrians in the vehicle's path and automatically apply braking when a collision is imminent.

The proliferation of ADAS features has increased substantially over the past decade. PAEB is now standard or widely available on many new vehicles sold in the United States. Early evaluations, including AAA's 2019 study, found that while some PAEB systems performed adequately in controlled daylight testing, their effectiveness diminished sharply at night. Specifically, none of the vehicles tested in 2019 detected or avoided a pedestrian target under nighttime conditions.

Since then, manufacturers have introduced hardware and software improvements aimed at enhancing detection performance, particularly in low-light scenarios. Regulators and consumer safety organizations, such as the National Highway Traffic Safety Administration (NHTSA) and the Insurance Institute for Highway Safety (IIHS), have also placed increased emphasis on pedestrian protection in their assessment protocols.

A growing body of research has explored factors that may influence system performance, including pedestrian movement, position, and clothing. Recent work by the Highway Loss Data Institute (HLDI) of IIHS has highlighted a potential limitation: high-visibility clothing, while designed to increase pedestrian conspicuity for human drivers, may in some cases reduce detectability for automated crash prevention systems. The HLDI study reported that certain PAEB systems were less likely to recognize pedestrians wearing high-visibility clothing, raising questions about the consistency of these systems under real-world conditions [2]. While the HLDI work examined system performance related to high-visibility garments, it did not specifically address ANSI Class 3 clothing.

Although these studies have advanced the field, gaps remain in our understanding of how current-generation PAEB systems perform across a range of pedestrian apparel types, particularly under challenging nighttime



conditions. The present research seeks to build on prior findings by systematically evaluating the detection and response of multiple newer model year vehicles to pedestrian targets dressed in both standard and ANSI Class 3 high-visibility clothing, in both day and night scenarios.

III. VEHICLE SELECTION & PREPARATION

A. ADAS Requirements

Vehicles included in this study were required to be equipped with the manufacturer's latest available PAEB system for the selected vehicle model. Test vehicles were not permitted to be altered in any way and were required to be in good operating condition, free of diagnostic alerts, telltales, or other indications of malfunction at the time of testing. All PAEB systems were evaluated using the default, middle, or next latest sensitivity setting as specified by the manufacturer.

B. Test Vehicle Selection Process

Test vehicles were selected to represent the latest model year versions of the vehicles evaluated in AAA's previous 2019 PAEB study, where available. When the latest model was not available for testing, such as in the case of the Honda Accord, the 2024 model year was selected after confirming with the manufacturer that it was equipped with their most current PAEB system. All selected vehicles were required to be standard production models available for retail sale in the United States. This selection process was designed to enable a direct comparison of PAEB system performance to the baseline established in 2019.

C. Test Vehicles

	Model Year	Automaker	Model	Trim	VIN	Mileage at Testing	Tire Info	Tread Depth	Test Vehicle Weight (lbs)	AEB Fitment	Pedestrian Detection
Test Vehicles	2024	Honda	Accord	LX	1HGCV1F27RA009145	31,626	HANKOOK 225/50/R17	11/32nds	3,682	Std.	☑
	2025	Toyota	Camry	SE	4T1DAACK7SU136084	1,176	HANKOOK 235/45/R18	11/32nds	3,980	Std.	☑
	2025	Chevrolet	Malibu	LT	1G1ZD5ST8SF154352	5,956	GOODYEAR 225/55/R17	10/32nds	3,583	Std.	☑
	2025	Tesla	Model 3	Long Range RWD	5YJ3E1EA3SF993522	1,383	Michelin 235/45/R18	10/32nds	4,306	Std.	☑

Figure 2: Test Vehicle Information at Time of Testing. Image Source: AAA

D. Test Vehicle Preparation

Test vehicles were acquired, inspected, and confirmed to be in good operating condition with no check-engine lights or similar indications of malfunction. Tires were confirmed to be damage free, have adequate tread depth (greater than 7/32"), and be at the manufacturer prescribed pressure.

Prior to testing, each test vehicle, with the exception of the Tesla Model 3, was taken to an appropriate dealership where wheel alignments and ADAS sensor calibrations were performed per manufacturer specification. The Tesla Model 3 was taken for wheel alignments; however, sensor calibrations were not necessary per the manufacturer.

IV. TEST EQUIPMENT AND RESOURCES

A. Data Acquisition Equipment

1) Oxford Technical Solutions (OxTS) RT3000 V3 with RT-Range S Hunter Capabilities

Each vehicle was outfitted with an OxTS RT3000 v3 with RT-Range S Hunter capabilities. This Inertial Navigation System (INS) was utilized to capture vehicle kinematic information, such as position and orientation, and process vehicle-to-target measurements relative to the vehicle under test. The RT3000 units interfaced with a site-installed GPS base station to incorporate real-time kinematics (RTK) technology. The unit's RT-Range capability interfaced with the pedestrian target platform via wireless LAN. All measurements from the unit were captured at a rate of 100 Hz.

Position Accuracy	0.01 m
Velocity Accuracy	0.01 m/s
Roll & Pitch Accuracy	0.03°
Heading Accuracy	0.1°
Slip Angle Accuracy	0.15°
Output Data Rate	100 Hz

Figure 3: OxTS RT3000 specifications. Image Source: AAA

Forward Range	0.03 m RMS
Lateral Range	0.03 m RMS
Resultant Range	0.03 m RMS
Forward Velocity	0.02 m/s RMS
Lateral Velocity	0.02 m/s RMS
Resultant Velocity	0.02 m/s RMS
Resultant Yaw Angle	0.1° RMS
Lateral Distance to Lane	0.02 m RMS

Figure 4: OxTS RT-Range S Hunter specifications. Image Source: AAA

2) Electret Microphone with MAX4466 Amplifier

An Electret microphone, paired with a MAX4466 amplifier, was strategically positioned within each test vehicle to capture the auditory Forward Collision Warning (FCW) events during each test run. Audio signals were recorded at a sampling rate of 20,000 Hz.

Directivity	omnidirectional
Operating Frequency	20 ~ 20,000 Hz
Sensitivity	-44 ±2 dB
Operating Volotage	3 ~ 5.5 V dc
Current Consumption	0.5 mA max.
Signal to Noise Ratio	60 dBA
Power-Supply Rejection Ration	112 dB

Figure 5: Electret Microphone with MAX4466 specifications. Image Source: AAA



3) Futek LAU220 Pedal Force Sensor

Each vehicle was equipped with a brake pedal force sensor to verify that no braking intervention was applied by the test driver during test runs. Brake pedal force was captured at a rate of 100 Hz.

Rated Output (RO)	2mV/V
Nonlinearity	± 0.25% of RO
Hysteresis	± 0.25% of RO
Nonrepeatability	± 0.10% of RO
Off Center Loading	± 1% or better @

Figure 6: Futek LAU220 specifications. Image Source: AAA

4) DEWESoft CAM-120 Cameras with CAM-BOX2 Distribution Box

Test vehicles were equipped with a single camera mounted on the front of the roof, angled forward and downward. The camera was programmed to capture video at a reduced frame rate of 30 Hz to efficiently document and verify impact between the vehicle and the pedestrian target during test runs.

Image Sensor	Sony ICX618
Sensor Type	CCD
FPS	120 FPS @ 640x480
Dynamic Range	32 dB autogain function
Shutter Time	58 ns-60 s (autoshutter function)

Figure 7: DEWESoft CAM-120 specifications. Image Source: AAA

5) DEWESoft CAN-2 Interface

Test vehicles were equipped with a CAN interface to capture data from OxTS instrumentation. Vehicle kinematics and range data were captured at a rate of 100 Hz and time-synced with pedal force, FCW audio, and video.

6) Data Logging Equipment

Test vehicles were equipped with a DEWESoft SIRIUS® data logger to log pedal force measurements and FCW audio signals at a rate of 100 Hz and 20,000 Hz, respectively. Each data logger was equipped with anti-aliasing filters to attenuate frequencies above the Nyquist frequency.

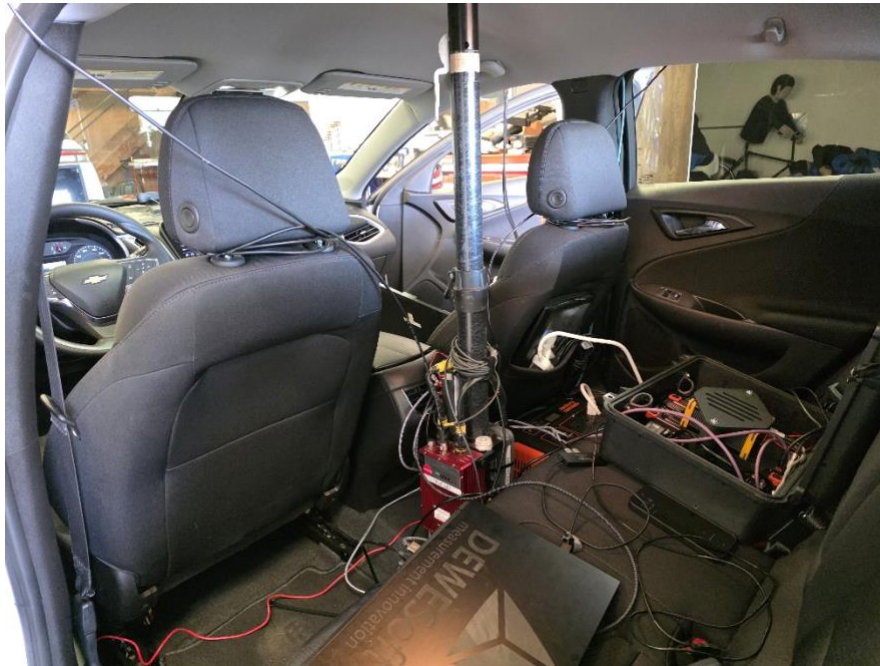


Figure 8: OxTS RT3000 V3 IMU and DEWESoft Data Logger in Vehicle. Image Source: AAA

B. Test Target Equipment

1) ABD LaunchPad™ 80 (LP80)

The LP80 is a hardened, satellite guided, self-propelled, low-profile vehicle, which serves as a dynamic platform for various testing targets. The LP80 has a top speed of 80 km/h and a maximum deceleration rate of 0.6 G. The positions of the vehicle under test and the LP80 are measured continually using differential GPS with RTK correction. Kinematic data relating to the vehicle under test is broadcast to the LP80 via wireless LAN. This information allows the LP80 to arrive at predefined locations relative to the vehicle under test in a repeatable manner.

Additionally, data from the LP80 was processed by the RT3000 to calculate LP80 kinematics relative to the vehicle under test.

Longitudinal Acceleration	+0.3 g, -0.6 g
Path Following Accuracy	0.05 m
Position Measurement Accuracy	0.02 m

Figure 9: ABD LaunchPad™ 80 specifications. Image Source: AAA



Figure 10: ABD LP80™ with 4activePA-adult Articulating Pedestrian Target in ANSI Class 3 Attire.

Image Source: AAA

2) 4activePA-adult Articulating Pedestrian Target

The articulating adult pedestrian target is designed to be representative of a typical 50th percentile adult male and is intended for use in either dynamic or static test scenarios. The body height and width are 71 inches and 20 inches, respectively. As the adult pedestrian target was dynamic throughout the entirety of the test scenario, it was positioned atop the LP80 platform to maintain upright stability during motion, resulting in a total height increase of approximately 3 inches.

C. Test Facility

All closed-course testing was conducted on roadways specifically designed for standardized ADAS testing on the grounds of Minter Field Airport in Shafter, California.

All test scenarios were conducted on a vehicle dynamics pad comprised of dry asphalt free of visible moisture. The surface was straight and flat, free of potholes and other irregularities that could cause significant variations in the trajectory of the test vehicles or target.



Figure 11. Aerial view of test track used for PAEB evaluation. Image Source: Dynamic Research Inc.

V. INQUIRY #1: HOW HAS NIGHTTIME PEDESTRIAN DETECTION PERFORMANCE OF THE EVALUATED PAEB SYSTEMS CHANGED COMPARED TO SIMILAR TESTS CONDUCTED IN 2019?

A. Objective

To determine whether the performance of PAEB systems in detecting and responding to an adult pedestrian crossing the path of the vehicle at night has improved since AAA's 2019 PAEB evaluation.

B. Methodology

Each test vehicle was evaluated on a closed course under controlled nighttime conditions, using the same test scenario as the 2019 baseline study. The vehicle was driven at a constant speed of 40 km/h (25 mph) along a straight, dry asphalt roadway. All test runs were conducted with the vehicle's low-beam headlights activated and no overhead street lighting present. The test scenario is illustrated in Figure 10.

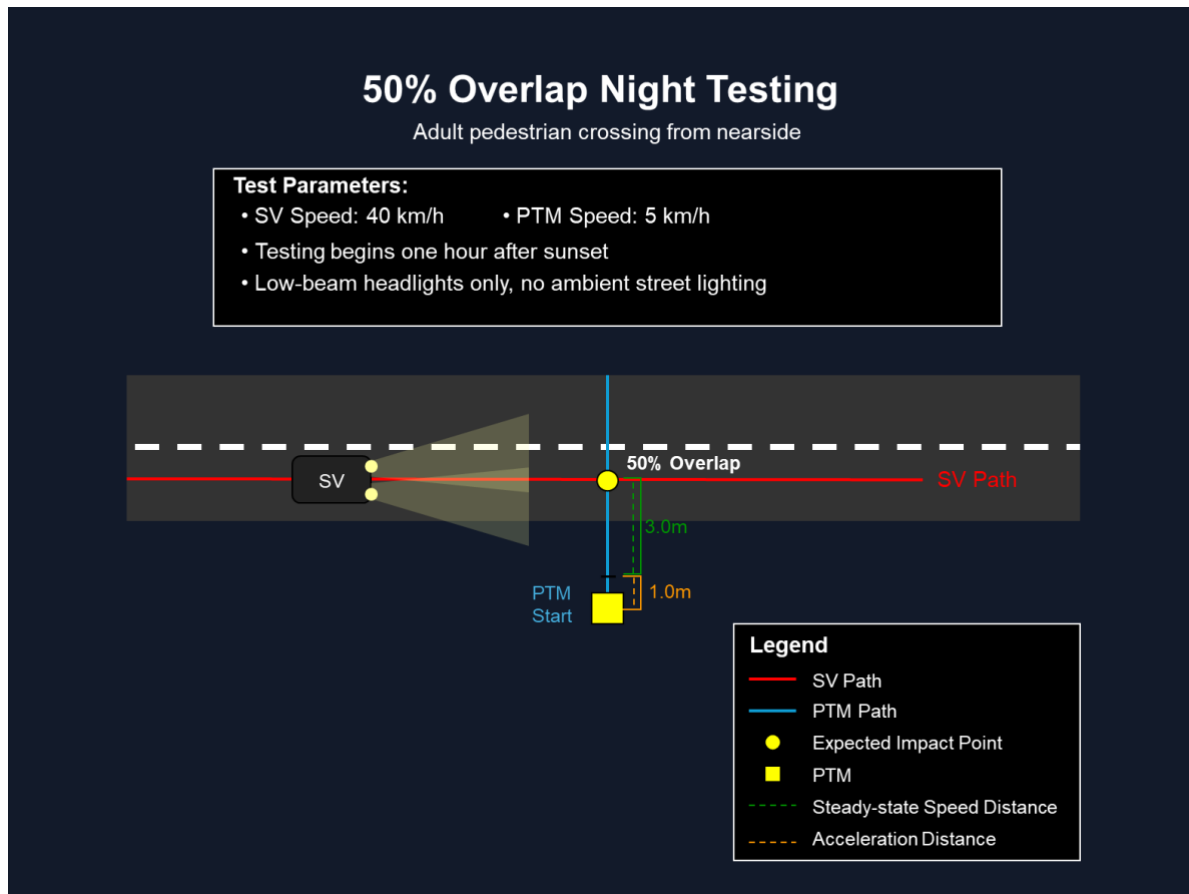


Figure 12: Testing Scenario Illustration. Image Source: AAA

An articulating adult pedestrian target dressed in its standard non-reflective clothing was positioned on a robotic platform and programmed to cross perpendicularly in front of the vehicle at a walking speed of 5 km/h (3.1 mph). The pedestrian target began its motion 4 meters from the centerline of the vehicle path, with a 1-meter acceleration phase followed by 3 meters at steady-state speed. The pedestrian's entry was timed such that, in the absence of a FCW or PAEB intervention, a collision would occur at 50% overlap between the center of the vehicle's front bumper and the centerline of the pedestrian.

Test tolerances were established as follows:

- Vehicle Speed: ± 1.6 km/h (± 1.0 mph) of the nominal test speed
- Vehicle Lateral Position: ± 0.3 meters (± 1.0 foot) of the lane centerline
- Vehicle Yaw Rate: ± 1.0 degree per second
- Pedestrian Speed: ± 0.4 km/h (± 0.25 mph) of the nominal crossing speed
- Pedestrian Path: ± 0.1 meter (± 0.33 foot) of the intended crossing path

Any test run in which the vehicle or pedestrian target deviated outside of these tolerances within a five second Time-to-Collision (TTC) was deemed invalid and repeated.

During each run, the driver maintained steady throttle application until the FCW alert was issued. The accelerator pedal was then released within 0.5 seconds to simulate a typical driver reaction, with no further



braking or steering intervention provided. Each test vehicle was subjected to a minimum of five valid runs. Metrics recorded included the presence and timing of FCW and PAEB activation, collision avoidance or mitigation outcome, and vehicle speed at the time of intervention or impact. Results were compared to those from AAA's 2019 evaluation to assess changes in nighttime pedestrian detection performance.

C. Test Results

1) Honda Accord

Vehicle	Test Scenario	Run No.	Forward Collision Warning			Automatic Braking			Impact		Min Dist (m)	Peak Decel (g)
			Alert?	Distance (m)	TTC (s)	Applied?	Distance (m)	TTC (s)	Impact?	Speed (km/h)		
2019 Honda Accord	50% Overlap, Night, Low Beams	Run1	N	N/A	N/A	N	N/A	N/A	Y	39.2	0	N/A
		Run2	N	N/A	N/A	N	N/A	N/A	Y	39.2	0	N/A
		Run3	N	N/A	N/A	N	N/A	N/A	Y	39.68	0	N/A
		Run4	N	N/A	N/A	N	N/A	N/A	Y	39.36	0	N/A
2024 Honda Accord	50% Overlap, Night, Low Beams	Run1	N	N/A	N/A	N	N/A	N/A	Y	40.21	0	N/A
		Run2	Y	6.92	0.62	Y	5.92	0.53	Y	17.54	0	1
		Run3	Y	10.58	0.92	Y	8.86	0.77	N	N/A	1.13	1.03
		Run4	N	N/A	N/A	N	N/A	N/A	Y	39.6	0	N/A
		Run5	Y	10.88	0.98	Y	9.88	0.9	N	N/A	1.36	1.02

Figure 13: 2019 vs 2024 Honda Accord run-level results. Image Source: AAA

In 2019, the Honda Accord failed to detect or respond to the adult pedestrian target under nighttime conditions. No FCW or PAEB activation was observed in any run, and a collision occurred in all cases at full test speed.

By contrast, the 2024 Honda Accord demonstrated marked improvements. In three out of five runs, the system issued a FCW and applied automatic braking. In two of these runs (Runs 3 and 5), the Accord was successful in avoiding impact with the pedestrian target. Minimum distances to the target were 1.13 and 1.36 meters, respectively. In one additional run (Run 2), the system intervened but was unable to prevent contact; however, the impact speed was reduced to 17.5 km/h compared to the initial test speed of approximately 40 km/h. In the remaining two runs, the system did not provide any warning or intervention, resulting in impacts at full speed.

Overall, these results indicate that the 2024 Honda Accord PAEB system offers improved pedestrian detection and mitigation capability at night relative to the 2019 model. However, the system did not respond in all cases, and occasional failures to alert or intervene were still observed.



2) Toyota Camry

Vehicle	Test Scenario	Run No.	Forward Collision Warning			Automatic Braking			Impact		Min Dist (m)	Peak Decel (g)
			Alert?	Distance (m)	TTC (s)	Applied?	Distance (m)	TTC (s)	Impact?	Speed (km/h)		
2019 Toyota Camry	50% Overlap, Night, Low Beams	Run1	N	N/A	N/A	N	N/A	N/A	Y	38.56	0	N/A
		Run2	N	N/A	N/A	N	N/A	N/A	Y	40.48	0	N/A
		Run3	N	N/A	N/A	N	N/A	N/A	Y	38.4	0	N/A
		Run4	N	N/A	N/A	N	N/A	N/A	Y	39.52	0	N/A
2025 Toyota Camry	50% Overlap, Night, Low Beams	Run1	Y	21.73	1.96	Y	12.81	1.19	N	N/A	1.51	0.96
		Run2	Y	23.77	2.19	Y	11.99	1.15	N	N/A	1.57	0.83
		Run3	Y	21.15	1.91	Y	12.80	1.20	N	N/A	1.44	1.03
		Run4	Y	23.14	2.14	Y	14.47	1.38	N	N/A	2.13	0.95
		Run5	Y	21.53	1.94	Y	13.03	1.21	N	N/A	1.79	1.00

Figure 14: 2019 vs 2025 Toyota Camry run-level results. Image Source: AAA

In 2019, the Toyota Camry did not provide any FCW or PAEB in response to the pedestrian target under nighttime conditions. All four test runs resulted in impacts at full test speed.

The 2025 Toyota Camry demonstrated substantial improvement. In all five runs, the system issued a FCW at an average distance of approximately 22.26 meters (TTC $\approx$ 2.03 s) and applied automatic braking at an average distance of 13.02 meters (TTC $\approx$ 1.23 s) from the pedestrian target. No collisions occurred in any run. The minimum distance to the pedestrian ranged from 1.44 to 2.13 meters, with peak deceleration values between 0.83 and 1.03 g.

These results indicate that the 2025 Camry's PAEB system successfully detected, warned, and intervened to avoid pedestrian collisions in all test runs under nighttime conditions—a notable advancement compared to the 2019 model year.

3) Chevrolet Malibu

Vehicle	Test Scenario	Run No.	Forward Collision Warning			Automatic Braking			Impact		Min Dist (m)	Peak Decel (g)
			Alert?	Distance (m)	TTC (s)	Applied?	Distance (m)	TTC (s)	Impact?	Speed (km/h)		
2019 Chevrolet Malibu	50% Overlap, Night, Low Beams	Run1	N	N/A	N/A	N	N/A	N/A	Y	39.2	0	N/A
		Run2	N	N/A	N/A	N	N/A	N/A	Y	39.2	0	N/A
		Run3	N	N/A	N/A	N	N/A	N/A	Y	39.36	0	N/A
		Run4	N	N/A	N/A	N	N/A	N/A	Y	39.52	0	N/A
2025 Chevrolet Malibu	50% Overlap, Night, Low Beams	Run1	Y	9.04	0.81	Y	7.01	0.63	Y	11.32	0.00	1.02
		Run2	Y	10.58	0.96	Y	8.81	0.80	Y	34.83	0.00	0.69
		Run3	Y	14.52	1.29	Y	8.88	0.79	N	N/A	1.23	1.03
		Run4	Y	9.10	0.82	Y	6.97	0.63	Y	21.1	0.00	0.91
		Run5	N	N/A	N/A	N	N/A	N/A	Y	39.23	0.00	N/A

Figure 15: 2019 vs 2025 Chevrolet Malibu run-level results. Image Source: AAA



In 2019, the Chevrolet Malibu did not provide any FCW or PAEB in response to the pedestrian target under nighttime conditions. All test runs resulted in collision with the target at full test speed.

The 2025 Chevrolet Malibu demonstrated improvement. In four out of five runs, the system issued a FCW and applied automatic braking. In one run (Run 3), impact was successfully avoided, with a minimum distance to the pedestrian of 1.23 meters and a peak deceleration of 1.03 g. In three of the runs (Runs 1, 2, and 4), the system intervened but was unable to prevent contact; however, the impact speed was reduced in each case, with the lowest recorded at 11.3 km/h (Run 1). In Run 5, the system did not provide any warning or intervention, and a collision occurred at full test speed.

These results indicate that, while the 2025 Malibu's PAEB system is capable of detecting and responding to nighttime pedestrian crossings in some cases, its performance was inconsistent and did not reliably prevent impacts across all test runs. Some improvement over the 2019 model was observed, particularly in speed reduction and one instance of impact avoidance.

4) Tesla Model 3

Vehicle	Test Scenario	Run No.	Forward Collision Warning			Automatic Braking			Impact		Min Dist (m)	Peak Decel (g)
			Alert?	Distance (m)	TTC (s)	Applied?	Distance (m)	TTC (s)	Impact?	Speed (km/h)		
2019 Tesla Model 3	50% Overlap, Night, Low Beams	Run1	N	N/A	N/A	N	N/A	N/A	Y	39.36	0	N/A
		Run2	N	N/A	N/A	N	N/A	N/A	Y	39.2	0	N/A
		Run3	N	N/A	N/A	N	N/A	N/A	Y	40	0	N/A
		Run4	N	N/A	N/A	N	N/A	N/A	Y	39.36	0	N/A
2025 Tesla Model 3	50% Overlap, Night, Low Beams	Run1	Y	25.81	2.33	Y	2.54	0.32	N	N/A	0.46	1.03
		Run2	Y	25.07	2.22	Y	3.97	0.46	N	N/A	0.26	1.02
		Run3	Y	27.92	2.46	Y	2.38	0.31	N	N/A	0.34	1.04
		Run4	Y	23.86	2.1	Y	3.65	0.41	N	N/A	0.29	1.05
		Run5	Y	24.9	2.19	Y	3.63	0.41	Y	14.02	0	1.03

Figure 16: 2019 vs 2025 Tesla Model 3 run-level results. Image Source: AAA

In 2019, the Tesla Model 3 did not provide any FCW or PAEB in response to the pedestrian target during nighttime testing. All test runs resulted in impacts with the pedestrian at or near the nominal test speed.

The 2025 Tesla Model 3 showed notable improvement. In all five runs, the system issued a FCW at an average distance of approximately 25.51 meters (TTC $\approx$ 2.26 s) and applied automatic braking at an average distance of 3.23 meters (TTC $\approx$ 0.38 s) from the target. In four runs, the system successfully avoided contact, with minimum distances to the pedestrian ranging from 0.26 to 0.46 meters and peak deceleration between 1.02 and 1.05 g. One run (Run 5) resulted in an impact, but the impact speed was reduced to 14.0 km/h.

These results indicate a substantial improvement in nighttime pedestrian detection and automatic braking performance for the Tesla Model 3 between 2019 and 2025. The updated system was generally effective in avoiding collisions or significantly reducing impact speed under the test conditions.



VI. INQUIRY #2: HOW DOES OUTFITTING THE PEDESTRIAN TARGET WITH AN ANSI CLASS 3 ENSEMBLE AFFECT THE PERFORMANCE OF THE EVALUATED PAEB SYSTEMS DURING BOTH DAY AND NIGHT TESTING IN THE SAME SCENARIO?

A. Objective

To evaluate the effect of an ANSI Class 3 high-visibility clothing ensemble on the ability of PAEB systems to detect and respond to an adult pedestrian crossing the travel path, under both daytime and nighttime conditions.

B. Methodology

Each test vehicle was evaluated on a closed-course under controlled daytime and nighttime conditions, using the same perpendicular crossing scenario as described in Inquiry #1. For daytime testing, runs were conducted under full daylight with clear visibility and no precipitation. Nighttime testing began approximately one hour after sunset, with all runs performed using the vehicle's low beam headlights and no ambient street lighting. The test scenario is illustrated in Figure 10.

An articulated adult pedestrian target was positioned on a robotic platform and programmed to cross perpendicularly in front of the vehicle at a walking speed of 5 km/h (3.1 mph). The pedestrian target began its motion 4 meters from the centerline of the vehicle path, with a 1-meter acceleration phase followed by 3 meters at steady-state speed. The pedestrian's entry was timed such that, in the absence of FCW or PAEB intervention, a collision would occur at 50% overlap between the center of the vehicle's front bumper and the centerline of the pedestrian.

For each lighting condition (day and night), test runs were first completed with the pedestrian target dressed in standard non-reflective clothing (baseline). The procedure was then repeated with the pedestrian target outfitted in an ANSI Class 3 high-visibility shirt and pants. The nighttime baseline results with standard clothing also served as the reference condition for Inquiry #1.

Test tolerances were established as follows:

- Vehicle Speed: ± 1.6 km/h (± 1.0 mph) of the nominal test speed
- Vehicle Lateral Position: ± 0.3 meters (± 1.0 foot) of the lane centerline
- Vehicle Yaw Rate: ± 1.0 degree per second
- Pedestrian Speed: ± 0.4 km/h (± 0.25 mph) of the nominal crossing speed
- Pedestrian Path: ± 0.1 meter (± 0.33 foot) of the intended crossing path

Any test run in which the vehicle or pedestrian target deviated outside of these tolerances within a five second Time-to-Collision (TTC) was deemed invalid and repeated.

During each test run, the driver maintained steady throttle application until the FCW alert was issued. The accelerator pedal was then released within 0.5 seconds to simulate a typical driver reaction, with no further braking or steering intervention provided. Each test vehicle was subjected to a minimum of five valid runs per condition (baseline and ANSI, day and night).

Metrics recorded included the presence and timing of FCW and PAEB activation, collision avoidance or mitigation outcome, minimum distance to the pedestrian target, and vehicle speed at the time of intervention



or impact. Results were compared across baseline and ANSI Class 3 conditions under both day and night scenarios to assess the influence of high-visibility apparel on system performance



Figure 17: Test Vehicle and Target Zero Position Check on Test Track. Image Source: AAA

C. Test Results

1) Honda Accord

a) Daytime Results

Vehicle	Test Scenario	Run No.	Forward Collision Warning			Automatic Braking			Impact		Min Dist (m)	Peak Decel (g)
			Alert?	Distance (m)	TTC (s)	Applied?	Distance (m)	TTC (s)	Impact?	Speed (km/h)		
2024 Honda Accord	50% Overlap, Day, Standard Clothing	Run1	Y	18.36	1.63	Y	11.73	1.05	N	N/A	2.94	0.84
		Run2	Y	18.23	1.62	Y	11.38	1.03	N	N/A	2.62	0.86
		Run3	Y	17.29	1.55	Y	11.16	1.01	N	N/A	2.41	0.87
		Run4	Y	18.44	1.66	Y	11.44	1.04	N	N/A	2.66	0.87
		Run5	Y	17.5	1.58	Y	11.52	1.05	N	N/A	2.80	0.91
2024 Honda Accord	50% Overlap, Day, Hi-Vis Clothing	Run1	Y	18.15	1.64	Y	11.41	1.04	N	N/A	2.90	0.83
		Run2	Y	18.16	1.6	Y	11.46	1.04	N	N/A	3.07	0.87
		Run3	Y	17.23	1.55	Y	11.55	1.05	N	N/A	2.83	0.87
		Run4	Y	17.94	1.61	Y	11.48	1.05	N	N/A	2.81	0.85
		Run5	Y	17.29	1.55	Y	11.71	1.06	N	N/A	2.89	0.86

Figure 18: Standard Clothing vs High-Vis Clothing 2024 Honda Accord—Daytime. Image Source: AAA



In daytime testing with the pedestrian target in standard non-reflective clothing, the Accord provided FCW and PAEB in all five runs. FCW activation occurred between 17.5 and 18.4 meters, and AEB was applied between 11.1 and 11.7 meters. No impacts occurred, and minimum distances to the target ranged from 2.41 to 2.94 meters. Peak deceleration values were up to 0.91 g.

With the pedestrian target dressed in ANSI Class 3 high-visibility clothing, the system's performance was similar. FCW and AEB were observed in all runs, with activation distances between 17.3 and 18.2 meters for FCW and 11.4 to 11.7 meters for AEB. No impacts were recorded. Minimum distances ranged from 2.81 to 3.07 meters, with peak deceleration values up to 0.87 g.

b) Nighttime Results

Vehicle	Test Scenario	Run No.	Forward Collision Warning			Automatic Braking			Impact		Min Dist (m)	Peak Decel (g)
			Alert?	Distance (m)	TTC (s)	Applied?	Distance (m)	TTC (s)	Impact?	Speed (km/h)		
2024 Honda Accord	50% Overlap, Night, Standard Clothing	Run1	N	N/A	N/A	N	N/A	N/A	Y	40.21	0	N/A
		Run2	Y	6.92	0.62	Y	5.92	0.53	Y	17.54	0	1
		Run3	Y	10.58	0.92	Y	8.86	0.77	N	N/A	1.13	1.03
		Run4	N	N/A	N/A	N	N/A	N/A	Y	39.6	0	N/A
		Run5	Y	10.88	0.98	Y	9.88	0.9	N	N/A	1.36	1.02
2024 Honda Accord	50% Overlap, Night, Hi-Vis Clothing	Run1	N	N/A	N/A	N	N/A	N/A	Y	40.57	0	N/A
		Run2	N	N/A	N/A	N	N/A	N/A	Y	40.14	0	N/A
		Run3	N	N/A	N/A	N	N/A	N/A	Y	39.87	0	N/A
		Run4	N	N/A	N/A	N	N/A	N/A	Y	40.54	0	N/A
		Run5	N	N/A	N/A	N	N/A	N/A	Y	40.90	0	N/A

Figure 19: Standard Clothing vs High-Vis Clothing 2024 Honda Accord—Nighttime. Image Source: AAA

At night, the Accord's system performance declined. With standard clothing, the system did not provide FCW or AEB in two runs, both of which resulted in impacts at full test speed. In the other three runs, FCW and AEB were triggered; two impacts were avoided (minimum distances of 1.13 and 1.36 meters), and one impact was mitigated (impact speed reduced to 17.5 km/h). Peak deceleration exceeded 1 g in successful avoidance runs.

With the pedestrian target in ANSI Class 3 high-visibility clothing, no FCW or AEB activation was observed in any run, and all five runs resulted in impacts at full test speed



2) Toyota Camry

a) Daytime Results

Vehicle	Test Scenario	Run No.	Forward Collision Warning			Automatic Braking			Impact		Min Dist (m)	Peak Decel (g)
			Alert?	Distance (m)	TTC (s)	Applied?	Distance (m)	TTC (s)	Impact?	Speed (km/h)		
2025 Toyota Camry	50% Overlap, Day, Standard Clothing	Run1	Y	19.99	1.83	Y	12.33	1.16	N	N/A	1.38	0.82
		Run2	Y	23.29	2.13	Y	12.13	1.17	N	N/A	1.73	0.89
		Run3	Y	22.01	1.97	Y	12.68	1.18	N	N/A	1.59	1.01
		Run4	Y	22.51	2.07	Y	12.01	1.15	N	N/A	1.86	0.99
		Run5	Y	22.35	2.03	Y	12.34	1.17	N	N/A	1.88	0.84
2025 Toyota Camry	50% Overlap, Day, Hi-Vis Clothing	Run1	Y	22.29	2.00	Y	12.80	1.19	N	N/A	1.62	0.86
		Run2	Y	23.89	2.17	Y	12.65	1.19	N	N/A	1.67	1.02
		Run3	Y	23.71	2.11	Y	12.68	1.17	N	N/A	1.58	1.04
		Run4	Y	21.98	1.96	Y	13.20	1.21	N	N/A	1.73	0.91
		Run5	Y	23.78	2.18	Y	12.99	1.21	N	N/A	1.54	0.97

Figure 20: Standard Clothing vs High-Vis Clothing 2025 Toyota Camry—Daytime. Image Source: AAA

During daytime testing with the pedestrian target in standard non-reflective clothing, the Toyota Camry issued a FCW and applied PAEB in all five runs. FCW activation occurred between 19.99 and 23.29 meters (TTC: 1.83–2.13 s), and AEB was applied at 12.01 to 12.68 meters (TTC: 1.15–1.18 s). No impacts occurred. Minimum distances to the target ranged from 1.38 to 1.88 meters, with peak deceleration values up to 1.01 g.

With the pedestrian target outfitted in ANSI Class 3 high-visibility clothing, system performance was consistent across all runs. FCW was provided at 21.98 to 23.89 meters (TTC: 1.96–2.18 s), and AEB was applied at distances between 12.65 and 13.20 meters (TTC: 1.17–1.21 s). No impacts were observed. Minimum distances ranged from 1.54 to 1.73 meters, and peak deceleration values reached up to 1.04 g.

b) Nighttime Results

Vehicle	Test Scenario	Run No.	Forward Collision Warning			Automatic Braking			Impact		Min Dist (m)	Peak Decel (g)
			Alert?	Distance (m)	TTC (s)	Applied?	Distance (m)	TTC (s)	Impact?	Speed (km/h)		
2025 Toyota Camry	50% Overlap, Night, Standard Clothing	Run1	Y	21.73	1.96	Y	12.81	1.19	N	N/A	1.51	0.96
		Run2	Y	23.77	2.19	Y	11.99	1.15	N	N/A	1.57	0.83
		Run3	Y	21.15	1.91	Y	12.80	1.20	N	N/A	1.44	1.03
		Run4	Y	23.14	2.14	Y	14.47	1.38	N	N/A	2.13	0.95
		Run5	Y	21.53	1.94	Y	13.03	1.21	N	N/A	1.79	1.00
2025 Toyota Camry	50% Overlap, Night, Hi-Vis Clothing	Run1	Y	19.68	1.77	Y	13.04	1.19	N	N/A	1.33	0.77
		Run2	Y	23.85	2.16	Y	13.47	1.23	N	N/A	1.68	1.06
		Run3	Y	24.23	2.15	Y	12.53	1.15	N	N/A	1.59	0.84
		Run4	Y	22.38	2.03	Y	12.53	1.17	N	N/A	1.63	0.96
		Run5	Y	19.56	1.73	Y	13.50	1.22	N	N/A	1.39	0.91

Figure 21: Standard Clothing vs High-Vis Clothing 2025 Toyota Camry—Nighttime. Image Source: AAA

During nighttime testing with the pedestrian target in standard non-reflective clothing, the Toyota Camry provided FCW and PAEB in all five runs. FCW activation distances ranged from 21.15 to 23.77 meters (TTC: 1.91–2.19 s), and AEB activation occurred between 11.99 and 14.47 meters (TTC: 1.15–1.38 s). No impacts were observed. Minimum separation distances to the target ranged from 1.44 to 2.13 meters, and peak deceleration values reached up to 1.03 g.



With the pedestrian target dressed in ANSI Class 3 high-visibility clothing, the system's performance remained consistent. FCW was issued at 19.56 to 24.23 meters (TTC: 1.73–2.16 s), and AEB was applied at distances between 12.53 and 13.50 meters (TTC: 1.15–1.23 s). No impacts were recorded in any run. Minimum separation distances ranged from 1.33 to 1.68 meters, and peak deceleration values reached up to 1.06 g.

3) Chevrolet Malibu

a) Daytime Results

Vehicle	Test Scenario	Run No.	Forward Collision Warning			Automatic Braking			Impact		Min Dist (m)	Peak Decel (g)
			Alert?	Distance (m)	TTC (s)	Applied?	Distance (m)	TTC (s)	Impact?	Speed (km/h)		
2025 Chevrolet Malibu	50% Overlap, Day, Standard Clothing	Run1	Y	17.47	1.77	Y	9.35	0.85	N	N/A	2.01	1.03
		Run2	Y	17.53	1.61	Y	10.03	0.93	N	N/A	2.95	1.03
		Run3	Y	20.02	1.96	Y	10.79	0.97	N	N/A	3.41	1.05
		Run4	Y	18.90	1.72	Y	10.35	0.95	N	N/A	3.31	1.05
		Run5	Y	18.63	1.70	Y	11.52	1.06	N	N/A	4.51	1.02
2025 Chevrolet Malibu	50% Overlap, Day, Hi-Vis Clothing	Run1	Y	20.08	1.80	Y	10.12	0.91	N	N/A	2.17	1.02
		Run2	Y	23.23	2.08	Y	10.68	0.97	N	N/A	3.05	1.01
		Run3	Y	21.73	2.01	Y	9.35	0.88	N	N/A	2.41	1.02
		Run4	Y	21.95	2.01	Y	9.78	0.91	N	N/A	2.64	0.99
		Run5	Y	18.82	1.73	Y	10.32	0.95	N	N/A	2.97	1.02

Figure 22: Standard Clothing vs High-Vis Clothing 2025 Chevrolet Malibu—Daytime. Image Source: AAA

During daytime testing with the pedestrian target in standard non-reflective clothing, the Chevrolet Malibu issued a FCW and applied PAEB in all five runs. FCW activation distances ranged from 17.47 to 20.02 meters (TTC: 1.61–1.96 s), and AEB activation occurred between 9.35 and 11.52 meters (TTC: 0.85–1.06 s). No impacts were observed. Minimum separation distances ranged from 2.01 to 4.51 meters, and peak deceleration values reached up to 1.05 g.

With the pedestrian target outfitted in ANSI Class 3 high-visibility clothing, system performance remained consistent. FCW was provided at 18.82 to 23.23 meters (TTC: 1.73–2.08 s), and AEB was applied at distances between 9.35 and 10.68 meters (TTC: 0.88–0.97 s). No impacts were recorded. Minimum distances ranged from 2.17 to 3.05 meters, and peak deceleration values were up to 1.02 g.

b) Nighttime Results

Vehicle	Test Scenario	Run No.	Forward Collision Warning			Automatic Braking			Impact		Min Dist (m)	Peak Decel (g)
			Alert?	Distance (m)	TTC (s)	Applied?	Distance (m)	TTC (s)	Impact?	Speed (km/h)		
2025 Chevrolet Malibu	50% Overlap, Night, Standard Clothing	Run1	Y	9.04	0.81	Y	7.01	0.63	Y	11.32	0	1.02
		Run2	Y	10.58	0.96	Y	8.81	0.8	Y	34.83	0	0.69
		Run3	Y	14.52	1.29	Y	8.88	0.79	N	N/A	1.23	1.03
		Run4	Y	9.1	0.82	Y	6.97	0.63	Y	21.1	0	0.91
		Run5	N	N/A	N/A	N	N/A	N/A	Y	39.23	0	N/A
2025 Chevrolet Malibu	50% Overlap, Night, Hi-Vis Clothing	Run1	Y	10.93	0.98	Y	7.79	0.71	N	N/A	0.36	1.02
		Run2	Y	11.84	1.09	Y	9.22	0.85	N	N/A	1.56	1.02
		Run3	Y	14.71	1.36	Y	7.89	0.74	N	N/A	0.95	1.05
		Run4	Y	15.82	1.43	Y	6.47	0.59	Y	32.65	0.00	0.66
		Run5	Y	18.12	1.63	Y	6.09	0.56	Y	16.50	0.00	1.12

Figure 23: Standard Clothing vs High-Vis Clothing 2025 Chevrolet Malibu—Nighttime. Image Source: AAA

During nighttime testing with the pedestrian target in standard non-reflective clothing, the Chevrolet Malibu issued a FCW and applied PAEB in four out of five runs. FCW activation distances ranged from 9.04 to 14.52 meters (TTC: 0.81–1.29 s), and AEB activation occurred between 6.97 and 8.88 meters (TTC: 0.63–0.80 s). Impact was avoided in only one run, with a minimum distance to the target of 1.23 meters. In the remaining runs, impacts occurred at speeds ranging from 11.32 to 39.23 km/h. Peak deceleration values reached up to 1.03 g.

With the pedestrian target in ANSI Class 3 high-visibility clothing, FCW and AEB were provided in all runs. Activation distances for FCW ranged from 10.93 to 18.12 meters (TTC: 0.98–1.63 s), and for AEB from 6.09 to 9.22 meters (TTC: 0.56–0.85 s). Impact was avoided in three runs, with minimum separation distances between 0.36 and 1.56 meters. Two runs resulted in impacts at 32.65 and 16.50 km/h. Peak deceleration values reached up to 1.12 g.

4) Tesla Model 3

a) Daytime Results

Vehicle	Test Scenario	Run No.	Forward Collision Warning			Automatic Braking			Impact		Min Dist (m)	Peak Decel (g)
			Alert?	Distance (m)	TTC (s)	Applied?	Distance (m)	TTC (s)	Impact?	Speed (km/h)		
2025 Tesla Model 3	50% Overlap, Day, Standard Clothing	Run1	Y	27.07	2.37	N	N/A	N/A	N	N/A	0.14	0.2
		Run2	Y	26.08	2.39	N	N/A	N/A	N	N/A	0.21	0.2
		Run3	Y	25.46	2.35	N	N/A	N/A	N	N/A	0.22	0.2
		Run4	Y	23.83	2.17	N	N/A	N/A	Y	26.19	0	0.2
		Run5	Y	23.76	2.2	N	N/A	N/A	Y	25.73	0	0.2
2025 Tesla Model 3	50% Overlap, Day, Hi-Vis Clothing	Run1	Y	21.32	1.94	Y	3.74	0.43	N	N/A	0.1	0.99
		Run2	Y	20.64	1.85	Y	4.74	0.5	Y	11.93	0	0.99
		Run3	Y	24.26	2.21	Y	3.44	0.41	N	N/A	0.05	0.97
		Run4	Y	25.29	2.25	Y	2.54	0.32	N	N/A	0.07	0.97
		Run5	Y	24.49	2.23	Y	3.05	0.38	N	N/A	0.04	0.98

Figure 24: Standard Clothing vs High-Vis Clothing 2025 Tesla Model 3—Daytime. Image Source: AAA

During daytime testing with the pedestrian target in standard non-reflective clothing, the Tesla Model 3 provided a FCW in all five runs, but PAEB was not applied in any case. No impacts occurred in three runs due to regenerative braking upon accelerator pedal release, with minimum distances to the target between 0.14 and 0.22 meters. Two runs (Runs 4 and 5) resulted in impacts at speeds of 26.19 and 25.73 km/h, respectively. Peak deceleration was limited to 0.2 g in all runs, which was solely due to regenerative braking.

When the pedestrian target was dressed in ANSI Class 3 high-visibility clothing, both FCW and AEB were triggered in all five runs. FCW activation distances ranged from 20.64 to 25.29 meters (TTC: 1.85–2.25 s), and AEB activation occurred between 2.54 and 4.74 meters (TTC: 0.32–0.5 s). Four runs avoided impact, with minimum distances between 0.04 and 0.1 meters. One run (Run 2) resulted in an impact at 11.93 km/h. Peak deceleration values for successful AEB runs ranged from 0.97 to 0.99 g.

b) Nighttime Results

Vehicle	Test Scenario	Run No.	Forward Collision Warning			Automatic Braking			Impact		Min Dist (m)	Peak Decel (g)
			Alert?	Distance (m)	TTC (s)	Applied?	Distance (m)	TTC (s)	Impact?	Speed (km/h)		
2025 Tesla Model 3	50% Overlap, Night, Standard Clothing	Run1	Y	25.81	2.33	Y	2.54	0.32	N	N/A	0.46	1.03
		Run2	Y	25.07	2.22	Y	3.97	0.46	N	N/A	0.26	1.02
		Run3	Y	27.92	2.46	Y	2.38	0.31	N	N/A	0.34	1.04
		Run4	Y	23.86	2.1	Y	3.65	0.41	N	N/A	0.29	1.05
		Run5	Y	24.9	2.19	Y	3.63	0.41	Y	14.02	0	1.03
2025 Tesla Model 3	50% Overlap, Night, Hi-Vis Clothing	Run1	Y	27.26	2.42	Y	4.56	0.53	N	N/A	0.76	1.02
		Run2	Y	25.62	2.34	Y	3.55	0.44	N	N/A	0.48	1.04
		Run3	Y	28.86	2.56	Y	3.52	0.44	N	N/A	0.77	1.03
		Run4	Y	25.86	2.34	Y	3.47	0.44	N	N/A	0.46	1.04
		Run5	Y	26.43	2.4	Y	3.65	0.46	N	N/A	0.64	1.03

Figure 25: Standard Clothing vs High-Vis Clothing 2025 Tesla Model 3—Nighttime. Image Source: AAA

During nighttime testing with the pedestrian target in standard non-reflective clothing, the Tesla Model 3 provided a FCW and applied PAEB in all five runs. FCW activation distances ranged from 23.86 to 27.92 meters (TTC: 2.10–2.46 s), and AEB activation occurred between 2.38 and 3.97 meters (TTC: 0.31–0.46 s). Impact was avoided in four runs, with minimum separation distances from 0.26 to 0.46 meters. One run (Run 5) resulted in an impact at 14.02 km/h. Peak deceleration values ranged from 1.02 to 1.05 g.

With the pedestrian target in ANSI Class 3 high-visibility clothing, FCW and AEB were also provided in all runs. FCW activation distances ranged from 25.62 to 28.86 meters (TTC: 2.62–2.86 s), and AEB activation occurred between 3.47 and 4.56 meters (TTC: 0.44–0.53 s). No impacts occurred in any run, with minimum separation distances from 0.46 to 0.77 meters. Peak deceleration values were between 1.02 and 1.04 g.

VII.DISCUSSION

A. How has nighttime pedestrian detection performance of the evaluated PAEB systems changed compared to similar tests conducted in 2019?

The results of this study demonstrate significant improvements in nighttime pedestrian detection and automatic emergency braking performance among newer model year vehicles compared to those evaluated in 2019. In the 2019 baseline, none of the tested vehicles provided FCW, PAEB, or avoided impact with the pedestrian target in any nighttime run. By contrast, in 2025, all four evaluated vehicles exhibited at least some detection and mitigation capability under the same conditions.

Among the newer models, the Toyota Camry consistently detected and avoided the pedestrian target in all nighttime baseline runs, with full FCW and AEB engagement observed (5/5 impact avoidance). The Tesla Model 3 also demonstrated strong performance, avoiding impact in 4 out of 5 runs, with one mitigated collision. The Chevrolet Malibu and Honda Accord showed improvement over 2019, but their performance was less consistent. The Malibu issued warnings and applied braking in most runs but successfully avoided impact in only 1 out of 5 runs. The Accord avoided impact in 2 out of 5 runs. These results indicate that while newer PAEB systems are capable of functioning under low-light conditions, the effectiveness remains variable by make and model and more progress is needed.



Performance of Pedestrian Automatic Emergency Braking Systems

A summary of FCW and PAEB system responses, as well as the frequency of impact avoidance, is provided in Figure 23 for all vehicles tested under nighttime conditions in both 2025 and 2019.

Nighttime PAEB						
Test Vehicle	2025			2019		
	Provided FCW	Applied AEB	Avoided Pedestrian Target	Provided FCW	Applied AEB	Avoided Pedestrian Target
Honda Accord	3/5	3/5	2/5	0/4	0/4	0/4
Toyota Camry	5/5	5/5	5/5	0/4	0/4	0/4
Chevrolet Malibu	4/5	4/5	1/5	0/4	0/4	0/4
Tesla Model 3	5/5	5/5	4/5	0/4	0/4	0/4
Note: The results are presented as the number of occurrences out of total test runs per vehicle per scenario.						

Figure 26: 2025 vs 2019 Nighttime PAEB Frequency of Occurrences. Image Source: AAA

Figure 24 further illustrates the differences in system response distances and minimum achieved separation across models and test years.

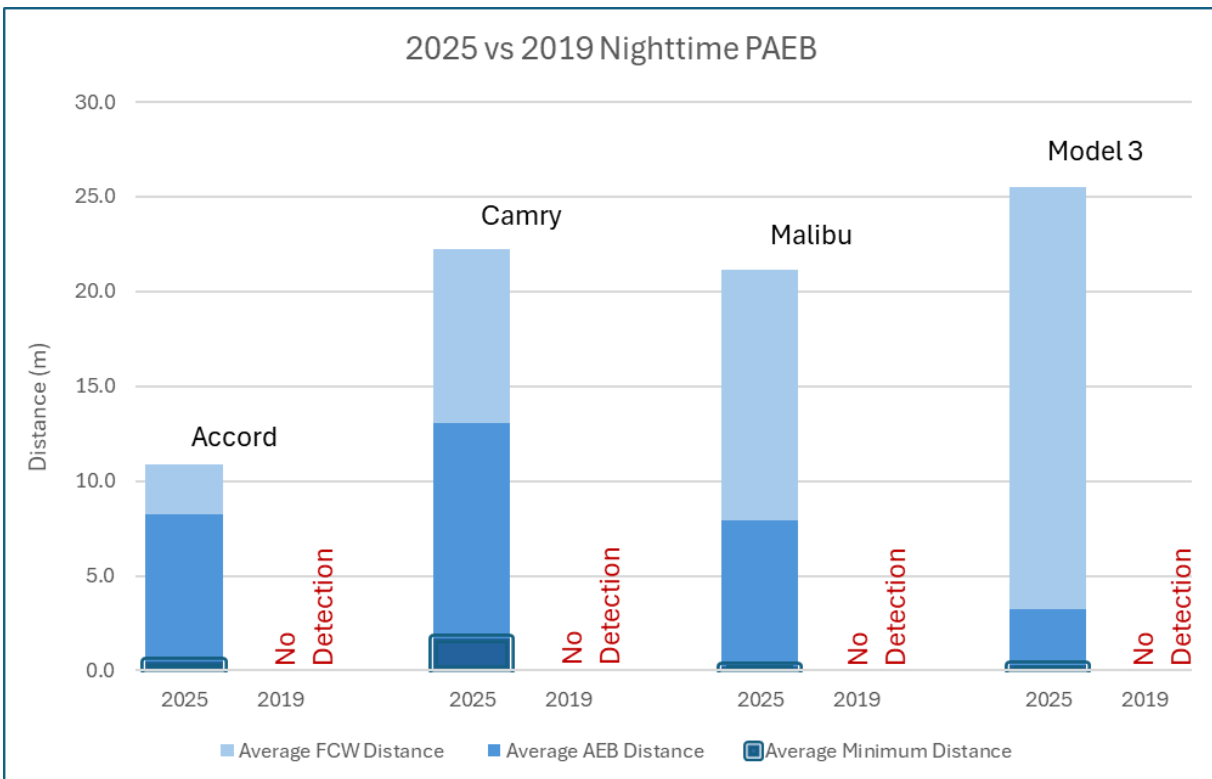


Figure 27: 2025 vs 2019 Nighttime PAEB Averages. Image Source: AAA



B. How does outfitting the pedestrian target with an ANSI Class 3 ensemble affect the performance of the evaluated PAEB systems during both day and night testing in the same scenario?

During daytime testing, outfitting the pedestrian target in ANSI Class 3 clothing had no significant effect on PAEB system performance for the Honda Accord and Toyota Camry, with both vehicles providing consistent detection, intervention, and impact avoidance in every run as seen in Figures 25 and 26.

For the Chevrolet Malibu, Forward Collision Warning was issued slightly earlier on average with ANSI Class 3 high-visibility clothing, though overall impact avoidance remained unchanged.

For the Tesla Model 3, Forward Collision Warning occurred slightly later with ANSI Class 3 high-visibility clothing, resulting in Automatic Emergency Braking activation in all runs, compared to no AEB activations in the standard clothing condition where regenerative braking was sufficient to avoid impact. The Model 3 avoided impact in 4 out of 5 runs with ANSI Class 3 high-visibility clothing, compared to 3 out of 5 with standard clothing.

Daytime PAEB						
Test Vehicle	Standard Clothing			Hi-Vis Clothing		
	Provided FCW	Applied AEB	Avoided Pedestrian Target	Provided FCW	Applied AEB	Avoided Pedestrian Target
Honda Accord	5/5	5/5	5/5	5/5	5/5	5/5
Toyota Camry	5/5	5/5	5/5	5/5	5/5	5/5
Chevrolet Malibu	5/5	5/5	5/5	5/5	5/5	5/5
Tesla Model 3	5/5	0/5	3/5	5/5	5/5	4/5
Note: The results are presented as the number of occurrences out of total test runs per vehicle per scenario.						

Figure 28: Standard vs Hi-Vis Clothing Daytime PAEB Frequency of Occurrences. Image Source: AAA

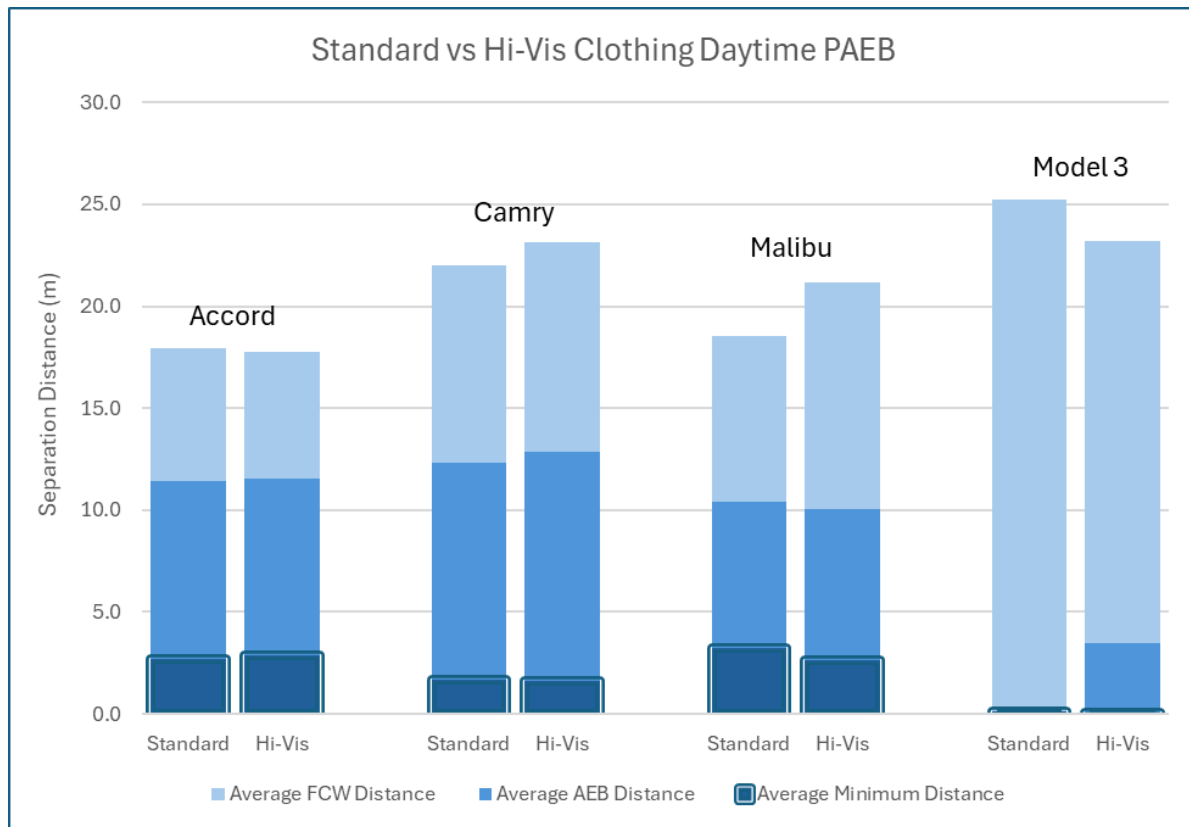


Figure 29: Standard vs Hi-Vis Clothing Daytime PAEB Averages. Image Source: AAA

Under nighttime conditions, the effect of ANSI Class 3 high-visibility clothing on PAEB system performance varied by vehicle. The Toyota Camry maintained full detection and avoidance in all runs regardless of pedestrian apparel. The Tesla Model 3 also avoided impact in all runs with ANSI Class 3 high-visibility clothing, while one impact occurred in the standard clothing condition. For the Model 3, average detection was slightly earlier with ANSI Class 3 high-visibility clothing.

The Chevrolet Malibu exhibited later FCWs at night overall, but impact avoidance improved with ANSI Class 3 high-visibility clothing, avoiding impact in three out of five runs compared to only one with standard clothing. In contrast, the Honda Accord did not detect or respond to the pedestrian target in any nighttime run with ANSI Class 3 high-visibility clothing, resulting in impacts in every case.



Nighttime PAEB						
Test Vehicle	Standard Clothing			Hi-Vis Clothing		
	Provided FCW	Applied AEB	Avoided Pedestrian Target	Provided FCW	Applied AEB	Avoided Pedestrian Target
Honda Accord	3/5	3/5	2/5	0/5	0/5	0/5
Toyota Camry	5/5	5/5	5/5	5/5	5/5	5/5
Chevrolet Malibu	4/5	4/5	1/5	5/5	5/5	3/5
Tesla Model 3	5/5	5/5	4/5	5/5	5/5	5/5

Note: The results are presented as the number of occurrences out of total test runs per vehicle per scenario.

Figure 30: Standard vs Hi-Vis Clothing Nighttime PAEB Frequency of Occurrences. Image Source: AAA

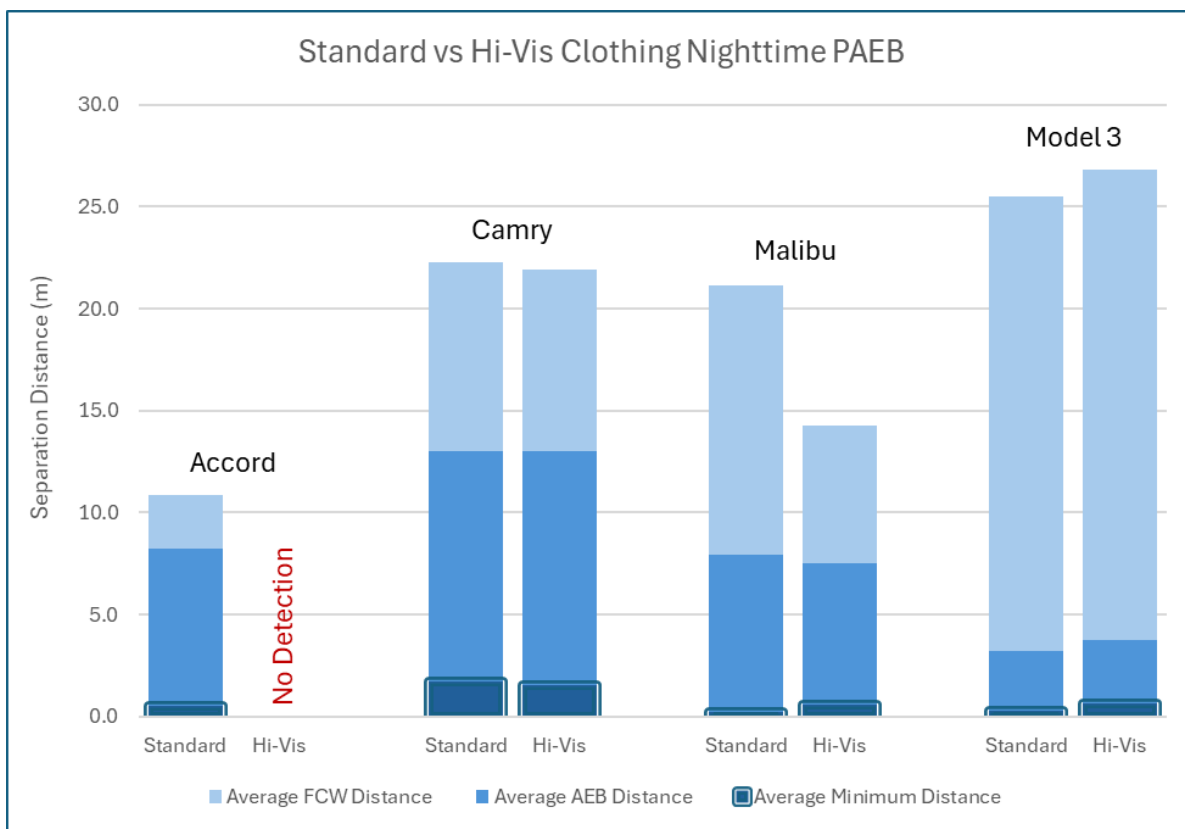


Figure 31: Standard vs Hi-Vis Clothing Nighttime PAEB Averages. Image Source: AAA

These results suggest that while some PAEB systems are robust to changes in pedestrian apparel, others may experience degraded performance—potentially missing or misclassifying pedestrians wearing high-visibility clothing ensembles, especially during nighttime conditions.



VIII. KEY FINDINGS

1. Nighttime PAEB impact avoidance improved overall from 0% in 2019 to 60% in 2025, but detection and response were inconsistent by model.
2. ANSI Class 3 high-visibility clothing had no negative effect on daytime PAEB performance and sometimes improved detection, but nighttime responses varied by vehicle, ranging from improved avoidance to complete loss of detection.

IX. RECOMMENDATIONS

Manufacturers are encouraged to enhance the reliability and consistency of PAEB system performance in nighttime conditions, with particular attention to reducing the frequency of missed detections and late responses that may lead to collisions. Evaluation and development efforts should also consider system effectiveness when pedestrians are wearing different types of apparel, including high-visibility clothing, to ensure robust detection across a range of real-world scenarios. High-visibility clothing is used by those working at the roadside to improve their visibility to drivers and avoid accidental collision, but testing found that it can actually reduce detection rates by PAEB systems in some cases.

Regulators and standards organizations are encouraged to continue strengthening pedestrian safety protocols by incorporating a broader range of nighttime scenarios and conditions involving high-visibility apparel. Expanding current evaluation practices to address these factors will provide a more complete assessment of PAEB system performance and support further improvements in reducing pedestrian crashes and fatalities.

For the driving public, it remains essential to understand the current limitations of PAEB technologies. While these systems can provide additional layers of safety, they are not a substitute for attentive driving. Drivers should always remain vigilant for pedestrians, particularly in low-light environments or situations where visibility may be compromised. Relying solely on vehicle automation for pedestrian detection and collision avoidance is not advised.

Improving the consistency of PAEB system performance for varying attire supports broader road safety initiatives and contributes to saving lives, particularly for vulnerable roadside workers and emergency responders.



X. REFERENCES

- [1] American Automobile Association, "AAA Warns Pedestrian Detection Systems Don't Work When Needed Most," 3 October 2019. [Online]. Available: <https://newsroom.aaa.com/2019/10/aaa-warns-pedestrian-detection-systems-dont-work-when-needed-most/>. [Accessed 21 May 2025].
- [2] Highway Loss Data Institute, "High-visibility clothing may thwart pedestrian crash prevention sensors," 9 January 2025. [Online]. Available: <https://www.iihs.org/news/detail/high-visibility-clothing-may-thwart-pedestrian-crash-prevention-sensors>. [Accessed 21 May 2025].
- [3] GHSA, "Pedestrian Traffic Fatalities by State: 2023 Preliminary Data (January - December)," Governors Highway Safety Association, Washington DC, 2024.
- [4] GHSA, "Pedestrian Traffic Fatalities by State: 2024 Preliminary Data (January - June)," Governors Highway Safety Association, Washington DC, 2025.
- [5] United States Census Bureau, "Population Estimates," December 2024. [Online]. Available: <https://www.census.gov/library/stories/2024/12/population-estimates.html>. [Accessed 27 June 2025].



Performance of Pedestrian Automatic Emergency Braking Systems

XI. APPROVALS

		Date	Signature
Group Manager, Automotive Research Center, ACSC	Megan McKernan	9/16/2025 1:57 PM PDT	DocuSigned by: <i>Megan McKernan</i> B796441AEACA41C...
Project Lead—AAA National	John Partridge	9/16/2025 5:14 PM EDT	Signed by: <i>John Partridge</i> 22307D516E3C4AA...
Director—AAA National	Greg Brannon	9/17/2025 9:52 AM EDT	DocuSigned by: <i>Greg Brannon</i> 41843433C88C4C9...