Analysis of the Field Effectiveness of General Motors Model Year 2019-2023 Advanced Driver Assistance System (ADAS) Features

Prepared by

Andrew J. Leslie*

Raymond J. Kiefer*

Carol A. Flannagan*

Susan H. Owen†

*University of Michigan Transportation Research Institute (UMTRI)

†General Motors LLC

February 10, 2025

Technical Report Documentation Page

1. Report No. UMTRI-2025-3	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Analysis of the Field Effectiveness of General Motors Model Year 2019-2023 Advanced Driver Assistance System (ADAS) Features		5. Report Date February 10, 2025
		6. Performing Organization Code
7. Author(s) Andrew J. Leslie, Raymond J. Kiefer, Carol A. Flannagan, Susan H. Owen		8. Performing Organization Report No.
9. Performing Organization Name and Address University of Michigan Transportation Research Institute 2901 Baxter Rd. Ann Arbor MI 48109		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. GAC 4221A / PO 7100309041
12. Sponsoring Agency Name and Address General Motors LLC Warren Technical Center 30200 Mound Road Warren, MI 48090-9010		13. Type of Report and Period Covered Technical Report
		14. Sponsoring Agency Code 310055

15. Supplementary Notes

The authors would like to thank Helen Spradlin and Lisa Park of UMTRI for their assistance in obtaining data and managing the project.

16. Abstract

This police-report based study examined the extent to which General Motors advanced driver assistance (ADAS) features are reducing system-relevant crashes, both overall and for crashes with reported injuries. A total of 565,936 crashing Model Year 2019–2023 vehicles were identified by matching VIN-linked content data to police-reported crashes from 15 states. The quasi-induced exposure method was used to compare system-relevant and system-irrelevant (control) crash counts for equipped and unequipped vehicles. Logistic regression was used to adjust for 13 covariates. Results indicated that fusion Automatic Emergency Braking, camera Automatic Emergency Braking, and camera Forward Collision Alert features reduced rear-end striking crashes by 54%, 39%, and 17%, respectively. Corresponding 52%, 47%, and 28% effectiveness values were observed in the injury-focused analysis, providing evidence of additional crash mitigation benefits. For Front Pedestrian Braking, a 25% reduction in front pedestrian injury crashes was observed. The Lane Keep Assist with Lane Departure Warning feature provided 9% and 6% reductions, respectively, in roadway departure crashes and same-direction sideswipe crashes. The Lane Change Alert with Side Blind Zone Alert system reduced lane change crashes by 11%. Reverse Automatic Braking, Rear Cross Traffic Alert, and Rear Park Assist (where each of these systems generally included all of the preceding systems) produced, respectively, an 84%, 57%, and 51% reduction in backing crashes. These results continue to provide widespread evidence of the substantial crash avoidance and injury reduction (crash mitigation) opportunities afforded by ADAS features and support identifying opportunities for accelerating progress toward a zero crashes vision.

17. Key Word advanced driver assistance system, ADAS, active safety, crash avoidance	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 39	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Table of Contents

Table of Figures

Table of Tables

Executive Summary

Background and Methodological Approach

This effort is the seventh in a series of Advanced Driver Assistance Systems (ADAS) field effectiveness studies the University of Michigan Transportation Research Institute (UMTRI) has conducted in collaboration with General Motors (GM). The current study used ADAS content data provided by GM to UMTRI for 11,479,488 Model Year 2019-2023 (MY 19-23) vehicles spanning across all GM brands (i.e., Buick, Cadillac, Chevrolet, and GMC). These data were matched by UMTRI to police report crash data from 15 states, which resulted in 565,936 matched crash cases. The wide range of ADAS features evaluated were designed to address rear-end (striking), front pedestrian, sideswipe same direction, opposite direction sideswipe (which includes head-on), single-vehicle road departure, lane change, and backing crashes.

ADAS feature effectiveness was estimated using a quasi-induced exposure logistic regression approach, under which system-relevant and system-irrelevant (control) crashes for a given feature are compared for both feature equipped and unequipped vehicle populations. The system-relevant crash type that a given ADAS feature is designed to address is expected to be less frequent in feature-equipped vehicles. The control crash type is selected using the criterion that it should not be impacted by the feature evaluated, and therefore, should occur at similar crash rates in feature-equipped and unequipped vehicle populations. Logistic regression was used to derive an odds ratio for estimating percent reductions in system-relevant crashes, and was adjusted for covariates which either characterize the crash-involved vehicles (model year, vehicle type, and vehicle model) or were police-reported (crash year, driver age, driver gender, posted speed limit, light condition, road surface condition, weather and the presence of alcohol, drugs, distracted driver, and fatigued driver). Odds ratios less than 1 indicate feature safety benefits, with the "1 - ADAS odds ratio" value indicating the percent reduction in system-relevant crashes.

The "crash prevention" analyses examined feature effectiveness for all system-relevant crashes, irrespective of police-reported injury levels. These analyses are sometimes referred to as the "all crashes" analyses. To further understand potential additional crash mitigation benefits for features addressing rear-end (striking) and lane departure crashes, corresponding "injury-focused" analyses were conducted, which focused on a crash subset in which some level of injuries was reported for crash-involved participants. The "injury" criterion was generated using the KABCO scale used by police for reporting injury severity levels, under which K=fatal injury, A=suspected serious injury, B=suspected minor injury, C=possible injury, and O=no apparent injury (i.e., property damage only). With the exception of the Front Pedestrian Braking feature, injury crashes were defined as occurring when a "K", "A", or "B" injury level was reported by the police, which is collectively referred to as a "KAB" crash. For the Front Pedestrian Braking feature, a KABC criterion was used due to the preponderance of pedestrian crashes involving injuries coupled with low pedestrian crash data volumes.

Summary of GM ADAS Effectiveness Findings

Table ES-1 provides the estimated percent reductions in police-reported system-relevant crashes and injury crashes for various ADAS features for GM MY 19-23 vehicles. The current ADAS effectiveness results are very consistent with the pattern of statistically significant effects and the magnitude of ADAS effectiveness levels observed in the recent MY 17-21 (Leslie et al., 2023) and MY 18-22 (Leslie et al., 2024) studies, which will be referred to in this section without repeatedly providing the Leslie et al. citations.

Table ES-1 Estimated percent reductions in police-reported system-relevant crashes and injury (KAB) crashes for various ADAS features for GM Model Year 2019-2023 vehicles. Shaded green cells denote statistical significance and striped cells indicate feature was not evaluated in the analysis.

Advanced Driver Assistance System (ADAS) Features Grouped by System-Relevant Crash Types	All Crashes	Injury (KAB) Crashes
Rear-End Striking Crashes		
Camera Forward Collision Alert	17%	28%
Fusion Automatic Emergency Braking (with Forward Collision Alert and Adaptive Cruise Control)	54%	52%
Camera Automatic Emergency Braking (with Forward Collision Alert)	39%	47%
Front Pedestrian Crashes		
Front Pedestrian Braking		25%[1]
Lane Departure-Same Direction Sideswipe Crashes		
Lane Departure Warning	-10%	-30%
Lane Keep Assist (with Lane Departure Warning)	6%	-1%
Lane Departure-Opposite Direction Sideswipe Crashes (includes Head-On Crashes)		
Lane Departure Warning	6%	-13%
Lane Keep Assist (with Lane Departure Warning)	8%	7%
Lane Departure-Single Vehicle Road Departure Crashes		
Lane Departure Warning	-8%	-25%
Lane Keep Assist (with Lane Departure Warning)	9%	8%
Lane Change Crashes		
Lane Change Alert (with Side Blind Zone Alert)	11%	
Backing Crashes		
Rear Park Assist (feature also included with Front and Rear Park Assist and Automatic Park Assist features)	51%	
Rear Cross Traffic Alert (with either Rear Vision Camera or Surround Vision)	57%	
Reverse Automatic Braking (with Rear Cross Traffic Alert, Rear Park Assist, and either Rear Vision Camera or Surround Vision)	84%	

[1] The injury criterion used for the Front Pedestrian Braking feature was KABC due to the rarity of pedestrian crashes coupled with the preponderance of injuries in such crashes. Due to this latter finding, the "all crashes" crash prevention analysis was not conducted in the current analysis.

Before discussing the updated GM MY 19-23 results, it should be noted that due to a shift in GM feature roll-out from less to more advanced (capable) features , the camera Forward Collision Alert analyses employed only sedans and pickups, the Lane Departure Warning analyses employed only pickups, and the Side Blind Zone Alert feature was not evaluated. As in the MY 18-22 backing feature analysis, Rear Vision Camera was used as the reference category (rather than "no backing feature") since the vast majority of GM MY 19-23 vehicles have rear-looking camera features. Finally, GM ADAS features relevant to reducing low-speed forward parking crashes (e.g., Front and Rear Park Assist and Surround Vision Camera) could not be evaluated, due to the inconsistency of parking crash coding across state crash databases.

Rear-End Striking Crashes

In both the crash prevention and injury-focused analyses, the camera and fusion Automatic Emergency Braking (AEB) features evaluated (which include Forward Collision Alert) produced approximately two to three times higher reductions in rear-end striking crashes than the "alert only" counterpart camera Forward Collision Alert (FCA) feature. In the crash prevention analysis, the camera FCA, camera AEB, and fusion AEB features were found to be 17%, 39%, and 54% effective, respectively, at reducing rear-end striking crashes. This can be compared to the corresponding 28%, 47%, and 52% effectiveness values observed in the injury-focused (KAB) analysis.

This pattern of results is consistent with the MY 17-21 and MY 18-22 findings indicating that the effectiveness levels of camera AEB and camera FCA increased in the injury-focused analysis, while fusion AEB maintained its "all crashes" effectiveness. In fact, in injury crashes the camera AEB feature reaches fusion AEB effectiveness levels. This suggests that the lower cost camera AEB feature may perform equally well for addressing injury (KAB) crashes and that the fusion AEB crash prevention benefit observed over camera AEB is occurring for possible/no apparent (i.e., "C" and "O") injury-level crashes, perhaps due to increased sensing performance (e.g., range, adverse weather robustness).

Front Pedestrian Crashes

The Front Pedestrian Braking (FPB) feature was found to be 25% effective in the injury-focused (KABC) analysis. This effectiveness level is within the 23%-32% crash prevention ("all crashes") reductions observed in the MY 17-21 and MY 18-22 efforts. Despite the known limitations of FPB under nighttime conditions, and consistent with these recent efforts, no significant interactions were observed in this analysis with potentially confounding factors (most notably, light condition). This could be due to the low pedestrian crash sample.

Lane Departure Crashes (Road Departure, Same Direction, Opposite Direction)

The Lane Keep Assist with Lane Departure Warning (LKA with LDW) feature outperformed the "alert only" counterpart LDW feature. Consistent with MY 17-21 and MY 18-22 efforts, LDW failed to provide a benefit in either the crash prevention or injury-focused analyses. In the crash prevention analysis, LKA with LDW was found to be 9% effective at reducing roadway departure crashes, and 6% effective at reducing same-direction sideswipe crashes. The non-significant 8% reduction observed for the opposite-direction sideswipe crash type is within the 7%-10% statistically significant levels observed across the MY 17-21 and MY 18-22 studies. Lane departure crash types showing a disbenefit in Table ES-1 are likely a result of the small sample size and should not be over-interpreted.

Unlike the MY 17-21 and MY 18-22 studies indicating that LKA with LDW reduced single vehicle road departure crashes in the injury-focused (KAB) analysis by 19%-22%, such a benefit failed to reach significance in the current effort and should be monitored in future analyses. This could be due to the change in the crash definition employed in the current effort, which required that the vehicle be traveling straight ahead, navigating a curve, or accelerating or slowing in lane, which effectively excluded a number of maneuvers (such as turning) and reduced crash data volumes. This change was made to better focus the results on the addressable portion of the system-relevant crash problem and to align with similar MITRE (2022, 2025) ADAS effectiveness efforts. More generally, results from Flannagan et al. (2016)) suggest that the relatively low usage of the LDW feature is a limiting factor in obtaining higher lane departure-related crash prevention and crash mitigation benefits.

Lane Change Crashes

The Lane Change Alert with Side Blind Zone Alert (LCA with SBZA) feature was found to be 11% effective at reducing lane change crashes in the crash prevention analysis, which can be compared to the 12%-15% reductions observed across the MY 17-21 and MY 18-22 studies.

Backing Crashes

Consistent with the MY 17-21 and MY 18-22 studies, a stack-up effect was observed in the crash prevention analysis under which Rear Park Assist (RPA), Rear Cross Traffic Alert (RCTA), and Reverse Automatic Braking (RAB) significantly reduced backing crashes by 51%, 57%, and 84%, respectively. It should be reminded more advanced backing features nearly always include the less advanced backing features. Note that these effectiveness estimates are based on police-reported backing crashes which occur on public roads and satisfy damage and/or injury reporting thresholds. As such, it is likely that these ADAS systems provide additional benefits when considering unreported crashes, such as those occurring on private property or in parking lots or producing only minor damage.

Comparing GM versus MITRE ADAS Effectiveness Findings

In a comparison of the current ADAS effectiveness findings relative to the large-scale, multiple OEM MITRE (2023, 2025) efforts, which also employed the quasi-induced exposure logistic regression approach, observed effectiveness levels were generally consistent for the FCA, AEB, LDW, and LKA features. However, for the FPB feature, GM effectiveness levels in the injury-focused (KABC) analysis were notably higher (25% versus 9%).

Concluding Remarks: Working Toward a Zero Crashes Vison

As in the previous GM ADAS field effectiveness studies UMTRI has conducted with GM, the ADAS features evaluated in the current MY 19-23 effort provide widespread evidence of substantial crash prevention and injury reduction (crash mitigation) safety benefits. For example, these findings support increased roll-out and development of ADAS features that provide some degree of automated control, since such features consistently outperform “alert only” feature counterparts (e.g., AEB with FCA versus FCA only, LKA with LDW versus LDW only, RAB versus other ADAS backing features). Although ADAS features require the driver to always remain attentive to driving, features that provide automatic vehicle control in potential crash situations have the distinct advantage of not strictly relying on drivers to respond to alerts in a timely and appropriate fashion, as imminent crash situations can unfold quickly. Note that drivers can always override ADAS-related automatic control, so attentive driving is still required to receive the full benefit of the systems.

In addition, these results suggest prioritized efforts for further addressing lane departure crashes, given the high levels of injury associated with such crashes (as discussed below). Effectiveness levels of lane departure features are likely being limited by lower customer use (Flannagan et al., 2016). While emerging SAE Level 2 partial driving automation features combining ACC and lane centering functionality, such as Super Cruise, have the potential to help address lane departure crashes, evaluating such benefits has been challenging from a statistical power standpoint (Leslie et al., 2022, 2025).

From the perspective of identifying feature improvement and new feature development opportunities, a mapping of the Swanson et al. (2019) “36 crashes” taxonomy against the nationally-based Crash Report Sampling System (CRSS) 2016-2020 dataset indicated 12 crash types accounted for 80% of the combined “K” (fatal) and “A” (suspected serious injury) police-reported KABCO counts. Six of these 12 crash types were addressed (with varying levels of effectiveness) by the forward collision, lane departure, pedestrian, and lane change features examined in the current effort.[2] The remaining six encompassed control loss, pedalcyclist (bicyclist), opposite direction/no maneuver (includes head-on crashes), and three intersection crash types (straight crossing paths, left turn across path/opposite direction, and left turn across path/lateral direction).

In closing, we recommend continuing this series of ADAS feature effectiveness studies, working to leverage additional state crash databases, and further developing telematics-based capabilities (e.g., crash- and feature usage-related data) to augment and potentially expedite ADAS feature effectiveness efforts. More generally, it is recommended that traffic safety be viewed via an holistic Safe System Approach, where opportunities for accelerating zero crashes vision progress are considered beyond ADAS features by traffic safety practitioners , including addressing driver behavior choices (e.g., seat belt use, speeding, and impairment due to alcohol, drugs, drowsiness, or distraction) and implementing roadway safety countermeasures (e.g., roundabouts, walkways, and bicycle lanes).

[2] Note that countermeasures addressing these 12 high harm crash types should also be generally effective in related lower harm crash type variations identified in Swanson et al. (2019). For example, rear-end striking crashes have five variations, three of which were part of the high harm crash type set.

Introduction

This effort is the seventh in a series of Advanced Driver Assistance Systems (ADAS) field effectiveness studies the University of Michigan Transportation Research Institute (UMTRI) has conducted in collaboration with General Motors (GM) (Flannagan and Leslie, 2020; Leslie et al., 2019, 2020, 2021, 2022, 2023, 2024). These studies address "achieved" (as opposed to potential) ADAS feature effectiveness which is influenced by factors such as customer feature usage, driver demographics, and driving conditions. Importantly, the wide range of ADAS features examined in these studies address multiple crash types and the combined effectiveness of features for assessing zero crashes vision progress.

Across these GM ADAS effectiveness studies, police-reported crash data from 10-15 states have been linked to millions of vehicles (ranging from 1.2-14.2 million) for which GM has provided ADAS safety content to UMTRI for analysis. ADAS feature effectiveness is estimated using a quasi-induced exposure method (Keall & Newstead, 2009), under which system-relevant and system-irrelevant (control) crashes for a given feature are compared for both feature-equipped and unequipped vehicle populations. The system-relevant crash type that the ADAS feature is designed to address (e.g., rear-end striking crashes for the Forward Collision Alert feature) is expected to be less frequent in feature-equipped vehicles. The control crash type is selected using the criterion that it should not be impacted by the feature evaluated, and therefore, should occur at similar crash rates in feature-equipped and unequipped vehicles.

The potential ADAS feature safety benefit is evaluated using odds ratios, which are adjusted via regression analyses employing covariates which characterize the crash-involved vehicles (model year, vehicle type, and vehicle model) and numerous police-reported variables. These latter variables have included crash year, driver age, driver gender, posted speed limit, light condition, road surface condition, weather, as well as the presence of alcohol, drugs, distracted driver, and fatigued driver. More generally, these covariates (notably driver age and gender and the random effect for vehicle model) help to remove the effect of driver income or other characteristics that might be reflected in differences between those who purchase ADAS systems. Odds ratios less than 1 indicate feature safety benefits, with the "1 - odds ratio" value indicating the percent reduction in system-relevant crashes. From a methodological standpoint, comparisons between this quasi-induced exposure logistic regression approach versus a Poisson regression approach have yielded converging effectiveness findings (Cicchino, 2022, 2023). A distinct advantage of the current approach is that it does not require information on vehicle miles traveled for vehicles used in the analysis.

Results from six previous field effectiveness studies examining GM ADAS features have indicated system-relevant crashes were reduced for Forward Collision Alert, Automatic Emergency Braking, Lane Keep Assist with Lane Departure, Lane Change Alert, Rear Vision Camera, Rear Park Assist, Rear Cross Traffic Alert, and Reverse Automatic Braking features (Flannagan and Leslie, 2020; Leslie et al., 2019, 2020, 2021, 2022, 2023, 2024). Across studies, the magnitude of feature benefits has been found to be largely consistent with the similarly long-running series of Cicchino (2018a, 2018b, 2019a, 2019b, 2022, 2023) studies examining a wide range of ADAS features, as well as with recent MITRE (2022, 2025) studies focused on features addressing rear-end, lane departure, and pedestrian crashes.

As demonstrated in recent GM ADAS effectiveness studies for Model Year 2017-2021 vehicles (Leslie et al., 2023) and Model Year 2018-2022 vehicles (Leslie et al., 2024), larger crash samples accumulated across the series of studies have created sufficient sample sizes for enabling the ability to (1) detect and more precisely estimate the effectiveness of features aimed at addressing rare crashes (e.g., Front Pedestrian Braking), (2) conduct analyses targeting an injury-related crash subset of rear-end and lane departure crashes, and (3) examine more detailed system-relevant crash types, including lane departure feature effectiveness for single vehicle road departure, same direction sideswipe, and opposite direction sideswipe (which includes head-on) crashes. The goal of the current Model Year 2019-2023 effort is to update GM ADAS effectiveness estimates by adding GM MY 23 vehicles and newly available state crash police report data. As in recent Leslie et al. (2023, 2024) efforts, older model year vehicles were excluded to modernize the dataset and improve representativeness of the results to the current fleet at large.

Methods

Data

Data on crash configurations and circumstances surrounding the crash came from police crash reports from 15 states in the U.S. (described further below) that were able to provide full 17-character Vehicle Identification Numbers (VINs). These data were matched to a database provided by GM to UMTRI indicating VIN and the presence of various ADAS content (collectively referred to as “safety content”).

Advanced Driver Assistance Systems (ADAS) and Feature Data

The GM safety content dataset contained VIN-linked data on 11,479,488 vehicles across all GM brands (i.e., Buick, Cadillac, Chevrolet, and GMC) for Model Year 2019-2023 (MY 19-23) vehicles. The previous MY 18-22 (Leslie et al., 2024) effort included 11,495,332 vehicles. This MY 19-23 range continues the “rolling window” approach used in the recent MY 18-22 (Leslie et al., 2024) and MY 17-21 (Leslie et al., 2023) analyses aimed at keeping the vehicle fleet more modern and representative of the fleet at large. For the remainder of the paper, for both brevity and clarity purposes, these previous MY 18-22 and MY 17-21 efforts will no longer repeatedly include citations to the corresponding Leslie et al. (2024) and Leslie et al. (2023) efforts. In addition to the change in Model Years examined, the Cadillac Lyriq, first released in MY 23 was added to the safety content dataset, and since the Chevrolet TRAX was briefly discontinued, MY 23 instances of the vehicle were not available for the current analysis. Table 1 indicates the vehicle models and range of Model Years examined, and Table 2 summarizes the number of vehicles included for each model year.

It should be briefly noted that this rolling window approach addresses a number of issues. For example, VINs provided for analysis prior to MY 20 were disproportionately sedans and included several subsequently discontinued models, making them a poor representation of the current GM fleet. Another example is that earlier model year vehicles included vehicle type-feature combinations that are either no longer offered or offered at insufficient volumes for supporting analyses (e.g., the Lane Departure Warning feature was largely not offered on SUVs in MY 16-17).

Table 1 Vehicle models and range of Model Years provided in Advanced Driver Assistance Systems (ADAS) safety content data provided by GM to UMTRI

Model Year (MY) Range	Models
2019	Buick Lacrosse, Cadillac ATS, Cadillac CTS, Cadillac XTS, Chevrolet Cruze, Chevrolet Volt
2019-2020	Buick Regal, Cadillac CT6, Chevrolet Impala
2019-2023	Buick Acadia, Buick Enclave, Buick Envision, Cadillac Escalade, Cadillac XT4, Cadillac XT5, Chevrolet Blazer, Chevrolet Bolt, Chevrolet Equinox, Chevrolet Malibu, Chevrolet Silverado, Chevrolet Silverado HD, Chevrolet Spark, Chevrolet Suburban, Chevrolet Tahoe, Chevrolet Traverse, GMC Sierra, GMC Sierra HD, GMC Terrain, GMC Yukon, GMC Yukon XL
2020	Chevrolet Sonic
2020-2022	Chevrolet TRAX
2020-2023	Buick Encore, Cadillac CT4, Cadillac CT5, Cadillac XT6, Chevrolet Camaro, Chevrolet Corvette, Chevrolet Colorado, Chevrolet Express, Chevrolet Silverado MD, GMC Canyon, GMC Savana
2021-2023	Chevrolet Trailblazer
2022-2023	GMC Hummer EV Pickup

Table 2 Vehicle count by Model Year

Model Year (MY)	Vehicle Count
2019	2,085,087
2020	2,590,408
2021	2,398,451
2022	1,983,181
2023	2,422,361

The ADAS features examined in this analysis break down into those that are intended to help the driver avoid or mitigate forward vehicle (rear-end striking, front-to-rear), front pedestrian, lane departure, lane change, and backing crashes. Since a given crash type may be addressed by multiple features, the analysis was conducted in a manner which allowed insights into the relative contribution of each feature in addressing the system-relevant crash type (e.g., AEB with FCA versus FCA only). The full list of features (and abbreviations) examined in this analysis are presented in Table 3, along with feature relationships that will be addressed in the results discussion. For example, certain features addressing different crash types are either always offered together (e.g., Lane Keep Assist with Lane Departure Warning) or have dependencies (e.g., Front Pedestrian Braking is only offered with AEB, Reverse Automatic Braking (RAB) implies the presence of forward AEB but not vice-versa).

Table 3 Analysis group, feature evaluated, and feature abbreviations

Analysis Group	Feature(s) Evaluated	Feature(s) Abbreviations
Forward Collision	Camera Forward Collision Alert[3]	Camera FCA
	Fusion[4] Automatic Emergency Braking with Adaptive Cruise Control (includes Forward Collision Alert)	Fusion AEB w/ACC
	Camera Automatic Emergency Braking (includes Forward Collision Alert)	Camera AEB
Front Pedestrian	Front Pedestrian Braking	FPB
Lane Departure	Lane Departure Warning[5]	LDW
	Lane Keep Assist with Lane Departure Warning	LKA w/LDW
Lane Change[6]	Lane Change Alert with Side Blind Zone Alert	LCA w/SBZA
Backing[7]	Rear Park Assist	RPA
	Rear Cross Traffic Alert (with either Rear Vision Camera or Surround Vision)	RCTA w/ RVC/SV
	Reverse Automatic Braking (with Rear Cross Traffic Alert, Rear Park Assist, and either Rear Vision Camera or Surround Visio)	RAB w/ RCTA, RPA, & RVC/SV

Police Crash Report Data

As shown in Table 4, UMTRI obtained police-reported crash data from 15 states (with time period indicated) that were able to provide full 17-character VINs for crash-involved vehicles.

---

[3] Camera FCA was only examined on sedans and pickup trucks due to insufficient SUV volumes.
[4] In preceding MY 18-22 analyses, this was labeled “Radar/Fusion” but the current and planned analyses no longer include any radar-only AEB features.
[5] LDW was only examined on pickup trucks due to insufficient sedan and SUV volumes.
[6] While the previous MY 17-21 and MY 18-22 studies examined the Side Blind Zone Alert (SBZA) feature, it was excluded from this analysis due to insufficient volumes.
[7] The backing analysis compares the listed features to vehicles equipped with only Rear Vision Camera (RVC), now standard on GM vehicles.

Table 4 States and calendar years of police crash report data available

State	Calendar Years
Connecticut	2018 – Q3 2024
Florida	2018 – Q1 2022
Idaho	2018 – 2023
Kansas	2018 – Q3 2024
Louisiana	2018 – 2022
Maryland	2018 –2023
Michigan	2018 – 2023
Missouri	2018 – 2023
Ohio[8]	2019 – Q2 2024
Nebraska	2018 – 2023
South Dakota	2018 – 2023
Tennessee	2018 – July 2023
Texas	2018 – June 2024
Utah	2018 – 2023
Wisconsin	2018 – 2022

Matched Subset Data

After alignment of the crash data across the 15 states (see subsequent *Crash Definitions and Variable Creation* section), 565,936 matches were observed out of the 11,479,488 VINs in this GM content dataset, for a 4.9% match rate. This represents approximately a 14% reduction in matches compared to the MY 18-22 analysis that can be explained by some state crash datasets not being updated for the current study (most notably data from Florida). As shown in Table 5, the matched dataset is weighted towards older vehicles despite ADAS penetration being weighted towards newer vehicles. This is largely due to the greater crash exposure (i.e., miles driven) of older vehicles. The fact that older vehicles have a disproportionate effect on the analysis underscores the importance of the "rolling window" approach described earlier.

As illustrated in Figure 1, where darker shading indicates higher numbers of matched crashes, Texas, Michigan, Florida, and Ohio collectively contributed 74.0% of the matched crash dataset (30.9% Texas, 20.9% Michigan, 12.2% Florida, and 9.9% Ohio). This pattern was likely due to a combination of factors, including the state population, GM vehicle sales penetration, and the years of data available.

Table 6 shows the distribution of vehicle types for the safety content database and the subset of matched crash cases. While sedans are overrepresented in the matched data set, the overrepresentation was reduced relative to the previous MY 18-22 effort (from +7.5% to +4.3%). For trucks, the underrepresentation was similarly reduced (from -6.4%. to -5.3%). These shifts were balanced by the increased overrepresentation of small/medium utility vehicles (from +0.4% to +3.2%) and underrepresentation of large utility vehicles (from -0.8% to -1.6%). Overall, the extremes of over- and under-representation continue to decrease.

---

[8] Ohio was only able to provide "sequence of crash events" data for 2019 onward, so to maintain consistent coding within the state, 2018 data from Ohio were excluded.

Table 5 Percent of vehicles in VIN dataset and matched dataset by Model Year range

Model Year (MY)	Percent of Content Data	Percent of Matched Cases
2019	18.2	32.8
2020	22.6	32.2
2021	20.9	20.6
2022	17.3	9.3
2023	21.1	5.1

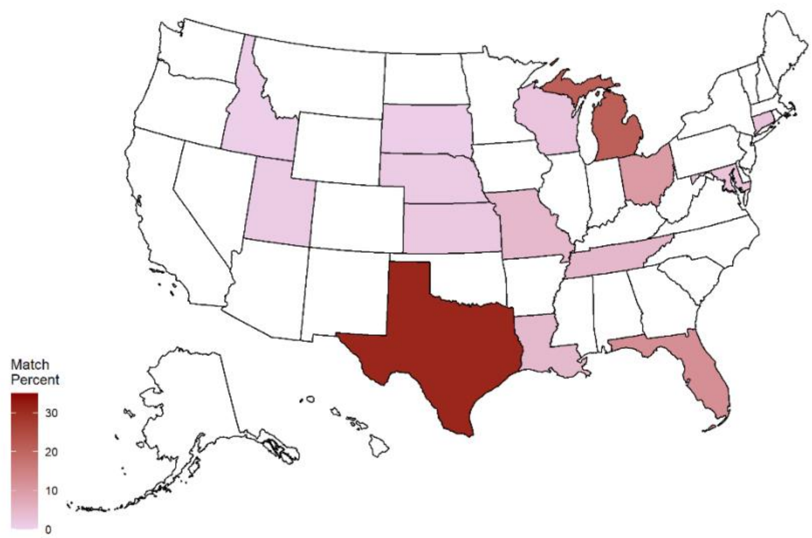

Figure 1 United States map showing the relative contribution levels of matched crashes from each of the 15 states used in this analysis

Table 6 Percent of available and matched vehicles by vehicle type for the GM MY 19-23 study

Vehicle Type	Percent of Content Data	Percent of Matched Cases	Difference
Small/Medium Utility	39.9	43.1	+3.2
Truck	34.6	29.3	-5.3
Large Utility	11.9	10.3	-1.6
Sedan	11.2	15.5	+4.3
Van	2.5	1.8	-0.7

Analysis Structure

The analysis approach focused on identifying system-relevant and associated "system-irrelevant" control crashes that could be compared to determine feature effectiveness. This method, called quasi-induced exposure (Keall & Newstead, 2009), was intended to control for the lack of traditional exposure data (e.g., miles traveled). The control crash needs to be a crash type that should not be impacted by the system and therefore occur at a similar rate in both feature-equipped and unequipped populations. An ideal control crash is one that occurs randomly as exposure (i.e., vehicle miles traveled) increases, rather than resulting from particular driver actions that might be associated with certain drivers more than others. The most commonly used control crash is rear-end struck, which is assumed to be generally unrelated to driver behavior. However, the control crash can be any crash type that is not affected by the system of interest, as long as driver demographics are controlled for in the analysis (as discussed further below). Conversely, the target (system-relevant) crash is one that should be affected (reduced) by the system and is therefore expected to be less frequent in the equipped population relative to the unequipped population. The prevalence of these crash types was then evaluated using odds ratios, which estimate the effectiveness of the system.

For example, a test of any of the various backing features evaluated uses backing crashes as the system-relevant crash type. Since the backing feature should be irrelevant for rear-end struck crashes, such crashes are used as the control crash type. This scenario is shown in Table 7, where A, B, C, D represent observed crash counts. The odds of an equipped vehicle being involved in a backing crash relative to a control crash is A/C, whereas the odds ratio for the effect of the backing feature is $\left(\frac{A}{C}\right) / \left(\frac{B}{D}\right)$. Crashes are sufficiently rare such that this ratio represents an estimate of the risk ratio, in this case the relative risk of experiencing a backing crash in an equipped versus unequipped (but otherwise similar) vehicle. In this analysis, ratios less than 1 indicate either crash prevention or injury reduction benefits. In the full analysis, a regression approach was used to adjust ratios for 13 covariates (as described below).

Table 7 The layout for quasi-induced exposure logistic regression

Crash Configuration	Backing Feature Equipment	
	Equipped	Not Equipped
Backing	A	B
Rear-end Struck	C	D

The final odds ratios were estimated using a mixed effects logistic regression model. For each model, the full set of 565,936 matched vehicles was limited to cases of the system-relevant and corresponding control crashes, and then a model predicting the probability of the system-relevant crash was constructed. The starting model included a random effect for the vehicle model (discussed further below), and fixed effects for the features and covariates. Backward selection using a likelihood ratio test was then performed until all non-significant effects were removed, with the exception of the forced model inclusion of the age and gender variables, which impact crash outcomes and provide a means of controlling for demographic patterns.

After completing the backward selection process, interactions between the feature and any significant predictors were tested, again with likelihood ratio tests. Given larger sample size in this analysis, several interactions reached significance via likelihood ratio tests but did not appear to contribute any meaningful explanatory information. As such, two additional filters were used to avoid overfitting the models. First, models including interactions were compared to the "main effect only" models using the Bayes Information Criterion (BIC), which evaluates the amount of information added to the model (i.e., the added value) with a penalty for the number of additional coefficients, with lower BIC values indicating a better model fit. In addition, significant interactions were provided to GM to assess plausibility. Ultimately, the two interactions identified meriting further investigation were not included in the final model estimates due to unclear interpretations but are discussed below.

The inclusion of vehicle model in the modelling process attempted to capture differences between the driver demographics associated with different vehicle make/models. Since such differences in the driver populations of feature-equipped and unequipped vehicles can mask (or heighten) feature effects, including vehicle model insulates the analysis from scenarios where unobserved factors (such as vehicle cost) restrict vehicle models (and their associated ADAS content) to certain demographics. Since the precise effect of various vehicle models is not of primary interest in this context, the vehicle model factor was included using random effects. Models include both a random intercept and a random slope for the feature of interest derived from the vehicle models.

The 13 covariates listed below were employed in this analysis, with the first 11 obtained from police accident reports. The remaining three covariates (Model Year, Vehicle Type, and Vehicle Model) were based on VIN data provided by GM to UMTRI.

- Driver age: *<25, 25-64, 65+*
- Driver gender: *Male, Female*
- Speed Limit (miles per hour): *Continuous*[9]
- Alcohol or Drug Presence (police-reported): *Yes, No*
- Distracted Driver: *No, Cell phone distraction, Other distraction*
- Fatigued Driver: *Yes, No*
- Weather: *Clear/Cloudy, Not Clear/Cloudy (rain, snow, etc.)*
- Road Surface Condition: *Dry, Not Dry (wet, icy, etc.)*
- Light Condition: *Daylight, Dawn/Dusk, Dark-Lit, Dark-Unlit*
- Model Year: *2019 – 2023*
- Crash Year: *2018 – 2024*
- Vehicle Type: *Sedan, Small/Medium Utility, Large Utility, Truck, Van (see* Table 8 *for definitions)*
- Vehicle model: *(see* Table 8*)*
- All other predictors are naturally categorical.

All predictors were categorical, with the exception of Speed limit, which was treated as continuous because higher speeds are expected to monotonically increase crash risk. In addition, driver age was treated as a three-level categorical variable to account for the typical U-shaped relationship between driver age and crash risk (Massie et al., 1995).

Table 8 Model to vehicle type mapping used for the logistic regression predictor variable

Vehicle Type	Models
Sedan	ATS, Bolt, Cruze, Camaro, Corvette, CT4, CT5, CT6, CTS, Impala, LaCrosse, Lyriq, Malibu, Regal, Sonic, Spark, Volt, XTS
Small/Medium Utility	Acadia, Blazer, Enclave, Encore, Envision, Equinox, Terrain, Trailblazer, Traverse, TRAX, XT4, XT5, XT6
Large Utility	Escalade, Suburban, Tahoe, Yukon, Yukon XL
Truck	Canyon, Colorado, Hummer EV Pickup, Sierra, Sierra HD, Silverado, Silverado HD, Silverado MD
Van	Express, Savana

[9] An additional speed threshold definition was employed in the Forward Collision Prevention Analysis to address that the camera AEB feature did not operate at speeds above 50 MPH.

Crash Definitions and Variable Creation

Although police crash reports have a core set of available fields common to most states, the coding of the variables associated with those fields is not uniform. For example, initial impact location is coded in various states with either an 8-, 12- or 16-point grid, with additional variability coming from the orientation of the reference grid around the vehicle. Consequently, before pooling the crash data across states, each state crash dataset was separately reduced to a standard set of crash definitions and potential covariates to ensure comparable, consistent data fields across all states included in the analysis. This challenge in aligning state crash data also led to binary coding for many covariates, including those associated with alcohol/drug involvement, distraction, weather, and road surface condition.

The assumed system-relevant and corresponding control crash definitions used in each analysis are shown in Table 9 and Table 10, respectively. The goal is to identify a group of crashes that best represents (with the available crash data elements) the system-relevant crashes that each feature is designed to address. For all analysis groups, rear-end struck (i.e., being struck from behind in a rear-end crash) served as the control crash type. Due to the potential ambiguity of crash configurations in police reports, and the subset of rear-end struck crashes included in the lane change analysis, it was possible for a rear-end struck crash to also qualify as a system-relevant crash (e.g., when the GM vehicle changed lanes in front of another vehicle and was subsequently impacted in the rear). In such circumstances, the crash was counted as system-relevant rather than a control crash. Finally, in addition to the crash type definitions provided in Table 9 and Table 10, some states had additional special variables used in the analysis that more directly indicated the crash type of interest.

Relative to the MY 18-22 effort, several of the crash definitions in Table 9 and Table 10 have been changed to additionally consider the host vehicle's pre-crash maneuvers, which had the effect of reducing data volumes. For the rear-end and pedestrian crashes, crashes were excluded if vehicles were backing, parked, or parking. For the lane departure crashes, vehicles were required to be traveling straight ahead, navigating a curve, or accelerating or slowing in lane, which effectively excluded a number of maneuvers (such as turning). These crash definition changes were made to better focus the results on the addressable portion of the system-relevant crash problem and align with similar large-scale analyses being conducted by MITRE (2022, 2025).

Similarly, the forward pedestrian crash category was modified to exclude crashes without pedestrian injury. This is because non-injury pedestrian crashes are likely to be underreported since they will not satisfy the reporting criteria in the states (based on cost of damage or presence of injury). This also brings the analysis into alignment with the MITRE analyses (2022, 2025).

As in all police-report based ADAS effectiveness studies to-date, we could not determine via the State Crash data whether or not a system was turned on or whether the driver used the feature properly (i.e., as characterized in the Owner's Manual system descriptions). If actual system usage is <100%, or if the system was turned on but not being used properly by an attentive driver, this analysis will underestimate the potential effectiveness relative to when a system was always turned on and used properly. (See Flannagan et al. (2016) for evidence of relatively low Lane Departure Warning feature usage.) That said, the purpose of this analysis is to estimate actual effectiveness as used in the field. If driver usage of the systems changes over time, those changes would be reflected in changes in realized effectiveness over time as well. Put in another way, the obtained results reflect *actual* field effectiveness which account for usage considerations.

As in MY 17-21 and MY 18-22 efforts, to further understand potential crash mitigation benefits for features addressing rear-end (striking) and lane departure crashes, corresponding "injury-focused" analyses were conducted. The "injury" criterion was generated using the KABCO scale used by police for reporting injury severity levels, under which K=fatal injury, A=suspected serious injury, B=suspected minor injury, C=possible injury, and O=no apparent injury (i.e., property damage only). This widely used scale is defined in the Model Minimum Uniform Crash Criteria (MMUCC) (USDOT, 2012) data standard. With the exception of the FPB feature, injury crashes were defined as occurring when a "K", "A", or "B" injury level was reported for any crash-involved participant, which is collectively referred to as a "KAB" crash. For the FPB feature, a KABC criterion was used due to the preponderance of pedestrian crashes involving injuries coupled with low pedestrian crash data volumes.

Table 9 System-relevant crash types and definitions by analysis group

Analysis Group	Crash Type	Definition
Forward Collision	Rear-End Striking	Manner of Crash = Rear-End AND Initial Contact Point on Vehicle = Front AND Motor Vehicle Maneuver/Action NOT IN (Backing, Parked, Parking)
Front Pedestrian	Front Pedestrian	Initial Contact Point on Vehicle = Front AND First Event = Pedestrian AND Speed Limit < 50 AND Motor Vehicle Maneuver/Action NOT IN (Backing, Parked, Parking) AND Worst Pedestrian Injury IN (K, A, B, C)
Lane Departure – Same Direction	Lane Departure	[Manner of Crash = Same Direction Sideswipe] AND Speed Limit > 30 AND Motor Vehicle Maneuver/Action IN (Driving Straight, Navigating a Curve, Slowing, Accelerating)
Lane Departure – Opposite Direction	Lane Departure	[Manner of Crash IN {Opposite Direction Sideswipe, Head-on}] AND Speed Limit > 30 AND Motor Vehicle Maneuver/Action IN (Driving Straight, Navigating a Curve, Slowing, Accelerating)
Lane Departure – Road Departure	Lane Departure	[Single Vehicle AND Harmful Event IN {Run off road, Cross centerline, Cross median, Fixed object}] AND Speed Limit > 30 AND Motor Vehicle Maneuver/Action IN (Driving Straight, Navigating a Curve, Slowing, Accelerating)
Lane Change	Lane Change	Motor Vehicle Maneuver/Action = Lane Change AND [Manner of Crash = Same-direction Sideswipe OR (Manner of Crash = Rear-end AND Initial Contact Point on Vehicle = Rear)]
Backing	Backing	Motor Vehicle Maneuver/Action = Backing AND Initial Contact Point on Vehicle = Rear

Table 10 Control crash type and definition by analysis group

Analysis Group	Crash Type	Definition
All Analyses	Rear-end Struck	Manner of Crash = Rear-end AND Initial Contact Point on Vehicle = Rear AND Motor Vehicle Maneuver/Action NOT IN (Backing, Parked, Parking)

Even though NHTSA, state agencies, and traffic safety researchers routinely rely on KABCO information to characterize crash harm, research has shown that police-reported injury level overestimates the incidence of medically-diagnosed (i.e., more precisely defined) serious injuries in crashes by as much as 2-3 times (Flannagan, Mann, & Rupp, 2013). Nonetheless, since KABCO is strongly correlated with injury level based on medical diagnosis, police-reported injury crashes are likely to be generally more severe than reported non-injury crashes. Consequently, an analysis restricted to injury-reported crashes still provides important insights into the extent to which features are not only avoiding injury crashes but also mitigating or preventing injuries when crashes do occur.

Results

The ADAS features evaluated were divided into five general analysis categories: forward (i.e., rear-end striking) collision, front pedestrian, lane departure (which included three crash sub-type analyses), lane change, and backing. Four of these five categories were used in the "crash prevention" (i.e., crash avoidance) analyses, with the exception being the front pedestrian category owing to preponderance of injuries in such crashes. Additional "injury-focused" analyses, focused on targeting an injury-related crash subset in which some level of injuries was reported for crash-involved participants, were conducted for the forward collision, lane departure, and front pedestrian categories. These analyses attempt to account for crash mitigation effects for crashes which were not prevented, where the feature may have reduced the crash severity. If so, this effect would help mitigate or prevent crash-related injuries and produce larger estimated effectiveness for injury crashes than in corresponding crash prevention analysis, which examined "all crashes", irrespective of the injury levels of crash-involved participants.

Each analysis category is discussed separately below.

Analysis Data Subsets

Table 11 shows the sample size of matched cases for both system-relevant and control crashes for each analysis category. These crashes are derived from the original set of 565,936 vehicle cases matched between GM VINs (with ADAS content indicated) and the set of police reported crashes from the 15 states used in the analysis. Note that some features are listed as co-occurring with other features since less advanced features are often bundled with their more advanced counterparts, which is addressed in the relevant analysis discussions below.

In recent model years, the volume of FCA-, LDW-, SBZA-equipped vehicles have decreased as GM has moved towards more capable counterparts of these features (AEB, LKA, and LCA, respectively). In the current MY 19-23 dataset the volumes for these lower-level features were quite low, particularly on small, medium, and large utility vehicles. Consequently, for the forward collision analysis, the camera FCA was only evaluated with sedans and pickups. For the lane departure analysis, the LDW was only evaluated with pickups. For the lane change analysis, SBZA was excluded due to generally low penetration levels. In addition, with the exception of the backing analysis, vans were excluded from all other analyses since ADAS volumes were generally very low (when offered) and higher-level counterparts were not available on vans.

Table 11 Count of vehicles analyzed by feature(s) evaluated and crash type (system-relevant versus control) for each analysis category

Analysis Category	Feature(s) Evaluated	Crash Type	
		System-Relevant	Control
Forward Collision	Unequipped with Forward Collision features	38,572	52,274
	Camera Forward Collision Alert (FCA)	986	1,352
	Fusion Automatic Emergency Braking (AEB) with Adaptive Cruise Control (ACC)	1,384	5,301
	Camera AEB (incudes Forward Collision Alert)	15,001	43,589
Front Pedestrian	Unequipped with Front Pedestrian feature	735	38,822
	Front Pedestrian Braking (FPB)	331	27,918
Lane Departure-Same Direction	Unequipped with Lane Departure features	18,644	35,875
	Lane Departure Warning (LDW)	1,329	1,618
	Lane Keep Assist (LKA) with LDW	11,747	30,606
Lane Departure-Opposite Direction	Unequipped with Lane Departure features	3,211	34,481
	Lane Departure Warning (LDW)	301	1,531
	Lane Keep Assist (LKA) with LDW	1,774	29,427
Lane Departure-Road Departure	Unequipped with Lane Departure features	9,388	34,481
	Lane Departure Warning (LDW)	567	1,531
	Lane Keep Assist (LKA) with LDW	5,075	29,427
Lane Change	Unequipped with Lane Change features	6,832	47,287
	Lane Change Alert (LCA) with SBZA	5,706	51,127
Backing	Rear Vision Camera or Rear Vision Camera Mirror (RVC)	4,626	40,115
	Rear Park Assist (RPA)	1,182	7,904
	Rear Cross Traffic Alert (RCTA) with RVC/SV	3,409	48,161
	Reverse Automatic Braking (RAB) with RCTA, RPA, and either RVC or SV	46	1,718

Forward Collision Prevention Analysis

Table 12 provides a summary of the features and crash types (system-relevant and control) used in the forward collision prevention analysis. Note that the camera Automatic Emergency Braking (AEB) feature evaluated only operated below 50 mph, all AEB features included the FCA feature, Adaptive Cruise Control (ACC) is only offered with AEB, and (as noted above) camera FCA-equipped vehicles included in the analysis were limited to sedans and pickups. In addition, since only a small proportion of camera AEB vehicles were also equipped with camera ACC, these two groups were merged in the analysis.

All feature levels shown in Table 12 were compared against the reference level of "Unequipped (no FCA or AEB)."

Table 12 Summary of the forward collision prevention and injury-focused analysis

Characteristic	Value
Feature Levels	Unequipped (no FCA or AEB) Forward Collision Alert (FCA) Fusion AEB with Adaptive Cruise Control (ACC) Camera AEB
System-relevant Crash	Rear-end Striking KAB Injury Rear-end Striking
Control Crash	Rear-end Struck
Analysis Subset Sample Sizes - all crashes - injury crashes	 55,943 (system-relevant); 102,516 (control) 5,044 (system-relevant); 98,840 (control[10])

Table 13 provides ADAS effectiveness estimates for reducing system-relevant crashes in both the crash prevention ("all crashes") and injury-focused analyses, along with corresponding odds ratios and 95th percentile confidence intervals. Results for the forward collision analysis indicated camera FCA, camera AEB, and fusion AEB reduced rear-end striking crashes by 17%, 39%, and 54%, respectively.

Injury Crash Analysis

Recall the injury-focused forward collision analysis targeted crashes where police reported an injury level of either K, A, or B on the police-reported KABCO scale for any participant in the crash. As shown in Table 13, camera FCA, camera AEB, and fusion AEB reduced (system-relevant) rear-end striking injury crashes by 28%, 47%, and 52%, respectively. Relative to the corresponding crash prevention analysis, estimated benefits increased substantially for FCA (+11%) and camera AEB (+8%), providing evidence of added crash mitigation benefits. In contrast, fusion AEB benefits decreased slightly (-2%), showing no evidence of such benefits. This elevated effect for camera FCA and camera AEB suggests these systems are addressing rear-end crashes that are more severe (more likely to involve injuries) at an even higher rate than less severe (e.g., property damage only) crashes, potentially by mitigating crash severity such that some injury crashes are shifted to lower-level "C" (Possible Injury) or "O" (No Apparent Injury) crashes.

[10] The number of control crashes in some injury crash models differs from the corresponding "all crashes" (crash prevention) models due to missing data combined with different significance of the main effects. For example, in the forward crash models weather condition is significant only in the injury model, which results in more missingness.

Table 13 Estimated percent reductions in police-reported system-relevant crashes and injury crashes for forward collision, front pedestrian, and lane departure ADAS features for GM Model Year 2019-2023 vehicles. Shaded green cells denote statistical significance

ADAS Features Grouped by System-Relevant Crash Types	All Crashes			Injury (KAB) Crashes		
	Effect %	Odd Ratio (95% CI)	p-value	Effect %	Odd Ratio (95% CI)	p-value
Rear-End Striking Crashes						
Camera Forward Collision Alert	17%	0.83 (0.71-0.96)	0.018	28%	0.72 (0.55-0.94)	0.020
Fusion Automatic Emergency Braking (with Forward Collision Alert and ACC)	54%	0.46 (0.41-0.52)	<0.001	52%	0.48 (0.38-0.60)	<0.001
Camera Automatic Emergency Braking (with Forward Collision Alert)	39%	0.61 (0.56-0.65)	<0.001	47%	0.53 (0.48-0.59)	<0.001
Front Pedestrian Crashes						
Front Pedestrian Braking				25%[11]	0.75 (0.57-0.98)	0.046
Lane Departure-Same Direction Sideswipe Crashes						
Lane Departure Warning	-10%	1.10 (0.98-1.23)	0.109	-30%.	1.30 (0.94-1.80)	0.117
Lane Keep Assist (with Lane Departure Warning)	6%	0.94 (0.90-0.98)	0.009	-1%	1.01 (0.87-1.17)	0.933
Lane Departure-Opposite Direction Sideswipe Crashes (includes Head-On Crashes)						
Lane Departure Warning	6%	0.94 (0.74-1.19)	0.595	-13%	1.13 (0.82-1.54)	0.468
Lane Keep Assist (with Lane Departure Warning)	8%	0.92 (0.82-1.03)	0.178	7%.	0.93 (0.77-1.13)	0.488
Lane Departure-Single Vehicle Road Departure Crashes						
Lane Departure Warning	-8%	1.08 (0.89-1.31)	0.448	-25%.	1.25 (0.91-1.72)	0.179
Lane Keep Assist (with Lane Departure Warning)	9%	0.91 (0.84-0.98)	0.026	8%.	0.92 (0.80-1.06)	0.263

[11] The injury criterion used for the Front Pedestrian Braking (feature was KABC due to the rarity of pedestrian crashes coupled with the preponderance of injuries in such crashes. Due to this latter finding, the crash prevention analysis was not conducted in the current analysis.

System Interactions

Driver age and speed limit were the only covariates found to interact with forward collision features that also met the BIC threshold discussed earlier, with both interactions observed in the crash prevention analysis. The driver age interaction indicated that older drivers (ages 65 and older) received less benefit from the forward prevention features than both middle-aged (26-64) and younger (age 25 or less) drivers. For older drivers, FCA did not yield a benefit and AEB effectiveness was between 15%-18% lower than for middle-aged drivers. This trend could plausibly be due to older drivers being associated with decreased reaction time, different driving patterns, and/or other demographic-related effects.

The speed limit interaction indicated that camera and fusion AEB benefits were reduced on high-speed (50 mph speed limit or greater) roads by 6% and 9%, respectively. This general reduction pattern is expected, since higher speed rear-end crashes are inherently more challenging to avoid or mitigate. However, one might have expected higher speed limit conditions to have more impact on camera than fusion AEB, given the increased sensing capabilities (e.g., sensor range) of fusion AEB. On the other hand, this pattern indicates the camera AEB is performing well under higher speed limit conditions. One important caveat of this analysis is that the actual driver speed surrounding the time of the crash is unknown, so drivers could have been travelling at speeds markedly lower than the posted speed limit (e.g., due to slowing traffic), such that equivalent effectiveness across camera and fusion AEB might be expected for higher speed limit conditions.

Unlike in the MY 17-21 and MY 18-22 analyses, the interaction indicating that camera-based FCA and AEB features had slightly lower performance on larger vehicles failed to meet the criteria for inclusion in this analysis. However, the directional patterns observed here were consistent with this interaction, as large SUVs and trucks were observed to have lower performance with camera AEB compared to sedans and small/medium SUVs. It is plausible that this inconsistency is due to the decreased sample size and the effect of vehicle type on system performance. Consequently, this interaction should continue to be monitored in future analyses.

Front Pedestrian Injury Crash Analysis

Table 14 shows a summary of the front pedestrian injury crash analysis. The ability to detect Front Pedestrian Braking (FPB) effects, particularly interactions with covariates, was limited by the rarity of the system-relevant front pedestrian crashes (1,066 (1.6%) of the 67,806 cases in the analysis subset).

FPB was compared against the reference level of “Unequipped (no FPB).”

Table 14 Summary of the front pedestrian injury-focused analysis

Characteristic	Value
Feature Levels	Unequipped (no FPB) Front Pedestrian Braking (FPB)
System-relevant Crash	Front Pedestrian Crash Daylight/Night VRU Crash
Control Crash	Rear-end Struck
Analysis Subset Sample Sizes	1,066 (system-relevant); 66,740 (control)

Recall the “injury-focused” front pedestrian analysis targeted crashes where police reported a pedestrian injury level of either K, A, B, or C on the police-reported KABCO scale. As shown in Table 13, FPB reduced (system-relevant) front pedestrian injury crashes by 25%. For comparison purposes, 23% and 31% effectiveness values were observed, respectively, in the MY17-21 and MY 18-22 crash prevention analyses (injury-focused analyses were not conducted). Consistent with these previous analyses, interactions were not observed between FPB and potentially confounding factors (most notably light condition), which may be attributed to the limited pedestrian crash sample.

Lane Departure Crash Prevention Analysis

Table 15 shows a summary of the lane departure crash prevention analysis, noting that the Lane Departure Warning (LDW) feature is only available on pickups in the crash prevention and injury-focused analyses. The Lane Keep Assist (LKA) with LDW system provides a limited form of automatic control via a brief steering wheel nudge, along with LDW alerts only if the vehicle continues to depart the lane. Hence, relative to the LDW (alone) feature, the LDW functionality is somewhat modified, such that the frequency of LDW alerts is markedly reduced in the LKA with LDW system.

This analysis used three system-relevant crash definitions that identify the three main subsets of the general “lane departure” crash type. These subsets are same direction sideswipes crashes, opposite direction sideswipes (which include head-on crashes), and single vehicle road departure crashes. As seen in Table 11 and Table 15, the plurality of system-relevant crashes were same direction sideswipes, though differences in severity across these crash subsets resulted in roughly comparable volumes of injury-related crashes.

The reference category for the feature factor is “Unequipped (no LDW or LKA).”

Table 15 Summary of the lane departure crash prevention and injury-focused analysis.

Characteristic	Value
Feature Levels	Unequipped (no LDW or LKA) Lane Departure Warning (LDW) Lane Keep Assist with LDW
System-relevant Crash	Lane Departure Crashes Injury Lane Departure Crashes
Control Crash	Rear-end Struck
Analysis Subset Sample Sizes All Crashes - Same Direction - Opposite Direction - Road Departure Injury Crashes - Same Direction - Opposite Direction - Road Departure	 31,720 (system-relevant); 68,099 (control) 5,286 (system-relevant); 65,439 (control) 15,030 (system-relevant); 65,439 (control) 1,511 (system-relevant); 68,608 (control[10]) 1,638 (system-relevant); 65,517 (control[10]) 2,761 (system-relevant); 65,439 (control)

As shown in Table 13, the LKA with LDW feature reduced (system-relevant) single vehicle road departure crashes by 9% and same direction sideswipe crashes by 6%, while failing to reach significance for opposite direction sideswipe crashes. LDW failed to provide a benefit for any of the three system-relevant crash types. Crash types showing a disbenefit in Table 13 are likely a result of the small sample size and should not be over-interpreted. When interpreting results across these system-relevant crash types, it should be stressed that for single vehicle roadway departure crashes, the GM vehicle is always responsible for the lane departure. In sharp contrast, this is not true for same direction and opposite direction sideswipe crashes, which necessarily involve two (or more) vehicles, where the “other” vehicle may have responsibility for the crash in a manner which is not addressable by lane departure features.

Injury Crash Analysis

As shown in Table 13, in this injury-focused analysis, neither the LKA with LDW or LDW (alone) features yielded a significant benefit in any of the three lane departure crash types examined. This is inconsistent with MY 17-21 and MY 18-22 findings that indicated the LKA with LDW feature reduced single vehicle road departure injury crashes by 19%-22%. One possible explanation for this inconsistency is that, in the current analysis, a change in the crash definition additionally required that the vehicle be traveling straight ahead, navigating a curve, or accelerating or slowing in lane, which effectively excluded a number of maneuvers (such as turning) and thereby reduced crash data volumes. Recall this crash definition change was made to better focus the results on the addressable portion of the system-relevant crash problem and align with similar analyses being conducted by MITRE (2022, 2025). In any case, the reason for the general decreased LKA with LDW effectiveness remains unclear and should continue to be monitored in future analyses.

System Interactions

Road surface condition and speed limit were the only covariates found to interact with lane departure features that also met the BIC threshold, consistent with MY 17-21 findings. Both interactions, observed in the crash prevention analysis, suggested that the LKA with LDW feature fails to show a benefit under "non-dry road" and "not clear/cloudy" weather conditions. This pattern is consistent with GM owner's manual recommendations advising drivers to disable this feature when roads are slippery (which eliminates any potential feature benefit).[12]

Lane Change Crash Prevention Analysis

Table 16 provides a summary of the lane change crash prevention analysis, noting that the Side Blind Zone Alert (SBZA) feature was excluded in this analysis due to low volumes. Vehicles with Lane Change Alert (LCA) included SBZA functionality. This feature provided substantially greater capability than SBZA (alone) for alerting drivers to vehicles rapidly approaching the side blind zone area. Since only a small number of LCA-equipped vehicles had additional mirror-, trailering-, or steering assist-related features that may also help address lane change crashes, these features were merged in the analysis with the LCA (with SBZA) feature.

To assess the effect of LCA with SBZA, the reference level was "Unequipped (no SBZA or LCA)."

Table 16 Summary of lane change crash prevention analysis

Characteristic	Value
Feature Levels	Unequipped (no SBZA or LCA) Lane Change Alert with SBZA
System-relevant Crash	Lane Change Crash
Control Crash	Rear-end Struck
Analysis Subset Sample Sizes	12,538 (system-relevant); 98,414 (control)

As shown in Table 17, LCA w/SBZA reduced (system-relevant) lane change crashes by 11%, close to the 12%-15% benefits observed across MY 18-22 and MY 17-21 studies.

[12] "Using LKA on slippery roads could cause loss of control of the vehicle and a crash. Turn the system off." (MY 2022 Cadillac CT5 User Manual)

Table 17 Estimated percent reductions in police-reported system-relevant crashes for lane change and backing ADAS features for GM Model Year 2019-2023 vehicles. Shaded green cells denote statistical significance(p<0.05) and CI=confidence interval.

ADAS Features Grouped by System-Relevant Crash Types	All Crashes		
	Effect %	Odd Ratio (95% CI)	p-value
Lane Change Crashes			
Lane Change Alert (with Side Blind Zone Alert)	11%	0.89 (0.85-0.93)	<0. 001
Backing Crashes			
Rear Park Assist (feature also included with Front and Rear Park Assist and Automatic Park Assist features)	51%	0.49 (0.41-0.59)	0.002
Rear Cross Traffic Alert (with either Rear Vision Camera or Surround Vision)	57%	0.43 (0.37-0.50)	<0. 001
Reverse Automatic Braking (with Rear Cross Traffic Alert, Rear Park Assist, and either Rear Vision Camera or Surround Vision)	84%	0.0.16 (0.11-0.24)	<0. 001

Backing Crash Prevention Analysis

Table 18 provides a summary of the backing crash prevention analysis. Since there was not a reliable way to identify different backing crash sub-types (e.g., parking, higher-speed backing, cross traffic) via available police report data, four lower-speed park assist-related features, all of which include the RPA feature, were collapsed and treated as a single "collective" RPA feature. These four features included Rear Park Assist (RPA), Front and Rear Park Assist (FRPA), Automatic Park Assist with Steering (APA2), and Enhanced Automatic Park Assist. Furthermore, the Surround Vision (SV) feature was not distinguished from Rear Vision Camera (RVC) for this analysis, since it includes RVC functionality, but additionally provides a 360-degree view around the vehicle. Furthermore, the Rear Vision Camera Mirror feature (which displays the RVC image in the interior rear-view mirror), offered only on vans, was merged with RVC in this analysis for reasons discussed below. Starting with MY 21 vehicles, two additional, low-volume variants of RVC (Front Curb View and Rear Trailer View) were also included as part of the collective RVC feature.

Due to GM's tendency to stack up backing/parking features, as shown in Table 18, the feature levels were treated as hierarchical with the more advanced feature taking priority as available (e.g., a car with Rear Cross Traffic Alert (RCTA) but not offering Reverse Automatic Braking (RAB) is placed in the RCTA group irrespective of park assist feature content). With two exceptions, this means that vehicles coded as having a particular backing feature also had all the backing systems listed above that feature in Table 18. (Note that we ignore the RVC versus SV camera distinction, as discussed above,) The two exceptions included a RCTA-equipped vehicle not including RPA system (approximately 1% of cases) and an RPA-equipped vehicle not including either RVC or SV (approximately 0.9% of cases).

Table 18 Summary of the backing crash prevention analysis

Characteristic	Value
Feature Levels	Rear Vision Camera or Rear Vision Camera Mirror (RVC)[13] Rear Park Assist (RPA)[14] Rear Cross Traffic Alert w/ RVC/Surround Vision (SV) Reverse Automatic Braking w/ RVC/SV, RPA, & RCTA
System-relevant Crash	Backing Crash
Control Crash	Rear-end Struck
Analysis Subset Sample Sizes	9,263 (system-relevant); 97,898 (control)

Unlike the other analysis groups, “Unequipped” was not used as the reference category for the backing crash analysis. As of MY 18, RVC was essentially standard on GM vehicles, with only trucks and vans offering trims without backing features in high volumes. This has the potential to skew results because it confounds the feature effect with a vehicle type effect. Instead, as in the MY 17-21 and MY 18-22 efforts, RVC was used as the reference category. While a fuller discussion is available in Leslie et al. (2024), two points will be briefly touched upon here. First, using RVC as the reference category makes it difficult to separately estimate the effect of RVC Mirror, since the van effect is confounded with the feature effect, which produces unstable results. To combat this, RVC Mirror was merged into the RVC variable (this was judged to be reasonable based on the results of the MY 17-21 analysis). Secondly, in order to maintain comparability to previous MY 17-21 and MY 18-22 efforts, the current results were “corrected” using the 34% effectiveness estimate for RVC obtained in the MY 17-21 analysis. That is, rather than a reference of odds ratio of 1 (or no benefit), the reference was shifted to an odds ratio of 0.66 (a 34% benefit). Note that this approach assumes that the RVC effect has not changed since the MY 17-21.

As shown in Table 17, after applying the estimated RVC reduction from the MY 17-21 analysis (34%), RPA, RCTA (with either RVC or SV), and RAB (with RCTA, RPA, and either RVC or SV) reduced backing crashes by 51%, 57%, and 84%, respectively. Corresponding values across the MY 17-21 and MY 18-22 efforts were 48%-49%, 59%-62%, and 83%-85%, respectively. These crash reduction benefits reveal a readily apparent “stack-up” effect indicating that system benefits generally increased as more advanced backing systems, which nearly always including each of the less advanced backing systems, were added.

System Interactions

Light condition and driver sex were the only covariates found to interact with backing feature type that met the BIC threshold. Since the light condition effect was not internally consistent, it will not be discussed here but will continue to be monitored in future research. Under the driver sex interaction, relative to male drivers, backing feature effectiveness for female drivers was 5% higher for RCTA and 23% higher for RPA. Thus, while there was not a qualifying interaction for vehicle type, the association between driver sex and vehicle type may result in some confounding of vehicle type effects (e.g., vehicle size). The consistency of this effect, which was not observed in either the MY 17-21 or MY 18-22 analysis, should continue to be monitored in future efforts.

---

[13] Rear Vision Camera includes the Front Curb View and Rear Trailer View features.

[14] Rear Park Assist includes the Rear Park Assist, Front and Rear Park Assist, Automatic Park Assist with Steering, and Enhanced Automatic Park Assist features.

Discussion

Summary of GM ADAS Effectiveness Crash Prevention (“All Crashes”) Findings

Results for the crash prevention (“all crashes”) analyses are shown in Table 19, which provides the percent effectiveness for ADAS features designed to address forward or lateral crashes. A breakdown is provided for GM MY 19-23 (the current analysis), 2018-2022 (Leslie et al., 2024), and 2017-2021 (Leslie et al., 2024) findings. Overall, the current GM MY 19-23 results are very consistent with the pattern of statistical significance and the magnitude of the effectiveness levels observed in the recent GM MY 17-21 (Leslie et al., 2023) and MY 18-22 (Leslie et al., 2023) studies.

The forward collision systems evaluated were found to be quite effective at reducing rear-end striking crashes, with the AEB feature (which includes FCA functionality) producing approximately two to three times higher reductions in rear-end striking crashes than the “alert only” camera FCA feature in both the crash prevention and injury-focused analyses. In the crash prevention analysis, the camera FCA, camera AEB, and fusion AEB features were found to be 17%, 39%, and 54% effective, respectively, at reducing rear-end striking crashes.

For features aimed at reducing lateral crashes, the LCA (with SBZA) feature was found to be 11% effective at reducing lane change crashes, while the less capable SBZA feature, which failed to yield benefits in the previous MY 17-21 and MY 18-22 analyses, was not evaluated. As with the more automated AEB versus FCA, the more automated LKA with LDW feature outperformed the “alert only” counterpart LDW feature. LKA with LDW was found to be 9% effective at reducing roadway departure crashes, and 6% effective at reducing same-direction sideswipe crashes. The non-significant 8% reduction observed for the opposite-direction sideswipe crash type is within the 7%-10% statistically significant levels observed in the MY 17-21 and MY 18-22 studies.

More generally, this pattern of results indicates that forward sensing features (i.e., AEB, FCA, and FPB) are providing higher effectiveness levels relative to lateral sensing features (i.e., LKA with LDW, LDW, LCA with SBZA, and SBZA). In addition, the lane departure-related results emphasize the importance of distinguishing between single vehicle (i.e., road departure) versus multi-vehicle (i.e., same- and opposite-direction sideswipe) crashes. Since the role of the equipped vehicle in multiple-vehicle lane departure crash cases is unclear (e.g., the other vehicle could have departed the lane and caused a caused the crash), more precise lane departure countermeasure effectiveness estimates are afforded with the single-vehicle road departure crash type.

Corresponding crash prevention (“all crashes”) results for ADAS backing features are shown in Table 20. It should be reminded that backing features are generally bundled, such that more advanced features nearly always include the less advanced backing features. For example, the RAB feature, which is the most advanced backing feature examined, is bundled with RCTA, RPA, and either RVC or SV. Furthermore, consistent with the MY18-22 backing analysis, “unequipped” is no longer used as reference category, since all GM vehicles have rear-looking camera features. Consequently, to make the numbers comparable to previous years, analyses were done using RVC as the reference category and the estimates were adjusted by 34% to reflect the most recent estimate of RVC effectiveness (over no backing feature) drawn from the MY17-21 analysis. Consistent with recent MY 17-21 and MY 18-22 efforts, Rear Park Assist (RPA), Rear Cross Traffic Alert (RCTA), and Reverse Automatic Braking (RAB) significantly reduced backing crashes by 51%, 57%, and 84%, respectively. These crash reduction benefits reveal a readily apparent “stack-up” effect indicating that system benefits generally increased as more advanced backing systems, which nearly always including each of the less advanced backing systems, were added. In addition, unlike in MY 17-21 and MY 18-22 efforts, driver sex was found to interact with backing feature type in the crash prevention ("all crashes") analysis, such that backing feature effectiveness for female drivers was 5% higher for RCTA and 23% higher for RPA.

Table 19 Estimated percent reductions in police-reported system-relevant crashes for forward collision, front pedestrian, lane departure, and lane change ADAS features for GM Model Year 2019-2023 vehicles. Shaded green cells denote statistical significance (p<0.

Advanced Driver Assistance System (ADAS) with Features Grouped by System-Relevant Crash Types	All Crashes		
	GM MY19-23	GM MY18-22	GM MY17-21
Forward Rear-End Crashes			
Camera Forward Collision Alert[15]	17%	16%	14%
Fusion Automatic Emergency Braking (with Forward Collision Alert and Adaptive Cruise Control)	54%	49%	49%
Camera Automatic Emergency Braking (with Forward Collision Alert)	39%	40%	40%
Front Pedestrian Crashes			
Front Pedestrian Braking[16]		31%	23%
Lane Departure-Same Direction Sideswipe Crashes			
Lane Departure Warning[17]	-10%	-8%	-5%
Lane Keep Assist (with Lane Departure Warning)	6%	8%	8%
Lane Departure-Opposite Direction Sideswipe Crashes (includes Head-On crashes)			
Lane Departure Warning[18]	6%	14%	9%
Lane Keep Assist (with Lane Departure Warning)	8%	10%	7%
Lane Departure-Single Vehicle Road Departure Crashes			
Lane Departure Warning[17]	-8%	-3%	-5%
Lane Keep Assist (with Lane Departure Warning)	9%	13%	15%
Lane Change Crashes			
Side Blind Zone Alert[18]		-7%	-4%
Lane Change Alert (with Side Blind Zone Alert)	11%	12%	15%

[15] For MY 19-23 analysis, the Forward Collision Alert feature is only evaluated for sedans and pickups.
[16] The injury criterion used for the Front Pedestrian Braking feature was KABC due to the rarity of pedestrian crashes coupled with the preponderance of injuries in such crashes.
[17] For MY 19-23 analysis, the Lane Departure Warning feature was only evaluated for pickups.
[18] For MY 19-23, the Side Blind Zone Alert feature not included in the analysis.

More generally, it should be noted that backing crashes are under-represented in police-report databases because these crashes tend to be fairly minor (below police-report level of damage) and often occur outside of police-report jurisdiction in parking lots and on private property. Consequently, outside of police-reported crashes, there is likely a substantial level of property damage-only which are being addressed by backing features evaluated. Although GM offers features that are relevant to low-speed forward parking crashes (e.g., Front and Rear Park Assist and Surround Vision Camera), the inconsistency of parking crash coding across state crash databases did not allow a reasonable evaluation of effectiveness levels for system-relevant forward parking crashes

Table 20 Estimated percent reductions in police-reported system-relevant crashes for forward collision, front backing ADAS features for GM Model Year 2019-2023 vehicles. Shaded green cells denote statistical significance (p<0.05).

Advanced Driver Assistance System (ADAS) Backing Features	All Crashes		
	GM MY 19-23	GM MY 18-22	GM MY 17-21
Rear Vision Camera	Reference[19]	Reference	34%
Rear Vision Camera Mirror			27%
Rear Park Assist (feature also included with Front and Rear Park Assist and Automatic Park Assist features)	51%	48%	49%
Rear Cross Traffic Alert (with either Rear Vision Camera or Surround Vision)	57%	59%	62%
Reverse Automatic Braking (with Rear Cross Traffic Alert, Rear Park Assist, and either Rear Vision Camera or Surround Vision)	84%	83%	85%

Summary of GM ADAS Effectiveness Injury-Focused Findings

Results for the injury-focused analyses are shown in

Table 21 for the current, MY 18-22, and MY 17-21 efforts. While the camera FCA, camera AEB, and fusion AEB features were found in the current analysis to be 17%, 39%, and 54% effective, respectively, at reducing all rear-end striking crashes in the crash prevention analysis, corresponding 28%, 47%, and 52% values were observed in the injury-focused (KAB) analysis. This pattern of results indicates that effectiveness levels for injury rear-end crashes is similar or higher than for all such crashes. This improved effectiveness provides compelling evidence that these forward collision features effectively mitigate (i.e., shift to lower severity) crashes that are not prevented by reducing impact speed through alerting the driver or automatic braking functionality. This pattern suggests that some rear-end striking crashes that might have otherwise involved reported injuries without FCA or AEB are being shifted to C-level (possible Injury) or O-level (property damage-only) crashes. The pattern of results for camera versus fusion AEB is consistent with the MY 17-21 and MY 18-22 studies indicating that: (1) unlike with fusion AEB, camera AEB provides a notable added crash mitigation effect, (2) the camera AEB feature provides comparable reductions in injury-producing rear-end crashes (hence, providing a lower cost alternative for addressing such crashes), and (3) given the increased effectiveness of fusion over camera

[19] Note that the backing feature estimates use the 34% estimated effectiveness for RVC as a correction factor to ensure comparability with the estimates from the previous MY 17-21 and MY 18-22 analysis.

AEB in the crash prevention analysis, overall, these results suggest fusion AEB outperforms camera AEB for (i.e., "C" and "O") injury-level crashes, perhaps due to increased sensing performance (e.g., range, adverse weather robustness).

Table 21 Estimated percent effectiveness for ADAS features in reducing rear-end and lane departure crashes in reducing system-relevant injury crashes for GM Model Year 2019-2023, 2018-2022, and 2017-2021 vehicles. Numbers in brackets indicate the change relative corresponding crash prevention analysis results.

Advanced Driver Assistance System (ADAS) with Features Grouped by System-Relevant Crash Types	Injury (KAB) Crashes		
	GM MY 19-23	GM MY 18-22	GM MY 17-21
Rear-End Crashes			
Camera Forward Collision Alert[16]	28% [+11%]	28% [+12%]	25% [+11%]
Fusion Automatic Emergency Braking (with Forward Collision Alert and Adaptive Cruise Control)	52% [-2%]	52% [+3%]	57% [+8%]
Camera Automatic Emergency Braking (with Forward Collision Alert)	47% [+8%]	51% [+11%]	53% [+13%]
Front Pedestrian Crashes			
Front Pedestrian Braking[17]	25% [-3%] (uses KABC criterion)		
Lane Departure-Same Direction Sideswipe Crashes			
Lane Departure Warning [18]	-30% [-20%]	-2% [+4%]	1% [+6%]
Lane Keep Assist (with Lane Departure Warning)	-1% [-7%]	5% [-3%]	9% [+1%]
Lane Departure-Opposite Direction Sideswipe Crashes (includes Head-On crashes)			
Lane Departure Warning [18]	-13% [-7%]	-2% [-16%]	-1% [-10%]
Lane Keep Assist (with Lane Departure Warning)	7% [-1%]	9% [-1%]	2% [-5%]
Lane Departure-Single Vehicle Road Departure Crashes			
Lane Departure Warning[18]	-25% [-17%]	-11% [-8%]	-6% [-1%]
Lane Keep Assist (with Lane Departure Warning)	8% [-1%]	19% [+6%]	22% [+7%]

The other forward-sensing feature evaluated, FPB, was found to be 25% effective in the injury-focused (KABC) analysis. These effectiveness levels are within the 23%-32% crash prevention ("all crashes") reductions observed in the MY 17-21 and MY 18-22 efforts. Despite the known limitations of this feature under nighttime conditions, and consistent with these recent efforts, no significant interactions were observed in this analysis with potentially confounding factors such as light condition. This could be due to the low pedestrian crash sample. Unlike the MY 17-21 and MY 18-22 findings indicating that LKA with LDW reduced single vehicle road departure crashes in the injury-focused (KAB) analysis by 19%-22%, such a benefit failed to be observed in the current effort. One possible explanation for this inconsistency is that a change in the crash definition was made which resulted in reduced crash data volumes. This change involved using a pre-crash movement police report variable which required that the vehicle be traveling straight ahead, navigating a curve, or accelerating or slowing in lane, which effectively excluded a number of maneuvers (such as turning). This crash definition change was made to better focus the results on the addressable portion of the system-relevant crash problem and to align with similar PARTS (2022, 2025) analyses. In any case, the reason for this LKA with LDW benefit inconsistency is unclear and should continue to be monitored in future analyses. More generally, results from Flannagan et al. (2016)) suggest that the relatively low usage of the LDW (compared to FCA and AEB) feature may be an important limiting factor in obtaining higher lane departure-related crash prevention and crash mitigation benefits.

Comparing Current GM versus MITRE (Across OEM) ADAS Effectiveness Findings

Table 22 provides a comparison of the current ADAS effectiveness findings to similar "across OEM" MITRE (2023) and MITRE (2025) efforts. This older MITRE (2023) effort included OEMs representing more than 65% of the 2021 U.S. market for sales of passenger cars and light commercial vehicles, including Honda, General Motors, Mazda, Mitsubishi, Nissan, Stellantis, Subaru, and Toyota (Statista, 2021). (Hyundai vehicles were added in MITRE (2025) effort.). This comparison indicated that the pattern of effectiveness findings is generally consistent across the FCA, AEB, LDW, and LKA with LDW features. However, for the Front Pedestrian Braking feature, GM effectiveness levels for the injury-focused KABC analysis were notably higher (25% versus 9%) than those reported by MITRE (2025).

Concluding Remarks: Working Toward a Zero Crashes Vision

As in the previous long-running series of GM ADAS field effectiveness studies UMTRI has conducted with GM, the wide variety of ADAS features evaluated in the current MY 19-23 effort provide further widespread evidence of the substantial crash prevention and injury reduction (crash mitigation) safety benefits afforded by these features. For example, these findings support increased roll-out and development of ADAS features that provide some degree of automated control, since such features consistently outperform "alert only" feature counterparts (e.g., AEB with FCA versus FCA only, LKA with LDW versus LDW only, RAB versus other ADAS backing features). Although ADAS features require the driver to always remain attentive to driving, features that provide automatic vehicle control in potential crash situations have the distinct advantage of not strictly relying on drivers to respond to alerts in a timely and appropriate fashion, as imminent crash situations can unfold quickly. Note that drivers can always override ADAS-related automatic control, so attentive driving is still required to receive the full benefit of the systems.

In addition, these results suggest prioritized efforts for further addressing lane departure crashes, given the high levels of injury associated with such crashes (as discussed below). Effectiveness levels of lane departure features are likely being limited by lower customer use (Flannagan et al., 2016). While emerging SAE Level 2 partial driving automation features combining ACC and lane centering functionality, such as Super Cruise, have the potential to help address lane departure crashes, evaluating such benefits is currently challenging from a statistical power standpoint (see Leslie et al., 2022, 2025).

Table 22 Estimated percent effectiveness for ADAS features in reducing system-relevant crashes (i.e., all such crashes) and injury (KAB) crashes for GM Model Year 2019-2023 and MITRE (Across OEM) Model Year 2015-2020 and 2015-2023 vehicles. Shaded green cells de

		Percent Reductions in System-Relevant Crashes Across Police-Reported KABCO Injury-Severity Levels						
		GM MY 2019-2023		MITRE MY 2015-2020			MITRE MY 2015-2023	
System-Relevant Crash Type	ADAS Feature	All Crashes	Injury KAB Crashes	All Crashes	Injury KABC Crashes	Injury KA Crashes	All Crashes	Injury KABC Crashes
Rear-End	Forward Collision Alert[16]	17% (camera)	28% (camera)	16% (across tech.)	19% (across tech.)	21% (across tech.)		
Rear-End	Automatic Emergency Braking (with Forward Collision Alert)	54% (fusion) 39% (camera)	52% (fusion) 47% (camera)	49% (across tech.)	53% (across tech.)	42% (across tech.)	49% (across tech.)	
Front Pedestrian	Front Pedestrian Braking[17]		25% (uses KABC criterion)		4%	2%		9%
Single-Vehicle Road Departure	Lane Departure Warning[17]	-8%	-25%	3%	5%	5%	2%	
Single-Vehicle Road Departure	Lane Keep Assist (with Lane Departure Warning)	9%	8%	8%.	7%.	13%	5%	

From the perspective of identifying feature improvement and new feature development opportunities, a mapping of the Swanson et al. (2019) "36 crashes" taxonomy against the nationally-based Crash Report Sampling System (CRSS) 2016-2020 dataset indicated 12 crash types accounted for 80% of the combined "K" (fatal) and "A" (suspected serious injury) police-reported KABCO counts. Six of these 12 crash types were addressed (with varying levels of effectiveness) by the forward collision, lane departure, pedestrian, and lane change features examined in the current effort.[20] The remaining six encompassed control loss, pedalcyclist (bicyclist), opposite direction/no maneuver (includes head-on crashes), and

[20] Note that countermeasures addressing these 12 high harm crash types should also generally benefit closely related lower harm crash type variations identified in Swanson et al. (2019). For example, rear-end striking crashes have five variations, three of which were part of the high harm crash type set.

three intersection crash types (straight crossing paths, left turn across path/opposite direction, and left turn across path/lateral direction).

In closing, we recommend continuing this series of ADAS feature effectiveness studies, working to leverage additional state crash databases, and further developing telematics-based capabilities (e.g., crash- and feature usage-related data) to augment and potentially expedite ADAS feature effectiveness efforts. More generally, when considering traffic safety from a more holistic Safe System Approach, there remain significant opportunities beyond ADAS features for accelerating zero crashes vision progress, including addressing driver behavior choices (e.g., seat belt use, speeding, and impairment due to alcohol, drugs, drowsiness, or distraction) and implementing roadway safety countermeasures (e.g., roundabouts, walkways, and bicycle lanes).

References

Cicchino, Jessica B. (2018a, September). Real-world effects of General Motors Forward Collision Alert and Front Automatic Braking Systems. Arlington, VA: Insurance Institute for Highway Safety

Cicchino, J. B. (2018b). Effects of lane departure warning on police-reported crash rates. *Journal of safety research*, *66*, 61-70.

Cicchino, Jessica B. (2019a). Real-world effects of rear automatic braking and other backing assistance systems. *Journal of Safety Research*, *68*, 41-47.

Cicchino, Jessica B. (2019b). Real-world effects of rear cross-traffic alert on police-reported backing crashes. *Accident Analysis & Prevention*, *123*, 350-355.

Cicchino, Jessica B. (2022). Effects of automatic emergency braking systems on pedestrian crash risk. *Accident Analysis & Prevention, 172,* 106686*.*

Cicchino, J.B. (2023). Effects of forward collision warning and automatic emergency braking on rear-end crashes involving pickup trucks. *Traffic Injury Prevention, 24,* 293-298.

Dang, J. N. (2007). Statistical analysis of the effectiveness of electronic stability control (esc) systems-final report (No. HS-810 794).

Flannagan, C. A., Kiefer, R. J., Bao, S., LeBlanc, D. J., and Geisler, S. P. (2014) Reduction of Backing Crashes by Production Rear Vision Camera Systems. *J Ergonomics S3:008. doi: 10.4172/2165-7556.S3-008*

Flannagan, C. A., LeBlanc, D.J., Kiefer, R.J., Bogard, S., Leslie, A. J., Zagorski, C.T., Zimmerman, C.W., Materna, W.S., and Beck, C.S. (2016). Large-scale field test of forward collision alert and lane departure warning systems (Report No. DOT HS 812 247). Washington, DC: National Highway Traffic Safety Administration.

Flannagan, C. A., and Leslie, A. J. (2020). *Crash Avoidance Technology Evaluation Using Real-World Crash Data* (No. DOT HS 812 841). United States. Department of Transportation. National Highway Traffic Safety Administration.

Keall, M., & Newstead, S. (2009). Selection of comparison crash types for quasi-induced exposure risk estimation. *Traffic injury prevention*, *10*(1), 23-29.

LeBlanc, D., Bogard, S., Nobukawa, K., Narayanaswamy, P., Leslie, A., ... Lobes, K. (2016, February). Field Study of Light Vehicle Crash Avoidance Systems Phase II: Automatic Emergency Braking (AEB) and Dynamic Brake Support (DBS). (Report No. DOT HS 812 615). Washington, DC: National Highway Traffic Safety Administration.

Leslie, A. J., Kiefer, R.J, Flannagan, C.A., Owen, S.H., and Schoettle, B.A. (2024). *Analysis of the Field Effectiveness of General Motors Model Year 2018-2022 Advanced Driver Assistance System Features*. University of Michigan, Ann Arbor, Transportation Research Institute. UMTRI-2024-05.

Leslie, A. J., Kiefer, R. J., Flannagan, C. A., Owen, S. H., Schoettle, B. A. (2023). *Analysis of the Field Effectiveness of General Motors Model Year 2017-2021 Advanced Driver Assistance System Features*. University of Michigan, Ann Arbor, Transportation Research Institute. UMTRI-2023-1.

Leslie, A. J., Kiefer, R. J., Flannagan, C. A., Owen, S. H., Schoettle, B. A. (2022). *Analysis of the Field Effectiveness of General Motors Model Year 2013-2020 Advanced Driver Assistance System Features*. University of Michigan, Ann Arbor, Transportation Research Institute. UMTRI-2022-2.

Leslie, A. J., Kiefer, R., Flannagan, C., Schoettle, B., and Owen, S. (2022). *Analysis of Field Effects Associated with the GM Super Cruise System*. University of Michigan, Ann Arbor, Transportation Research Institute. UMTRI-2022-3.

Leslie, A. J., Kiefer, R. J., Meitzner, M. & Flannagan, C. A. (2019). *Analysis of the Field Effectiveness of General Motors Production Active Safety and Advanced Headlighting Systems*. University of Michigan, Ann Arbor, Transportation Research Institute. UMTRI-2019-6.

Leslie, A. J., Kiefer, R. J., Meitzner, M. & Flannagan, C. A. (2021). Field effectiveness of General Motors advanced driver assistance and headlighting systems. *Accident Analysis and Prevention*, *159,* 106275.

Leslie, A. J., Kiefer, R.J, Owen, S.H., and Flannagan, C.A. (2025). Examination of General Motors Super Cruise System Field Effects Using State Police Report Crash Data, *Journal of Safety Research, 92,* 207-216.

Massie, D.L., Campbell, K.L., Williams, A.F., 1995. Traffic accident involvement rates by driver age and gender. *Accident Analysis and Prevention, 27 (1),* 73–87.

Michigan Traffic Crash Facts. *Worst injury in accident 2016-2020*. Michigan Office of Highway Safety Planning. Accessed Jan 2022. https://www.michigantrafficcrashfacts.org/querytool/table/0#q1;0;2020,2019,2018,2017,2016.

MITRE (2022). *Real-world Effectiveness of Model Year 2015–2020 Advanced Driver Assistance Systems*. MITRE Partnership for Analytics Research Partnership (PARTS). Retrieved from: https://www.mitre.org/news-insights/publication/real-world-effectiveness-model-year-2015-2020-advanced-driver-assistance].

MITRE (2025). *A Study on the Real-world Effectiveness of Model Year 2015–2020 Advanced Driver Assistance Systems*. MITRE Partnership for Analytics Research Partnership (PARTS). Retrieved from: https://www.mitre.org/sites/default/files/2025-01/PR-25-0114-Study-Real-world-Effectiveness-Model-year-2015%E2%80%932023-ADAS.pdf

Najm, W.G., Smith, J.D., and Yanagisawa, N. (2007). *Statistics of light-vehicle pre-crash scenarios based on 2011-2015 national crash data* (Report No. DOT HS 810 767). Washington, DC: National Highway Traffic Safety Administration.

Sivinski, R. (2011). Crash prevention effectiveness of light-vehicle electronic stability control: an update of the 2007 NHTSA Evaluation (No. HS-811 486).

Swanson, E., Foderaro, F., Yanagisawa, M., Najm, W. G., & Azeredo, P. (2019, August). *Statistics of light-vehicle pre-crash scenarios based on 2011-2015 national crash data* (Report No. DOT HS 812 745). Washington, DC: National Highway Traffic Safety Administration.