Analysis of the Field Effectiveness of General Motors Model Year 2018-2022 Advanced Driver Assistance System Features

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Executive Summary

Background and Methodological Approach

This effort is the sixth in a series of studies examining the field effectiveness of various GM Advanced Driver Assistance Systems (ADAS) features aimed at addressing a wide range of system-relevant crash types. The current updated GM MY 18-22 study employed VIN-linked feature ADAS content data from 13,240,512 vehicles across all GM brands (i.e., Buick, Cadillac, Chevrolet, and GMC). These data were matched to police report crash data from 15 states, which resulted in 654,129 matched crash cases.

ADAS feature effectiveness (i.e., percent reductions in system-relevant crashes) was estimated using "quasi-induced exposure" logistic regression. This method compares system-relevant and system-irrelevant (referred to as "control") crash counts for equipped and unequipped vehicles. This controls for the lack of traditional exposure data (e.g., miles traveled) by selecting control crashes that should be unaffected by the feature examined (i.e., control crashes should occur at a similar rate in both ADAS equipped and unequipped vehicle populations). The logistic regression estimates were made adjusting for various covariates, including driver demographics (age and gender), speed limit, driver behavior (alcohol, fatigue, and distraction presence), driving context (weather, road, and road surface conditions), crash year, model year, and vehicle type/model.

For the forward collision and lane departure features examined, sample sizes were large enough to support additional analyses of feature effectiveness for a more restricted set of crashes coded by the police to have "suspected injury" or higher injury severity for anyone involved in the crash (defined as "K", "A" or "B" on the KABCO injury scale), which will be referred to in the summary below simply as the "injury" analysis. This injury-focused analysis can be contrasted with the "all crashes" analysis, which did not consider the police-reported injury level.

High-Level Summary of GM ADAS Feature Effectiveness

Figure ES 1 below provides a high-level summary of ADAS feature effectiveness results found to be statistically significant for reducing system-relevant crashes, with results for the injury-focused analyses shown parenthetically in red. Percent effectiveness is relative to system-relevant crash types that the feature is designed to address. Non-significant results are included in the results section below.

Table ES-1 summarizes the estimated effectiveness of ADAS features designed to address forward or lateral crashes compared to prior studies. Overall, results from the current study are similar, except for the Lane Departure Warning (LDW) feature, which is being phased out by GM and is being replaced by the Lane Keep Assist (LKA) with LDW feature. In both the current and the MY17-21 efforts, the LDW feature did not produce significant benefits, which is attributed to changes across model years in the LDW-equipped penetrations. LDW effectiveness was a small but significant 4% in the MY 13-20 analysis.

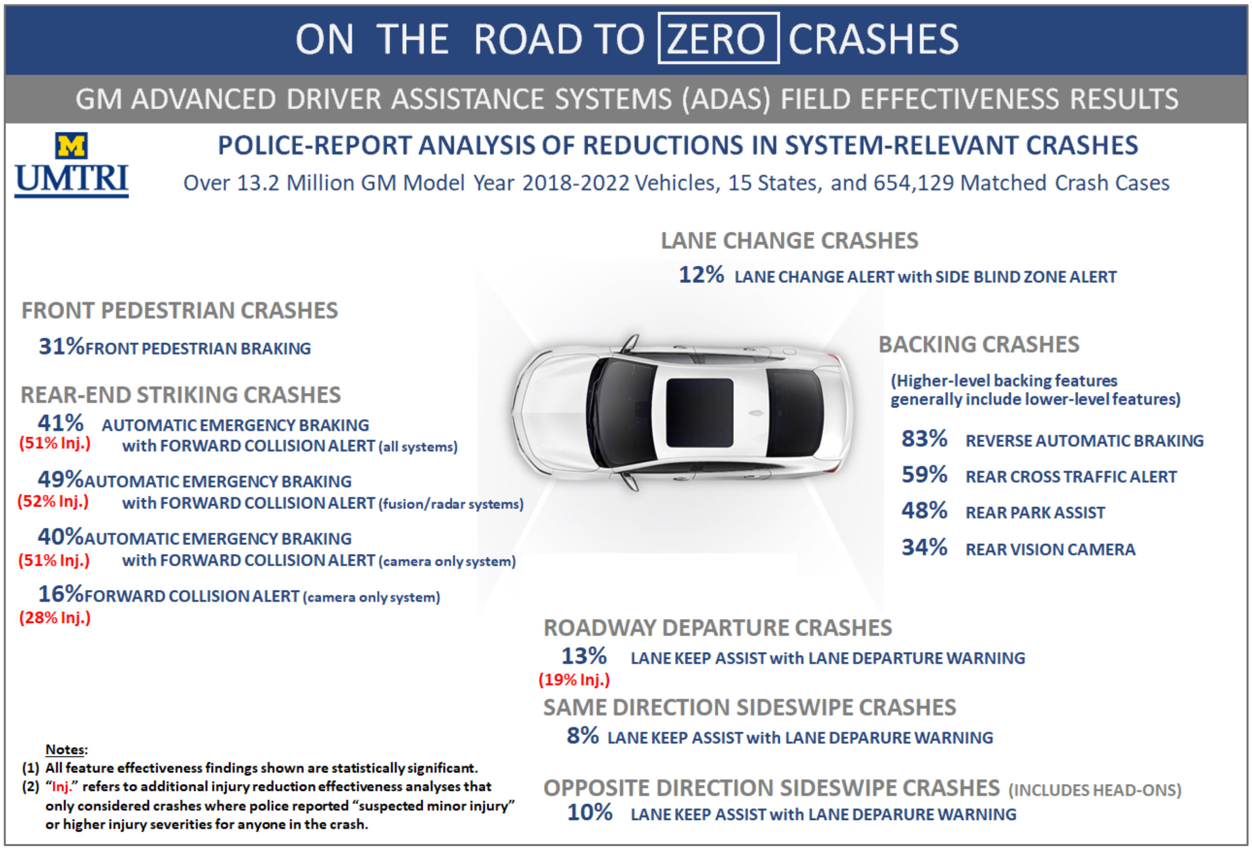
In the current analysis, the forward collision systems were found to be quite effective at reducing rear-end striking, with the more automated Automatic Emergency Braking (AEB) features producing greater benefit than the alert-only camera Forward Collision Alert (FCA) feature. Radar/fusion AEB systems were 49% effective, with camera-based AEB estimates lower at 40% effective. In contrast, the camera FCA feature was found to be 16% effective on rear-end striking crashes.

There was also a significant interaction between the type of forward collision prevention system and vehicle type. Similar to earlier analyses, the most notable differences occur in the AEB systems where larger vehicles (trucks and large SUVs) have lower system benefits than smaller vehicles (sedans and small/medium SUVs).

The Front Pedestrian Braking (FPB) feature was observed to reduce pedestrian crashes by 31%, which is somewhat higher than the MY17-21 estimate of 23% (though within the confidence interval from that study). Despite the known limitations of this feature under nighttime conditions, no significant interactions with light condition were identified in this analysis, which could be related to the relatively low sample of pedestrian crashes.

Lateral systems were generally less effective than forward collision systems, but the more automated LKA with LDW feature produced significant reductions in roadway departure, same-direction sideswipe, and opposite-direction sideswipe crashes (the latter of which includes head-on crashes) by 13%, 8%, and 10%, respectively. This pattern of lane departure countermeasure results emphasizes the importance of measuring effects using crash types that distinguish between single- and multi-vehicle crashes. Since the role of the equipped vehicle is less clear in multiple-vehicle lane departure crashes (e.g., the other vehicle could have left its lane and caused the crash), effectiveness estimates for single vehicle road departures (13%) may provide a more accurate assessment of feature effectiveness.

Figure ES 1 Estimated statistically significant percent reductions in system-relevant crashes for various GM Advanced Driver Assistance Systems (ADAS) when considering all system-relevant crashes, as well as when considering only system-relevant injury crashes (injury analysis restricted to rear-end striking and lane departure crashes).



ON THE ROAD TO ZERO CRASHES

GM ADVANCED DRIVER ASSISTANCE SYSTEMS (ADAS) FIELD EFFECTIVENESS RESULTS

UMTRI

POLICE-REPORT ANALYSIS OF REDUCTIONS IN SYSTEM-RELEVANT CRASHES

Over 13.2 Million GM Model Year 2018-2022 Vehicles, 15 States, and 654,129 Matched Crash Cases

FRONT PEDESTRIAN CRASHES

31% FRONT PEDESTRIAN BRAKING

REAR-END STRIKING CRASHES

41% (51% Inj.) AUTOMATIC EMERGENCY BRAKING with FORWARD COLLISION ALERT (all systems)

49% (52% Inj.) AUTOMATIC EMERGENCY BRAKING with FORWARD COLLISION ALERT (fusion/radar systems)

40% (51% Inj.) AUTOMATIC EMERGENCY BRAKING with FORWARD COLLISION ALERT (camera only system)

16% (28% Inj.) FORWARD COLLISION ALERT (camera only system)

LANE CHANGE CRASHES

12% LANE CHANGE ALERT with SIDE BLIND ZONE ALERT

BACKING CRASHES

(Higher-level backing features generally include lower-level features)

83% REVERSE AUTOMATIC BRAKING

59% REAR CROSS TRAFFIC ALERT

48% REAR PARK ASSIST

34% REAR VISION CAMERA

ROADWAY DEPARTURE CRASHES

13% (19% Inj.) LANE KEEP ASSIST with LANE DEPARTURE WARNING

SAME DIRECTION SIDESWIPE CRASHES

8% LANE KEEP ASSIST with LANE DEPARURE WARNING

OPPOSITE DIRECTION SIDESWIPE CRASHES (INCLUDES HEAD-ONS)

10% LANE KEEP ASSIST with LANE DEPARURE WARNING

Notes:

(1) All feature effectiveness findings shown are statistically significant.

(2) "Inj." refers to additional injury reduction effectiveness analyses that only considered crashes where police reported "suspected minor injury" or higher injury severities for anyone in the crash.

Table ES-1 Estimated percent reductions in system-relevant crashes for GM Advanced Driver Assistance System (ADAS) features related to forward and lateral crashes. (Note AEB includes FCA and shaded green cells denote statistically significant effects.)

GM ACTIVE SAFETY FEATURE	GM MY18-22 Crashes (CURRENT ANALYSIS)	GM MY17-21 Crashes	GM MY13-20 Crashes
FORWARD COLLSISION			
Camera Forward Collision Alert (FCA)	16%	14%	20%
Radar/Fusion AEB with ACC (Adaptive Cruise Cruise)	49%	49%	45%
Camera AEB	40%	40%	40%
Front Pedestrian Braking (FPB)	31%	23%	23%
LANE DEPARTURE – SAME DIRECTION SIDESWIPE			
Lane Departure Warning (LDW)	-8%	-5%	4%
Lane Keep Assist (LKA) with LDW	8%	8%	10%
LANE DEPARTURE – OPPOSITE DIRECTION SIDESWIPE (INCLUDES HEAD-ON CRASHES)			
Lane Departure Warning (LDW)	14%	9%	5%
Lane Keep Assist (LKA) with LDW	10%	7%	8%
LANE DEPARTURE – SINGLE VEHICLE ROAD DEPARTURE			
Lane Departure Warning (LDW)	-3%	-5%	8%
Lane Keep Assist (LKA) with LDW	13%	15%	17%
LANE CHANGE			
Side Blind Zone Alert (SBZA)	-7%	-4%	7%
Lane Change Alert (LCA) with SBZA	12%	15%	16%

For lane-change crashes, the Lane Change Alert (LCA) with Side Blind Zone Alert (SBZA) feature was 12% effective. SBZA alone, which has substantially lower detection ranges than LCA, was not found to be significant, consistent with previous findings.

Table ES-2 shows the results for the ADAS features aimed at addressing backing crashes. Backing features are generally bundled such that more advanced features also include the less advanced features. For example, Rear Automatic Braking (RAB), the most automated backing feature examined, is bundled with Rear Cross Traffic Alert (RCTA), Rear Park Assist (RPA), and either Rear Vision Camera (RVC) or Surround Vision (SV). In recent model years, all vehicles have some type of rear-crash-prevention system, so it is no longer possible to use “no backing system” as a reference category. For this year, analyses were done using RVC as the reference category and the estimates were adjusted by 34%, the most recent estimate of RVC effectiveness (over no system), to make the numbers comparable to previous years. Overall, a distinct stack-up effect is observed under which RPA, RCTA, and RAB significantly reduced backing crashes by 48%, 59%, and 83%, respectively (relative to having no system).

It should also be noted that relative to other crash types observed, backing crashes are known to be under-represented in police-report databases as they often occur off public roads (e.g., on private property or in parking lots) or do not reach reporting thresholds (e.g., minor crashes not causing property damage or simply not reported to the police). Consequently, with respect to the number of backing crashes being reduced by backing features in the field, there are likely substantially more "property damage only" crashes that are not being captured in police report data collection.

Furthermore, it should also be noted that although GM offers features that are relevant to low-speed forward parking crashes (e.g., Front and Rear Park Assist), the inconsistency of parking crash coding across state crash databases did not allow a reasonable evaluation of effectiveness levels for such features in reducing such forward parking crashes.

Table ES-2 Estimated percent reductions in system-relevant (target) crashes for GM Advanced Driver Assistance System (ADAS) features related to backing crashes. (Note shaded green cells denote statistically significant effects.)

GM ACTIVE SAFETY FEATURE	GM MY18-22 Crashes (CURRENT ANALYSIS)	GM MY17-21 Crashes	GM MY13-20 Crashes
BACKING (note more advanced backing features generally include less advanced backing features)			
Rear Vision Camera (RVC)	Reference[1]	34%	32%
Rear Vision Camera Mirror (RVC Mirror)	Reference[1]	27%	33%
Rear Park Assist (RPA, Front & Rear PA or Automatic PA 2)	48%	49%	41%
Rear Cross Traffic Alert (RCTA) with RVC/ Surround Vision (SV)	59%	62%	59%
Reverse Automatic Braking (RAB) with RVC/SV & RPA & RCTA	83%	85%	83%

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[1] Note that the backing system estimates use the 34% estimated effectiveness for RVC as a correction factor to ensure comparability with the estimates from previous studies. Additionally, RVC Mirror was merged with RVC due to confounding with the van vehicle type (see Results below).

Table ES-3 Summary of effectiveness of forward collision and lane departure-related GM Advanced Driver Assistance System (ADAS) features for the injury-focused analysis. (Note AEB includes FCA and shaded green cells denote statistically significant effects.)

GM ACTIVE SAFETY FEATURE	GM MY18-22 (CURRENT ANALYSIS)	GM MY18-22 Injury-Focused (CURRENT ANALYSIS)	GM MY17-21	GM MY17-21 Injury-Focused
FORWARD COLLISION				
Camera Forward Collision Alert (FCA)	16%	28%	14%	25%
Radar/Fusion AEB with ACC (Adaptive Cruise Control)	49%	52%	49%	57%
Camera AEB	40%	51%	40%	53%
LANE DEPARTURE - SAME DIRECTION SIDESWIPE				
Lane Departure Warning (LDW)	-8%	-2%	-5%	1%
Lane Keep Assist (LKA) with LDW	8%	5%	8%	9%
LANE DEPARTURE - OPPOSITE DIRECTION SIDESWIPE (INCLUDES HEAD-ON CRASHES)				
Lane Departure Warning (LDW)	14%	-2%	9%	-1%
Lane Keep Assist (LKA) with LDW	10%	9%	7%	2%
LANE DEPARTURE - SINGLE VEHICLE ROAD DEPARTURE				
Lane Departure Warning (LDW)	-3%	-11%	-5%	-6%
Lane Keep Assist (LKA) with LDW	13%	19%	15%	22%

For the forward collision and lane departure features examined, sample sizes were large enough to support an additional analysis focusing only on crashes involving injury. In state police reports, crash injuries are coded using the KABCO scale, which ranks injury on a five-level scale of “Fatal Injury (K)”, “Suspected Serious Injury (A)”, “Suspected Minor Injury (B)”, “Possible Injury (C)”, and “No Apparent Injury (O)”. For the injury analyses, only crashes with a “K”, “A”, or “B” on the KABCO rating were included. This analysis can be contrasted with the more general analysis approach described above, which included “all crashes” irrespective of the police-reported injury levels.

Table ES-3 presents the effectiveness estimates for the injury-focused analyses next to those for all crashes. In addition, the corresponding injury-focused results from the MY 17-21 analysis are provided for reference. Across all front collision systems examined, effectiveness for injury crashes is similar to or higher than that for all crashes. This improved effectiveness in crashes that police report as most severe provides compelling evidence that ADAS features effectively mitigate (i.e., shift to lower severity) some crashes that are not prevented by reducing impact speed through alerting the driver or automatic braking. This pattern suggests that some rear-end striking crashes that might have otherwise involved reported K-, A-, or B-injuries without FCA and/or AEB are being shifted to C-level injury or property damage-only crashes.

In the lateral collision injury-focused analysis, the only significant effect observed was for LKA with LDW on single vehicle road departure crashes, where the effectiveness was higher than in the all crashes case. As discussed above, this crash type can be more straightforward to interpret than two-vehicle same and opposite direction sideswipe crashes (where the role of the equipped vehicle is less clear).

Concluding Remarks: Working Toward a Zero Crashes Vison

The current effort not only quantifies the substantial crash reduction and crash mitigation (injury reduction) benefits afforded by a wide variety of production GM ADAS features, but also identifies potential strategies for moving closer toward a Zero Crashes vision. For example, the analysis suggests benefit from offering ADAS features that provide some degree of automated control (in addition to alerts), since such features consistently outperformed their less advanced "alert only" counterparts (e.g., AEB versus FCA, LKA with LDW versus LDW only). The results also highlighted the need to address lane departure and lane change crashes at higher levels of effectiveness, some of which may be achieved through higher levels of customer use.

When evaluating Zero Crashes vision progress, it should be remembered that overall crash reduction and crash mitigation benefits are determined by several factors, including the prevalence of the system-relevant crash, the feature effectiveness (which incorporates feature usage), and feature penetration across the entire fleet (not just the GM portion of the fleet). For example, based on Swanson et al. (2019)'s analysis of a national dataset of police-reported crashes, the current set of features examined have the maximum potential (i.e., if 100% effective) to address approximately 55.4% of all police-reported crashes in the US and 60.3% of fatal crashes. If we further assume that that the entire US fleet were equipped with the GM radar/fusion AEB, LKA (with LDW), LCA (with SBZA) and RAB (with RPA and RCTA) features examined here at their estimated effectiveness rates shown in Table ES-1, approximately 33.6% of addressable police-reported crashes, and 19.1% of all police-reported crashes, are estimated to be prevented.[2]

More generally, there remain significant opportunities for moving toward zero crashes beyond improving or expanding the ADAS features examined here, including increasing seat belt use, improving driver behavior (e.g., reducing speeding, alcohol or drug impairment, drowsiness, and distraction), and addressing additional crash configurations (e.g., intersection crashes). Going forward, we recommend continuing this series of ADAS feature effectiveness studies, leveraging additional state crash databases as they become available to researchers, and exploring the use of telematics-based data (such as GM's OnStar low-level EDR and AACN data). Telematics data could enhance GM's understanding of feature usage surrounding the crash and potentially enable more timely access to vehicle-generated crash data. Telematics-based crash data can be contrasted with state agency police report data, which often involve 1- to 2-year reporting delays but also provide more detailed data surrounding crash circumstances. Finally, we also recommend using these large-scale field effectiveness estimates for informing New Car Assessment Program (NCAP) decision-making and feature content planning.

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[2] These calculations are derived from the 2021 Crash Report Sampling System and the crash typology devised by Swanson, et al. (2019). For this calculation assume that: radar/fusion AEB applies to all rear-end crash types (20-24); LKA with LDW applies to drifting (17), opposite direction (18-19) and road departure (4-5) crashes; LCA with SBZA applies to lane change crashes (16); RAB (with RPA and RCTA) applies to the road departure backing (6) and back into vehicle (13) crash types.

Introduction

This report describes the sixth in a series of field effectiveness studies examining a wide range of Advanced Driver Assistance Systems (ADAS) offered on General Motors (GM) production vehicles. Across these studies, we have continued to increase the number of vehicles, models, vehicle types and features analyzed. Although safety features can be motivated by harm reduction opportunities apparent in the field (Najm, Smith, and Yanagisawa, 2007; Swanson et al., 2019), and evaluated in simulation, on test tracks, and on public roads, real-world crash data remains fundamental for understanding *achieved* ADAS safety benefits. Achieved safety benefits incorporate important real-world factors such as the extent to which drivers leave these features on, the demographics of drivers of ADAS-equipped vehicles, and the wide range of driving conditions experienced by drivers with these features.

In collaboration with GM and sponsored by the National Highway Traffic Safety Administration (NHTSA), Flannagan and Leslie (2020) conducted the first of this series of ADAS field effectiveness analyses examining GM Model Year 2013-2015 (MY 13-15) vehicles. In that study, police-reported crash data from 13 states was linked to over 1.2 million vehicles with known ADAS content provided by GM to UMTRI. The study used a method known as *quasi-induced exposure* (Keall & Newstead, 2009), where equipped and unequipped vehicles are compared on the rate of crashes that are specifically targeted by the feature (i.e., referred to here as “system-relevant” crashes) relative to system-irrelevant crashes unrelated to the function of a particular feature (referred to here as “control” crashes). These latter control crashes are used to control for crash exposure. Logically, the presence of a feature should reduce its system-relevant crashes more than non-system relevant crashes, whereas vehicles without the feature should have a “baseline” ratio of the two crash types (with the “baseline” ratio depending on the specific crash types involved.) Quasi-induced exposure has been used in other similar studies (e.g., Cicchino, 2018b; 2019b) and is the primary approach used when direct measures of exposure (e.g., distance traveled) are not available. Results from the initial police-report study (Flannagan and Leslie, 2020) indicated system-relevant crashes were reduced for GM’s Forward Collision Alert, Automatic Emergency Braking, Lane Keep Assist with Lane Departure, Rear Park Assist, Rear Cross Traffic Alert, and Reverse Automatic Braking features.

The original police report analysis was updated in 2019 (Leslie et al., 2019), 2020 (Leslie et al., 2021), 2021 (Leslie et al., 2022), and 2022 (Leslie, et al., 2023). In each study, newer crash and safety content data were added which, in general, resulted in larger matched sample sizes and smaller confidence intervals around the observed effectiveness estimates. (The 2022 effort was distinct here in that it dropped the oldest model years, MY 13-16, to improve representativeness which resulted in a small decrease in the analysis dataset compared to 2021.) Notably, the larger samples have enabled analysis of newer technologies (e.g., Front Pedestrian Braking; FPB) and more detailed crash types (e.g., three lane departure crash types). The magnitudes of the crash reduction effects for the various ADAS features examined in this sequence of police report analyses have been found to be largely consistent year to year.

As in the previous GM feature effectiveness studies, the goal of the project described in this report was to update GM feature effectiveness estimates by adding GM MY 22 vehicles with VIN-linked ADAS content, as well as incorporating more recent and newly available state crash police report data. As the sample size increases each year, both for vehicles and crashes, the ability to detect and accurately measure effectiveness improves. This analysis continues the process of “modernizing” the available GM VIN data by focusing on MY 18-22 vehicles. This continues to improve the correspondence between the VIN data and the current GM fleet by removing the portion of the VIN dataset that did not include all models (GM started providing all models with MY 20 with previous deliveries only including models that offered AEB) and phasing out models that are no longer offered and would not represent the current potential benefit of ADAS systems. Since older vehicles are more likely to fall into the “no ADAS” control groups, excluding them also avoids overestimation of system benefits that could arise from increased crash rates among older vehicles. However, excluding older vehicles also complicates some analyses. For example, in this iteration of the project the “no ADAS” control group was retired for the analysis of backing systems since the volume and distribution of vehicles without any relevant systems became impractically small.

Methods

Data

For this analysis, data on crash configurations and circumstances came from police crash reports obtained by UMTRI from 15 state agencies. These data were matched to a database provided by GM, which indicated for each Vehicle Identification Number (VIN) (i.e., each GM vehicle), the presence of various ADAS and headlighting feature content.

Advanced Driver Assistance Systems (ADAS) and Feature Data

The GM ADAS and headlighting content dataset (also referred to as “safety content”) contained VIN-linked data on 13,240,512 vehicles across all GM brands (i.e., Buick, Cadillac, Chevrolet, and GMC) and covered MYs 18-22. This five-year range is shifted one year relative to the previous MY 17-21 analysis, but still includes two years (MY 18 and 19) where GM did not provide data on all vehicle models. As touched upon earlier, the older vehicles were excluded in an effort to increase the representativeness of the analysis set of vehicles to the current GM fleet. The available VINs for MY 13-17 vehicles were disproportionately sedans, with truck models not added until MY 17, and include several discontinued models making them a poor representation of the current GM offerings. Additionally, earlier model years included system-vehicle type combinations that are no longer offered or offered at a high volume. (Most notably, the Lane Departure Warning without Lane Keep Assist feature was largely retired on SUVs across MY 16-17.) By removing the older vehicles, the analysis set is kept more modern and applicable to the fleet at large. A total of 1,745,180 MY 17 VINs used in the previous analysis were dropped for this iteration, but this analysis still saw an increase in total vehicles in the safety content dataset compared to the previous effort’s 11,266,320 vehicles.

Prior to MY 20, GM provided content data for a model/MY pair only when a (forward) Automatic Emergency Braking (AEB) feature was available on at least one trim level for that model/MY pair. Starting with the MY 20 dataset, this requirement was relaxed, allowing for the inclusion of a broader set of vehicles (including vans).

Two additional changes were made to the VIN data for this analysis. First, data on GMC Hummer EV Pickups were added to the dataset. Second, the Chevrolet Low Cab Forward was removed from the dataset as this is not considered a passenger vehicle. Table 1 shows the model-year range for each of the make-models included in the safety content dataset provided by GM to UMTRI. Table 2 summarizes the number of vehicles included for each model year.

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

Model Year (MY) Range	Models
2018-2019	Buick Lacrosse, Cadillac ATS, Cadillac CTS, Cadillac XTS, Chevrolet Cruze, Chevrolet Volt
2018-2020	Buick Regal, Cadillac CT6, Chevrolet Impala
2018-2022	Buick Acadia, Buick Enclave, Buick Envision, Cadillac Escalade, Cadillac XT5, Chevrolet Bolt, Chevrolet Equinox, Chevrolet Malibu, Chevrolet Silverado, Chevrolet Silverado HD, Chevrolet Suburban, Chevrolet Tahoe, Chevrolet Traverse, GMC Sierra, GMC Sierra HD, GMC Terrain, GMC Yukon, GMC Yukon XL
2019-2022	Cadillac XT4, Chevrolet Blazer, Chevrolet Spark
2020	Chevrolet Sonic
2020-2022	Buick Encore, Cadillac CT4, Cadillac CT5, Cadillac XT6, Chevrolet Camaro, Chevrolet Corvette, Chevrolet Colorado, Chevrolet Express, Chevrolet Silverado MD, Chevrolet TRAX, GMC Canyon, GMC Savana
2021-2022	Chevrolet Trailblazer
2022	GMC Hummer EV Pickup

Table 2 Vehicle count by Model Year

Model Year (MY)	Vehicle Count
2018	2,438,205
2019	2,085,087
2020	2,595,168
2021	2,402,680
2022	1,983,181

The ADAS features examined break down into those that are intended to help the driver avoid or mitigate forward (rear-end striking, front-to-rear), front pedestrian, lane departure, lane change, and backing crashes. Note that a given crash type may be addressed by multiple features. For example, forward rear-end striking crashes may be impacted by both the Automatic Emergency Braking and Forward Collision Alert features. The full list of features examined in this analysis is presented in Table 3, along with corresponding feature abbreviations used throughout this report. It is important to keep in mind that a number of these features have important relationships to each other, including dependencies, which are reflected in Table 3. In addition, certain features addressing different crash types were offered (or bundled) together in production (e.g., the Lane Keep Assist with Lane Departure Warning feature and the camera Forward Collision Alert features are co-dependent, Front Pedestrian Braking is only offered with the (forward) Automatic Emergency Braking (AEB) feature, Reverse Automatic Braking (RAB) implies the presence of forward AEB but not vice-versa, etc.). Where relevant, these relationships will be mentioned in the corresponding analysis discussion.

Table 3 Analysis group, feature evaluated, and feature abbreviations used in report

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

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[3] It should be noted that more advanced level backing/parking features generally include the functionality of less advanced backing/parking features.

Police Crash Report Data

UMTRI obtained data on police-reported crashes from 15 states that were able to provide full 17-character VINs for crash-involved vehicles. Table 4 shows the calendar years of the crash data provided to UMTRI from each of these states.

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

State	Calendar Years
Connecticut	2017 – Q3 2023
Florida[4]	2017 – Q1 2022
Idaho	2017 – July 2023
Kansas	2017 – July 2023
Louisiana	2017 – 2022
Maryland	2017 – August 2023
Michigan	2017 – 2022
Missouri	2017 – 2022
Ohio	2017 – July 2023
Nebraska[5]	2017 – 2020
South Dakota	2017 – 2022
Tennessee	2017 – July 2023
Texas	2017 – June 2023
Utah	2017 – 2022
Wisconsin	2017 – 2022

Matched Subset Data

After alignment of the crash data across the 15 states (see subsequent *Crash Definitions and Variable Creation* section), the resulting dataset was merged with the GM-provided VIN-linked safety content dataset to identify which vehicles were present in both the GM VIN and police report datasets. The result was 654,129 matches out of the approximately 13.2 million VINs in this GM content dataset (a 4.9% match rate). This represents an increase in matches of almost 9% relative to the MY 17-21 analysis and a larger matched dataset than any previous iteration of the analysis.[6] As shown in Table 5, the matched dataset is weighted towards older vehicles despite the available safety content data being weighted towards newer vehicles. This is largely due to the greater exposure of older vehicles to crashes (i.e., a MY 18 vehicle could have crashed anytime from 2017 to 2023 whereas a MY 22 vehicle must have crashed between 2021 and 2023). This pattern emphasizes the importance of removing the older vehicles since they had a great deal of exposure, increasing their influence on the matched crashes, but which are no longer representative of the current GM fleet overall.

As in previous studies, the matched data came predominantly from a small number of the available states. This was likely due to a combination of the range of police report data available to UMTRI, the

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[4] Due to changes in the data agreements required by Florida and the limited time available for data acquisition in this iteration of the project, it was not possible to update the available data.

[5] Due to a change to their data collection in 2021, Nebraska has not been able to provide crash data for 2021 or 2022.

[6] For brevity, in this report "previous" analyses or studies will refer to the series of GM ADAS feature effectiveness studies conducted by the authors of this report with the precise reference omitted (except for a Model Year range as appropriate. These reports are Flannagan & Leslie, 2020 and Leslie et al., 2019, 2020, and 2022, 2023.

state population, and GM vehicle sales in those states. Figure 1 provides the matched crash contribution levels for each of the 15 states included in the analysis, with darker shading indicating higher numbers of matched crashes. Florida, Michigan, and Texas contributed 61% of the matched crash dataset (17% FL, 18% MI, and 26% TX). The next highest volume state was Ohio with 8% of the dataset. This largely reflects the size of the states (e.g., FL and TX have the highest populations of the states available), the years of data available (e.g., in the previous study the matches from FL were closer to TX, but the FL data range was smaller for this study), and the GM sales penetration (e.g., MI produces matched crashes at a very high rate plausibly due to a larger market share).

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
2018	21.2	36.2
2019	18.1	24.1
2020	22.5	22.4
2021	20.9	13.1
2022	17.3	4.2

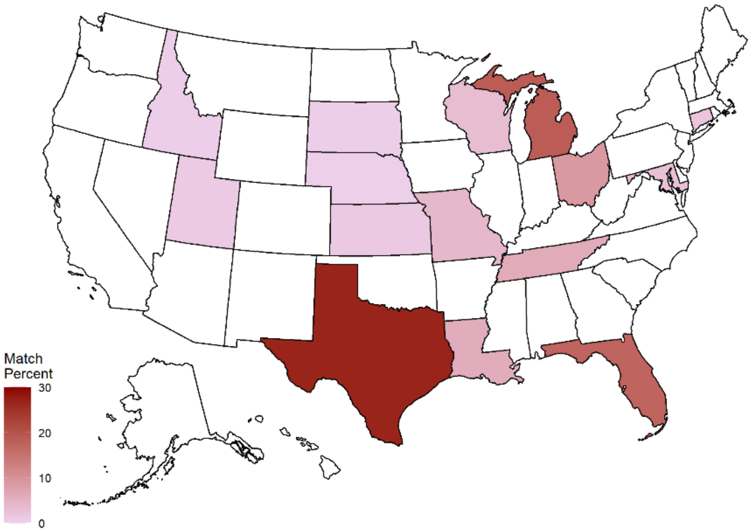

Figure 1 United States map showing the relative contribution levels of matched crashes from each of the 15 states used in this analysis

The progressive updating of the model year range continues to improve the representativeness of vehicle types in the matched dataset. Table 6 shows the distribution of vehicle types for the safety content database and the matched database and while sedans are still slightly overrepresented and trucks are still slightly underrepresented, the overall distribution is quite close. Notably the models are appropriately ordered, with small/medium utilities being the largest group, followed by trucks, sedans, large utilities, and vans, in that order.

Table 6 Percent of available and matched vehicles by vehicle type for the MY 18-22 study

Vehicle Type	Available MY 18-22	Matched MY 18-22	Difference
Sm./Med. Utility	38.7	39.1	+0.4
Truck	35.9	29.5	-6.4
Sedan	12.8	20.3	+7.5
Large Utility	10.8	10.0	-0.8
Van	1.8	1.1	-0.7

Analysis Structure

The analysis approach focused on identifying system-relevant crashes and associated control crashes that could be compared to determine the effectiveness of the feature evaluated. 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 feature and would, therefore, occur at a similar rate in both equipped and unequipped populations since these control crashes are assumed to occur randomly as exposure (i.e., vehicle miles traveled) increases (rather than due to particular driver actions). Conversely, the system-relevant crash is expected to be less frequent in the feature-equipped population relative to the control crash. The prevalence of these crash types was then evaluated using odds ratios.

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 (i.e., the relative risk of experiencing such a crash in an equipped vehicle versus an unequipped (but similar) vehicle). Ratios less than 1 indicate safety benefits. In the full analysis, we used a regression approach to adjust 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 654,129 matched vehicles was limited to cases of the system-relevant and associated 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, 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 driver demographic characteristics (namely, age and gender). The driver demographic characteristics were forced to be included in all models because they have been previously shown to impact crash outcomes and they provide a means for attempting to control for demographic patterns.

After the conclusion of the backward selection process, interactions between the feature and any significant predictors were tested, again with likelihood ratio tests. With the much larger sample size in this analysis, several interactions reached significance when evaluated by 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 with a penalty for the number of additional coefficients, with lower BIC values being more desirable. In parallel, the potential interactions were provided to GM for review to determine if they seemed plausible. Of the proposed interactions, only two were identified as meriting further investigation, but ultimately neither was included in the core model estimates due to the unclear interpretations. These are discussed in detail in the *Vehicle Type Interactions with Features* section below.

The inclusion of vehicle model in the modelling process attempted to capture differences between the driver demographics associated with various vehicle models. Since demographic differences in the driver populations of equipped and unequipped vehicles can mask (or heighten) the feature effect, including the vehicle model insulates the analysis from scenarios where unobserved factors (such as 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, a random effect treatment of the vehicle model factor was used.

The 13 covariates listed below were employed in this analysis, all of which were obtained from the police accident reports, except for Vehicle Type and Vehicle Model, which were associated with the VIN data provided by GM.

- Driver age: <25, 25-64, 65+
- Driver gender: *Male, Female*
- Speed Limit (miles per hour): *Continuous*[7]
- 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: *2017 – 2021*
- Crash Year: *2016 – 2021*
- Vehicle Type: Sedan, Small/Medium Utility, Large Utility, Truck, Van (see Table 8 for definitions)
- Vehicle model: (see Table 8)

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[7] Additional definition considered in forward collision, see Forward Collision Prevention Analysis for details.

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, 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

Crash Definitions and Variable Creation

Although police crash reports have a core set of available fields present in 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 dataset was separately reduced to a standard set of crash definitions and potential covariates to ensure comparable, consistent data fields across all states used in this analysis. The difficulty in aligning state crash field levels also leads to the need for binary coding for many covariates in order to maximize consistency of variable definitions across states, including for definitions associated with alcohol/drug involvement, distraction, weather, and road surface condition. Furthermore, although GM offers features that are relevant to low-speed forward parking crashes (e.g., Front and Rear Park Assist), the inconsistency of parking crash coding across state crash databases does not allow a reasonable evaluation of effectiveness levels for these features in reducing such forward parking crashes.

The assumed system-relevant and corresponding control crash definitions used in each analysis, developed in consultation with GM, are shown in Table 9 and Table 10, respectively. The goal is to identify a group of crashes that best represents (with the available 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. However, due to the potential ambiguity of crash configurations in police reports, and the subset of rear-end struck crashes included in the lane change crash 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 we used that more directly indicated the crash types of particular interest for this analysis.

The lane departure crash, which was updated in the MY 13-19 analysis, maintained that change in the current effort. Rather than pooling three types of system-relevant crashes, these types were analyzed separately. These three types included same direction sideswipes, opposite direction sideswipes (which includes head-on crashes), and single vehicle run-off-road crashes. This change brings the analysis in line with recent ADAS effectiveness studies (e.g., MITRE PARTS, 2022) and leverages the increasing volume of matched crashes to better examine specific crash circumstances.

As in prior studies, we could not determine based on the State Crash data whether the features analyzed were turned on or off at the time of the crash, or for that matter, whether the driver used these features properly (i.e., as directed in Owner's Manual feature descriptions). If actual feature usage is less than 100% (as has been observed with lane departure-related systems (Flannagan et al., 2016)), or if the feature was turned on but not being used properly or not being heeded by the driver, this analysis will underestimate the *potential* effectiveness if the feature were always turned on and used properly.

Starting with the MY 13-19 analysis, separate analyses were conducted to examine injury crashes for the two most populated matched crash groups (see Table 11): forward collision (rear-end striking with another vehicle) and lane departure.

In state police reports, crash injuries are coded using the KABCO scale, which ranks injury on a five-level scale of "Fatal Injury (K)", "Suspected Serious Injury (A)", "Suspected Minor Injury (B)", "Possible Injury (C)", and "No Apparent Injury (O)". This scale, which is defined in the Model Minimum Uniform Crash Criteria (MMUCC) (USDOT, 2012) data standard. For example, in Michigan 86% of vehicles in police-reported crashes report no injured occupants, meaning all occupants were coded with an "O".

Research has shown that police-reported injury level overestimates the incidence of serious injuries in crashes by as much as 2-3 times (Flannagan, Mann, & Rupp, 2013) when compared to a medical diagnosis. Nonetheless, KABCO is strongly correlated with injury level based on medical diagnosis. Thus, in this context, police-reported injury crashes are likely to be generally more severe than reported non-injury crashes. Therefore, an analysis restricted to injury-reported crashes should still provide insight into the performance of GM features for crashes that are capable of causing injury, even though the injury definition is not as precise as one using medical diagnosis. In general, NHTSA, state agencies, and traffic safety researchers routinely rely on KABCO information to characterize harm levels associated with crashes.

As in the MY 13-20 and MY 17-21 analyses, this analysis identified injury crashes based on the presence of "B or higher" injury on the KABCO scale for any crash participant (i.e., a "K", "A", or "B" injury). This is a substantially higher threshold than the "C or higher" injury threshold for GM vehicle occupants used in the older MY 13-19 study. The change was motivated by two factors: 1) the larger matched dataset supports the stricter injury requirement (better reflecting actual injury outcomes), and 2) there was an interest in including injured parties in the other vehicle to better reflect the severity of the crash overall.

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
Front Pedestrian	Front Pedestrian	Initial Contact Point on Vehicle = Front AND First Event = Pedestrian AND Speed Limit < 50
Lane Departure – Same Direction	Lane Departure	[Manner of Crash = Same Direction Sideswipe] AND Speed Limit > 30
Lane Departure – Opposite Direction	Lane Departure	[Manner of Crash IN {Opposite Direction Sideswipe, Head-on}] AND Speed Limit > 30
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
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

Results

The 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. Each of these five categories were used in "prevention" (i.e., crash avoidance) analyses.

As discussed above, additional "injury-focused" analyses were conducted for the forward collision and lane departure analysis categories. These analyses attempt to account for crash mitigation effects, where although the feature may not have prevented the crash, it may reduce the crash severity and thereby importantly help mitigate or prevent crash-related injuries.

Each analysis category is discussed separately below. Note that only significant feature-related effects are discussed here.

Analysis Data Subsets

Table 11 shows the sample size of matched cases for both system-relevant and associated control crashes for each analysis group and feature(s) evaluated. These crashes are derived from the original set of 654,129 vehicle cases matched between GM VINs (with ADAS and headlighting feature content indicated) and the set of police report crash cases from the 15 states used in this analysis. Note that some features are listed as co-occurring with other features due generally to the GM practice of bundling less advanced features with their more advanced counterparts, which will be addressed in the relevant analysis discussions below.

As in the MY 17-21 analysis, there have been reductions in certain older ADAS equipment groups even as the sample sizes increase overall. Notably the volumes of FCA-, radar AEB-, LDW- and SBZA-equipped vehicles in Table 11 are smaller than for other more sophisticated systems. These systems are less frequent in the MY18-22 equipment packages, being largely replaced by systems that include their functionality (e.g., LKA w/ LDW replacing LDW alone) or which are alternative versions of the system (e.g., camera AEB or fusion AEB rather than radar AEB). While this reduction in volume decreases the precision of the estimated effect sizes, as reflected by the larger confidence intervals observed in the current analyses, it importantly allows for more accurate estimation of the benefit of the systems to the current GM fleet mix.

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 systems	54,223	79,532
	Camera Forward Collision Alert (FCA)	1,718	2,340
	Radar/Fusion Automatic Emergency Braking (AEB) with Adaptive Cruise Control (ACC)	1,790	6,033
	Camera AEB	13,535	39,205
Front Pedestrian	Unequipped with Front Pedestrian system	1,013	58,070
	Front Pedestrian Braking (FPB)	210	20,183
Lane Departure – Same Direction	Unequipped with Lane Departure systems	33,576	52,993
	Lane Departure Warning (LDW)	1,907	1,983
	Lane Keep Assist (LKA) with LDW	14,237	28,515
Lane Departure – Opposite Direction	Unequipped with Lane Departure systems	5,898	50,886
	Lane Departure Warning (LDW)	384	1,867
	Lane Keep Assist (LKA) with LDW	2,195	27,186
Lane Departure – Road Departure	Unequipped with Lane Departure systems	13,267	50,886
	Lane Departure Warning (LDW)	631	1,867
	Lane Keep Assist (LKA) with LDW	4,600	27,186
Lane Change	Unequipped with Lane Change systems	8,551	63,446
	Side Blind Zone Alert (SBZA)	98	567
	Lane Change Alert (LCA) with SBZA	5,427	53,193
Backing	Rear Vision Camera or Rear Vision Camera Mirror (RVC)	6,129	52,200
	Rear Park Assist (RPA)	1,735	12,311
	Rear Cross Traffic Alert (RCTA) with RVC/SV	4,046	52,886
	Reverse Automatic Braking (RAB) with RVC/SV, RPA, & RCTA	60	1,520

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 AEB feature evaluated only operated below 50 mph, all AEB features include the FCA feature, ACC is only offered with AEB. There are several varieties of ACC systems offered, and a small proportion of camera AEB vehicles had a camera-based ACC, but ACC did not seem to impact effectiveness and is not included here. Finally, camera FCA here corresponds to vehicles equipped with the FCA feature, but not equipped with AEB. 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/possible injury mitigation analysis

Characteristic	Value
Feature Levels	Unequipped (no FCA or AEB) Forward Collision Alert (FCA) Radar/Fusion AEB with Adaptive Cruise Control (ACC) Camera AEB
System-relevant Crash	Rear-end Striking Injury Rear-end Striking
Control Crash	Rear-end Struck
Analysis Subset Sample Sizes	
- all crashes	71,266 (system-relevant); 127,110 (control)
- injury crashes	6,209 (system-relevant); 122,143 (control[8])

Figure 2, which demonstrates how feature effectiveness results will be presented in the remainder of the paper, shows the estimated odds ratios (with point values shown on right vertical axis) for each of the forward collision features evaluated, along with green bolded values corresponding to statistically significant reductions in the system-relevant crash type ($p<0.05$). (In relevant analyses, blue values are used to indicate estimated effects that were not statistically significant.)

As shown in Figure 2, all of the examined forward crash prevention features significantly reduced the risk of system-relevant rear-end striking crashes. FCA produced a 16% reduction (odds ratio=0.84), while all of the AEB features examined produced reductions of 49% for radar/fusion AEB and 40% for camera AEB. Additionally, even though the camera AEB feature does not function above 50 MPH, an interaction between the type of AEB feature and the speed limit was not significant. This may be because rear-end striking crashes are more common on lower speed roads (Najm, Smith, and Yanagisawa, 2007).

These results correspond very closely to the MY 17-21 analysis (see *Discussion* section). The AEB estimates of 49% and 40% are identical to those of the previous analysis.

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[8] The number of control crashes in some injury crash models differs from the corresponding “all crashes” models due to missingness 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.

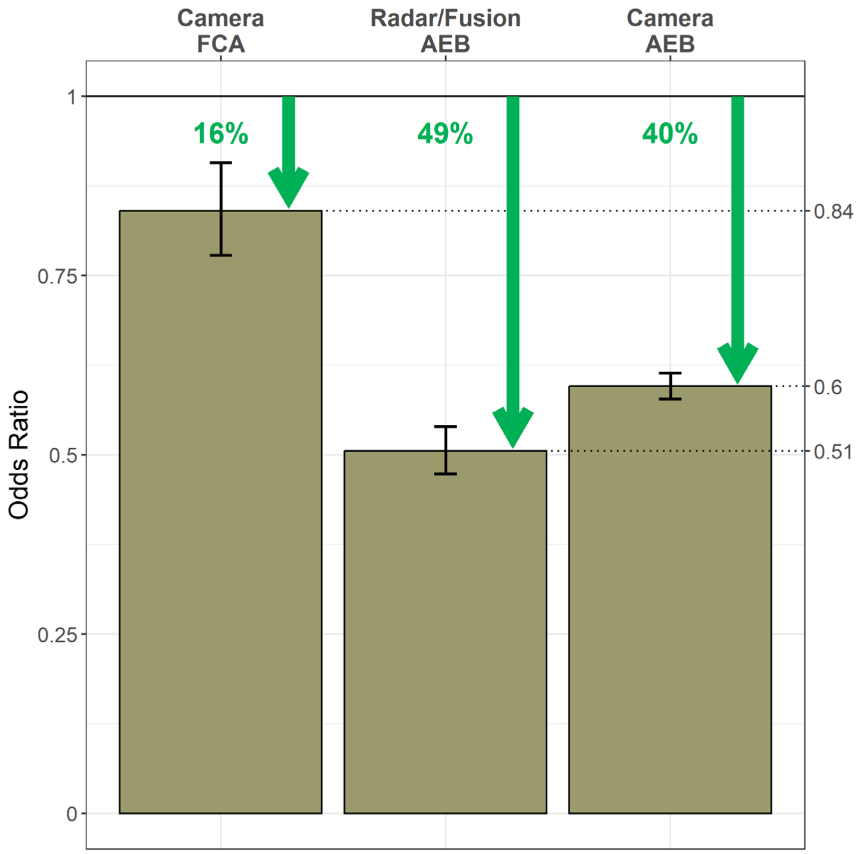

Figure 2 Estimated adjusted odds ratios and percent reductions in odds (i.e., system-relevant crashes) for forward collision crash prevention systems

Injury Crash Analysis

The forward collision injury analysis is presented in Figure 3. Recall this analysis is focused on more severe crashes where an injury level of K, A, or B on the police-reported KABCO scale was reported for any of the crash-involved persons. In general, system benefit estimates increased in injury crashes relative to the “all crashes” analysis. For example, camera AEB benefits increased to 51% from the all crash benefit of 40% and FCA increased to 28% from 16%. The increased benefits suggest that the presence of forward crash prevention systems have a mitigation effect on rear-ends, meaning that they reduce the severity, and resulting injury outcomes, of crashes even when the crash isn’t prevented.

Interestingly, while most systems increase in effectiveness, the estimate for radar/fusion AEB remains much closer, particularly accounting for uncertainty (52% in injury crashes vs. 49% in all crashes). While larger in previous years, the increase in benefit for fusion AEB has consistently been smaller than for other systems. For example, in the MY 17-21 analysis, while the camera AEB benefit increased by 13% (compared to 11% in this analysis) the fusion AEB benefit increased by 8% (compared to 3% this year). This may suggest that the fusion system benefit remains relatively stable across crash severities while other systems show more mitigation benefit. It is interesting to note that, as seen in Figure 3, the AEB systems seem to “level out” at around 50% benefits for the injury analysis, which is comparable to the fusion AEB estimate from the all crashes analysis. This has two notable implications: first, camera AEB systems seem to produce reductions in injury-producing crashes comparable to fusion AEB and, second, the larger benefit for fusion AEB in the all crashes analysis seems to be achieved by preventing more non-injury crashes. While the exact reason for the higher performance in non-injury crashes is not known, these results suggest that camera AEB is a reasonable alternative to fusion AEB when the goal is to reduce injuries without increasing vehicle costs.

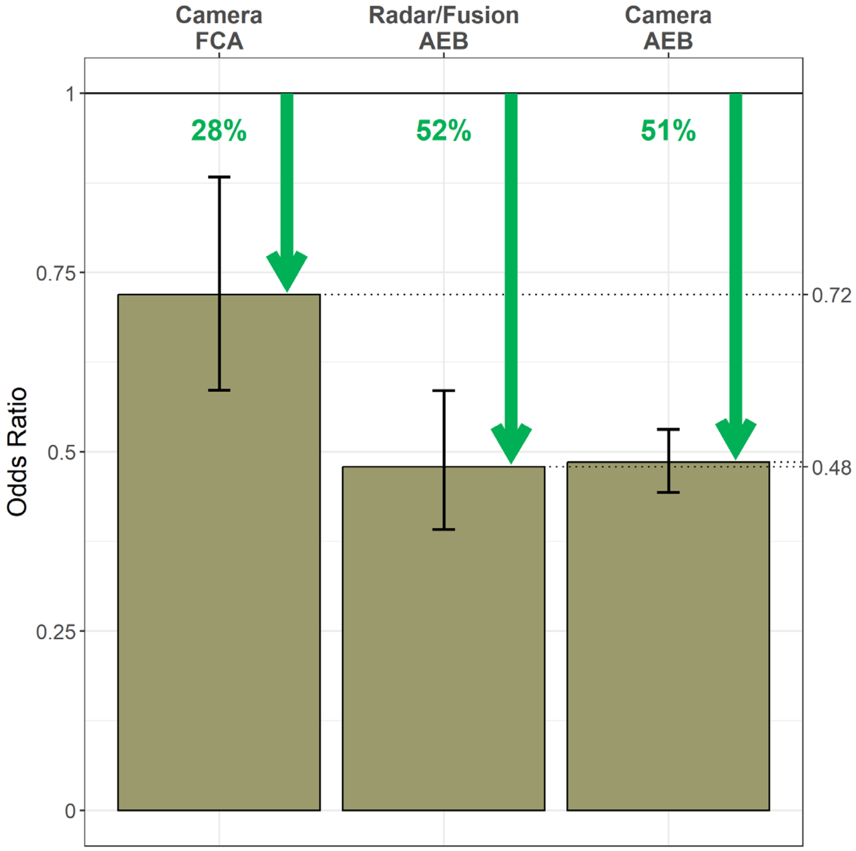

Figure 3 Estimated adjusted odds ratios and percent reductions in odds (i.e., system-relevant crashes) in injury ("B" or higher on KABCO scale) crashes for forward collision crash prevention systems in the injury-focused analysis.

System Interactions

The significant interaction between the type of forward collision prevention system and vehicle type identified in previous analyses was present again in this iteration and is depicted in Figure 4. As in the earlier analyses, the most notable differences seem to occur in the AEB systems where larger vehicles (trucks and large SUVs) have lower system benefits than smaller vehicles (sedans and small/medium SUVs). In MY 22, there was a notable expansion in system offerings with a small number of trucks being offered with radar/fusion AEB. While the sample size is too small to draw strong conclusions, the point estimate is interesting: the radar/fusion AEB equipped trucks may still have a slightly lower benefit in line with the other large vehicles. In aggregate, these results continue to support the conclusion that larger vehicles see less benefit from camera-based systems but indicate that we should continue to monitor trucks with fusion AEB to see if a similar pattern develops there.

The interaction for the "camera FCA only" seems more minor and seems to trend the opposite direction with trucks and vans seeing more benefit than sedans and small/medium SUVs. Given that FCA alone is less frequently offered on the smaller vehicles (and is nearly absent on large SUVs), this portion of the interaction likely does not merit in depth investigation.

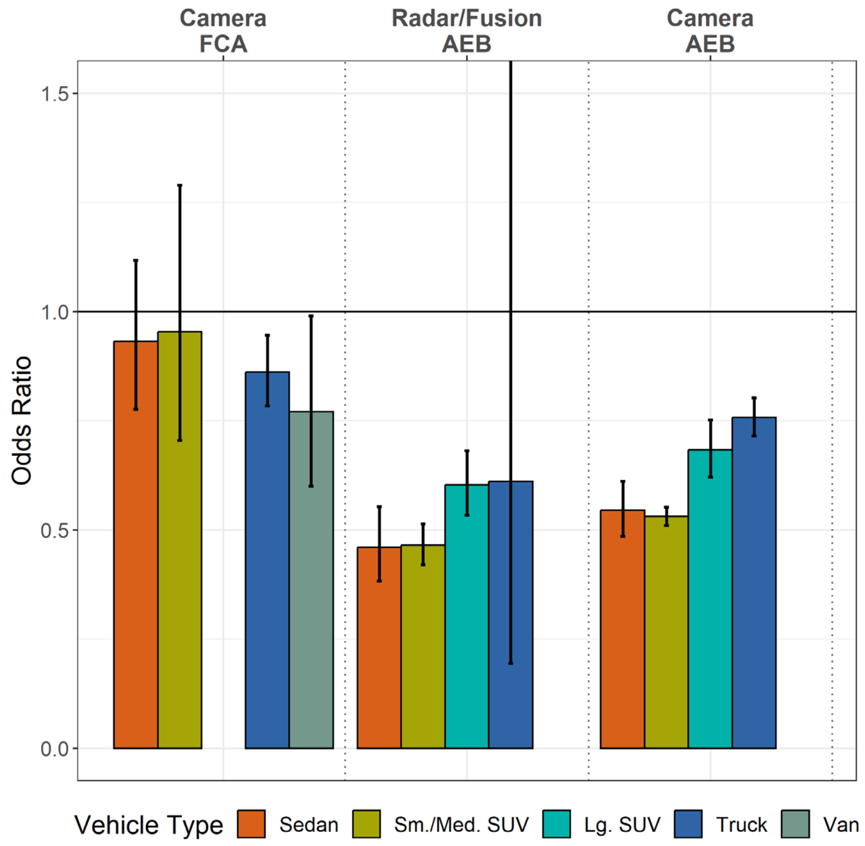

Figure 4 Estimated adjusted odds ratios for forward collision preventions systems when including an interaction between ADAS system and vehicle type

Lane Departure Crash Prevention Analysis

Table 13 shows a summary of the lane departure crash prevention analysis. It is important to note that the LKA with LDW feature provides a limited form of automatic control via a brief steering wheel nudge, along with LDW alerts only if necessary. Hence, relative to an "LDW only" feature which only provides alerts, the LKA with LDW feature by design effectively reduces the number of LDW alerts. The reference category for the feature factor is "Unequipped" for both the LDW (i.e., "LDW only") and LKA with LDW features.

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 13, the majority of the system-relevant crashes were same direction sideswipes, though the volume of injury-related crashes as defined in the current analysis were roughly comparable across the three crash subsets (due to the difference in severity of the crash types).

Figure 5 summarizes the results of this analysis. In all three of the crash types, LDW alone provided no significant benefit. While two crash types, same direction and road departure, have point estimates showing a disbenefit, this is likely a result of the small sample size and should not be over-interpreted.

By contrast, LKA with LDW provided a statistically significant benefit for all three crash types. The provided reduction in system relevant crashes was estimated to be 8% (odds ratio=0.92) for same-direction sideswipes, 10% (odds ratio=0.92) for opposite-direction sideswipes and head-on crashes, and 13% (odds ratio=0.87) for single vehicle road departures.

Table 13 Summary of the lane departure crash prevention and injury/possible injury mitigation 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	49,720 (system-relevant); 83,491 (control)
- Opposite Direction	8,477 (system-relevant); 79,939 (control)
- Road Departure	18,498 (system-relevant); 79,939 (control)
Injury Crashes	
- Same Direction	2,113 (system-relevant); 84,040 (control[6])
- Opposite Direction	2,629 (system-relevant); 83,491 (control[6])
- Road Departure	3,053 (system-relevant); 79,939 (control[6])

Overall, the effectiveness estimates from this study were consistent with the previous MY 17-21 analysis (see *Discussion* section). For LKA with LDW, the benefits were identical for same-direction sideswipes and changes in the other two crash types were well within the confidence intervals. The shifts for LDW were slightly larger, but given the decreasing penetration of the system and lack of significance, these differences are not concerning.

When viewing these results across system-relevant crash types, it is particularly important to consider that in the single vehicle roadway departure case, the GM host vehicle is always responsible for the lane departure. For same direction sideswipes and opposite direction sideswipes (which includes head-on crashes), which necessarily involve two vehicles, the crash can occur if either the GM host vehicle and/or the “other” crash-involved vehicle departs its lane. As such, if we assume that the “other” vehicle was responsible for approximately 50% of the system-relevant crash cases, then the estimated effectiveness of LDW and LKA with LDW for these cases could be half of the true estimate for crashes in which the GM vehicle initiates the crash. For instance, if the GM were assumed to be responsible in 50% of same direction sideswipes, it’s plausible that the benefit in “responsible” same-direction sideswipes would be 16% (8%*2) which is more in line with the estimate for single vehicle road departures.

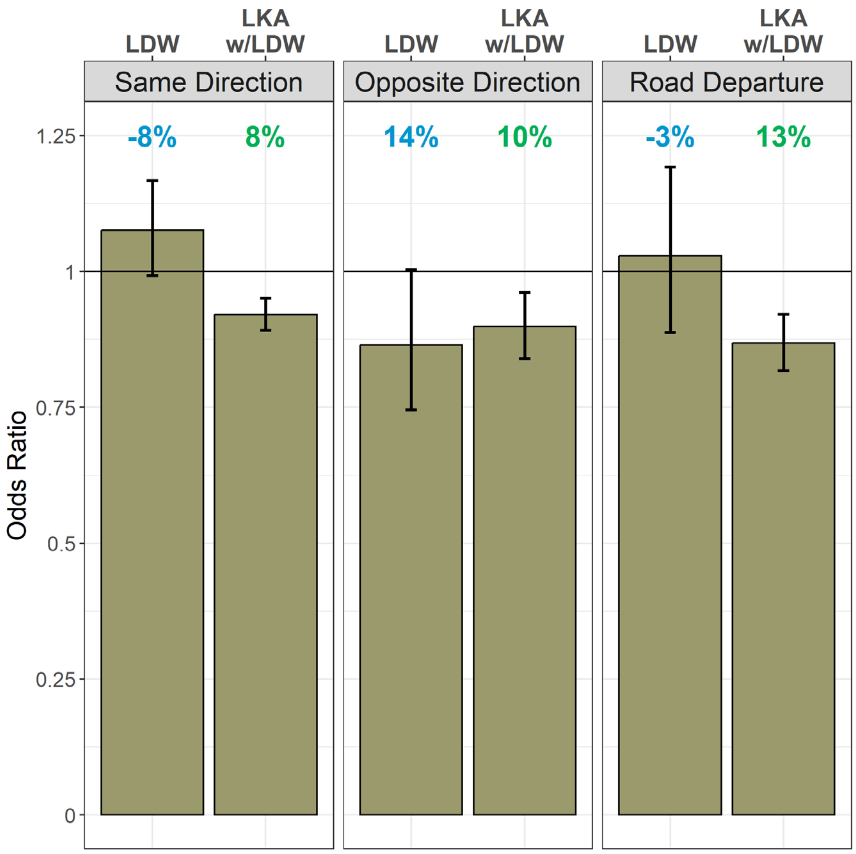

Figure 5 Estimated adjusted odds ratios and percent reductions in odds (i.e., system-relevant crashes) for the lane departure crash prevention systems

Injury Crash Analysis

As with the forward collision analysis, an injury-focused analysis of lane departure crashes was performed with results shown in Figure 6. As in the all-crashes analysis, LDW did not produce a significant reduction in system-relevant crashes for any of the three crash types studied. LKA with LDW only provided a significant reduction for single vehicle road departures with the estimated benefit being 19% (a 3% increase over the “all crashes” estimate). Overall, this pattern of effects was consistent with the MY 17-21 analysis, though there were some sizable changes in the non-significant effects (see Table 19 in the *Discussion*). However, with no changes in significance from the previous study and the wide confidence bounds, none of these changes were substantial enough to be of particular note.

System Interactions

In the MY 17-21 analysis, three interactions with system type were discussed: with vehicle type, with road surface condition, and with weather condition. While these interactions were tested again in this study, none reached the criteria of inclusion. This may be due, in part, to the decreasing volume of LDW only vehicles as the model year range of the study continues to advance. The status of these (and other) potential interactions will be monitored in follow on work.

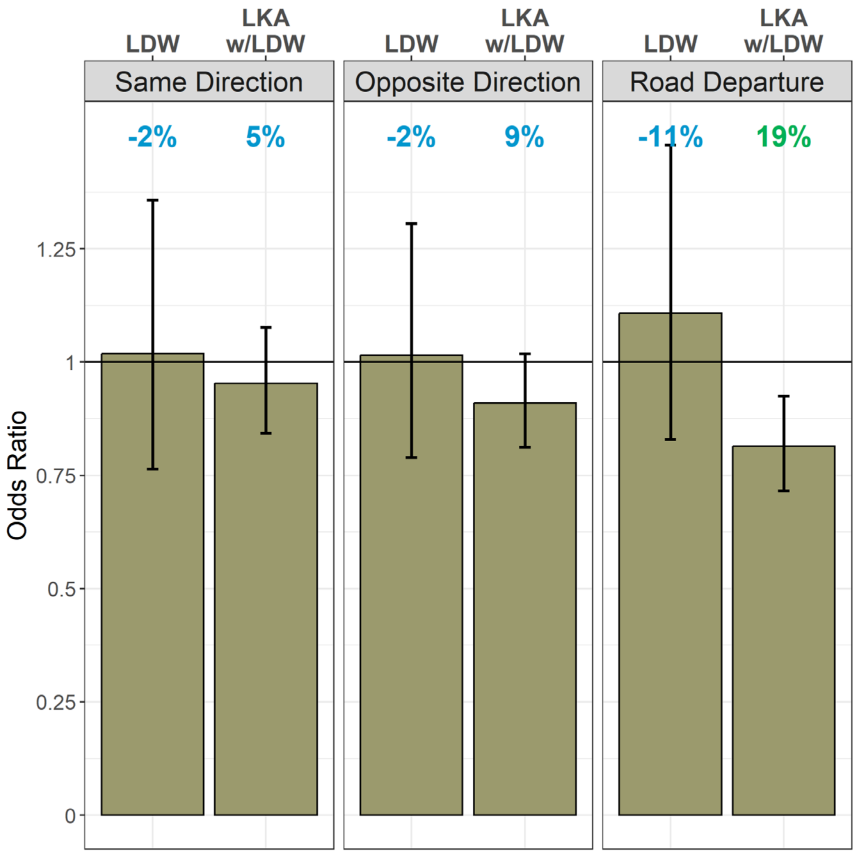

Figure 6 Estimated adjusted odds ratios and percent reductions in odds (i.e., system-relevant crashes) in injury ("B" or higher on KABCO scale) crashes for the lane departure crash prevention systems in the injury-focused analysis.

Lane Change Crash Prevention Analysis

Table 14 provides a summary of the lane change crash prevention analysis. Note that the LCA (with SBZA) feature provides substantially greater ranges for detecting approaching vehicles compared to the SBZA feature, which is of particular importance for alerting drivers to vehicles rapidly approaching from outside the side blind zone area. A small number of LCA equipped vehicles had additional systems, but these were low volume and/or expected to be low use and are not distinguished here. To assess the lane change feature effect, the reference level was "Unequipped" for LCA (with SBZA), SBZA, RCM (with LCA and SBZA), and Trailer SBZA.

Table 14 Summary of lane change crash prevention analysis

Characteristic	Value
Feature Levels	Unequipped (no SBZA, LCA, RCM) Side Blind Zone Alert (SBZA) Lane Change Alert with SBZA
System-relevant Crash	Lane Change Crash
Control Crash	Rear-end Struck
Analysis Subset Sample Sizes	14,076 (system-relevant); 117,206 (control)

The results of this analysis are summarized in Figure 7. Of the four systems investigated, only LCA produced a significant reduction in lane change crashes, with an estimated reduction of 12%. SBZA was not significant, and had a particularly large amount of uncertainty due to the low sample sizes (due to being replaced with LCA on new vehicles for SBZA).

The estimated LCA with SBZA was slightly lower than in the MY 17-21 study (see *Discussion* section), but within the confidence interval.

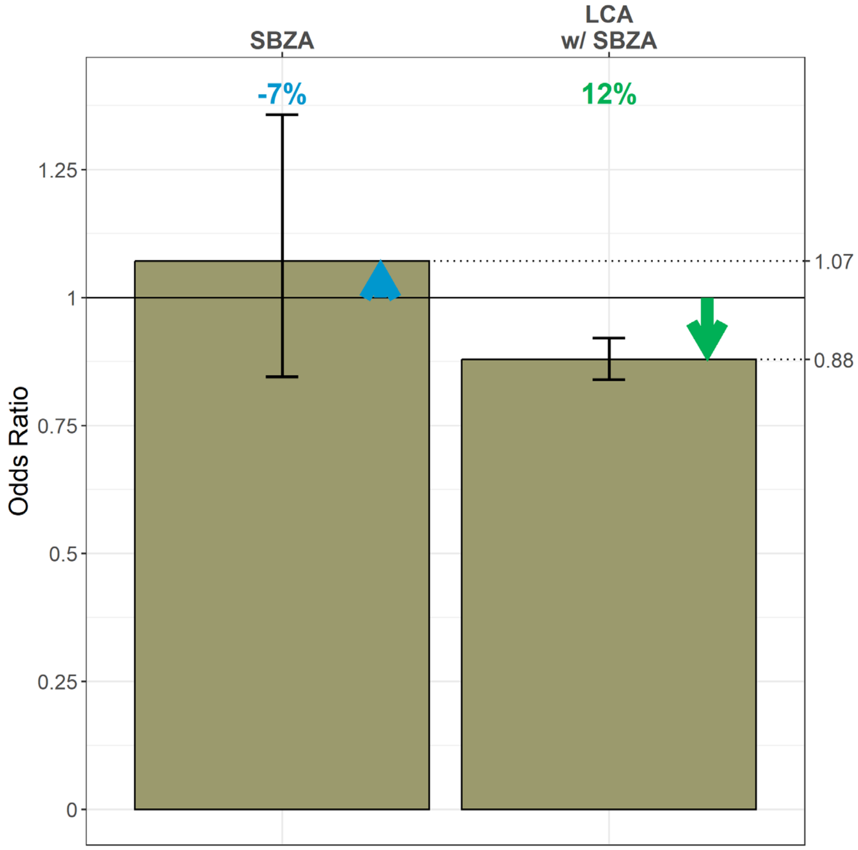

Figure 7 Estimated adjusted odds ratios and percent reductions in odds (i.e., system-relevant crashes) for the lane change crash prevention systems

Backing Crash Prevention Analysis

Table 15 provides a summary of the backing crash prevention analysis. Since there was not a reliable way to identify different backing crash types (e.g., parking, higher-speed backing, cross traffic) via available police reports, the four lower-speed park assist-related features (i.e., Rear Park Assist (RPA), Front and Rear Park Assist (FRPA), Automatic Park Assist with Steering (or APA2), and Enhanced Automatic Park Assist) were collapsed and treated as a single collective RPA feature. The Surround Vision (SV) system provides a 360-degree view around the vehicle but also includes RVC functionality and was not distinguished from RVC for this analysis. The van-only Rear Vision Camera Mirror system was analyzed as a separate feature in the MY 17-21 analysis but has been merged with RVC in this analysis for reasons discussed below. This feature displays the standard RVC image in the interior rear-view mirror but otherwise functions as RVC. 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 15, the feature levels were treated as hierarchical with the more advanced feature taking priority (e.g., a car with RCTA but not offering RAB automatically falls into the RCTA group regardless of the park assist feature equipment status). In most cases, this means that vehicles coded as having a particular backing feature also had all features listed above in Table 15. There were two exceptions to this hierarchical backing feature assumption which involved a relatively small number of cases in the available vehicle dataset: (1) RCTA did not include an RPA feature in approximately 0.9% of cases, (2) RPA did not include RVC or SV in approximately 0.4% of cases.

Unlike the other analysis groups "Unequipped" was not used as the reference category for this analysis. As of MY 18, RVC was essentially standard equipment on GM vehicles with only trucks and vans offering trims without backing systems in high volumes. This has the potential to skew results because it confounds the system effect with a vehicle type effect. In anticipation of this issue, the MY 17-21 analysis investigated using RVC as the reference category and that approach was adopted for this iteration. While a fuller discussion is available in Leslie, et al. 2023, two points merit discussion here. First, using RVC as the reference makes it difficult to separately estimate the effect of RVC Mirror. This is because the van effect is confounded with the system effect producing unstable results. To combat this, RVC Mirror was merged into the RVC variable (this is reasonable based on the results of the MY 17-21 analysis). Second, in order to maintain comparability to previously obtained effectiveness estimates, this year's results were "corrected" using the RVC estimate from the MY 17-21 analysis. Put another way, rather than a reference of odds ratio of 1 (or no benefit), the reference was shifted to an odds ratio 0.66 (a 34% benefit). Note that this approach assumes that the RVC effect has not changed but given the stability of the backing analysis over time, this is not unreasonable.

Table 15 Summary of the backing crash prevention analysis

Characteristic	Value
Feature Levels	Rear Vision Camera or Rear Vision Camera Mirror (RVC)[9] Rear Park Assist (RPA)[10] 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	11,970 (system-relevant); 118,970 (control)

Figure 8, summarizing the analysis, indicates that all the backing features examined significantly reduced the incidence of system-relevant backing crashes relative to RVC (and, transitively, relative to unequipped). These crash reduction benefits occur with a stack-up effect, such that more advanced backing features (which generally include all less advanced backing features) show increasing backing crash reduction levels. After applying the estimated RVC reduction from the MY 17-21 analysis (34%), the RPA effect is estimated at 48% (odds ratio=0.52), a 14% improvement over RVC. RCTA was estimated to provide a 59% reduction (odds ratio=0.41), which corresponds to a 11% improvement beyond RPA effectiveness levels. RAB again improved over the previous system with an estimated 83% reduction (odds ratio=0.17), a 24% improvement beyond observed RCTA effectiveness levels.

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[9] Rear Vision Camera includes the Front Curb View and Rear Trailer View systems.

[10] Rear Park Assist includes the Rear Park Assist, Front and Rear Park Assist, Automatic Park Assist with Steering, and Enhanced Automatic Park Assist systems.

These results are generally consistent with the MY 17-21 results (see *Discussion* section). There were small shifts in effectiveness estimates, but the relative effectiveness of the systems remained stable. While some changes are expected from the shift in reference category, these results suggest that the backing systems are maintaining their established effectiveness and that this approach is performing well.

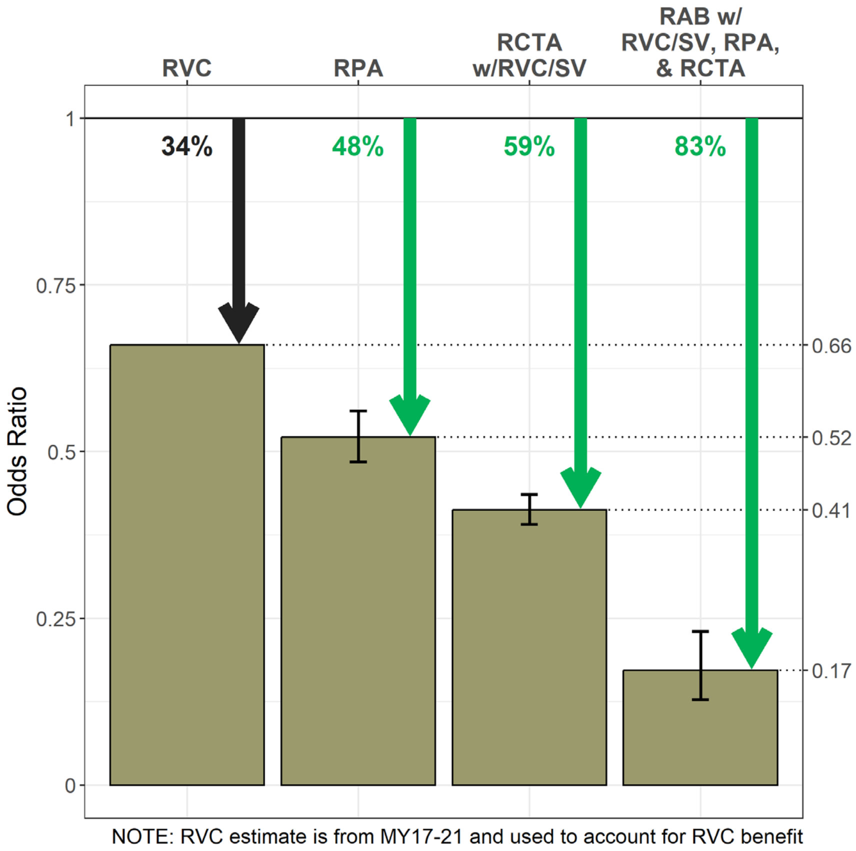

Figure 8 Estimated adjusted odds ratios and percent reductions in odds (i.e., system-relevant crashes) for the parking/backing crash prevention systems. The estimated effectiveness of RVC was obtained in the MY 17-21 analysis (Leslie et al., 2023) and is used here to aid interpretability.

Front Pedestrian Crash Prevention Analysis

Table 16 shows a summary of the front pedestrian crash prevention analysis. Note that Front Pedestrian Braking (FPB) is only offered on vehicles equipped with AEB, operates below 50 MPH, and has known limited nighttime performance. Furthermore, since FPB was not available on vans, vans were excluded from this analysis. The ability to detect FPB effects that might exist, particularly interactions with covariates, was limited by the rarity of system-relevant front pedestrian crashes (1,223 (1.5%) of the 79,476 cases in the analysis subset). FPB was compared against the reference level of "Unequipped" with FPB.

Table 16 Summary of the front pedestrian crash prevention 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	1,223 (system-relevant); 78,253 (control)

Figure 9 shows the analysis results, which indicate that FPB provided a significant 31% reduction (odds ratio=0.69) in system-relevant front pedestrian crashes. This is substantially larger than the 23% estimate obtained in the MY 17-21 analysis, but falls within the confidence bounds from that study (see *Discussion* section). This change may be due to the increased fleet penetration of the system. The system will be monitored in follow-on studies to evaluate whether it maintains this level of effectiveness.

While there are a number of potential interactions between the FPB feature and various confounding factors (including light condition) that are of particular interest, no significant interactions were identified in this analysis. As mentioned above, this may be related to the lower sample size of pedestrian crashes and the lack of significant interactions does not necessarily mean that FPB performance is the same in all conditions.

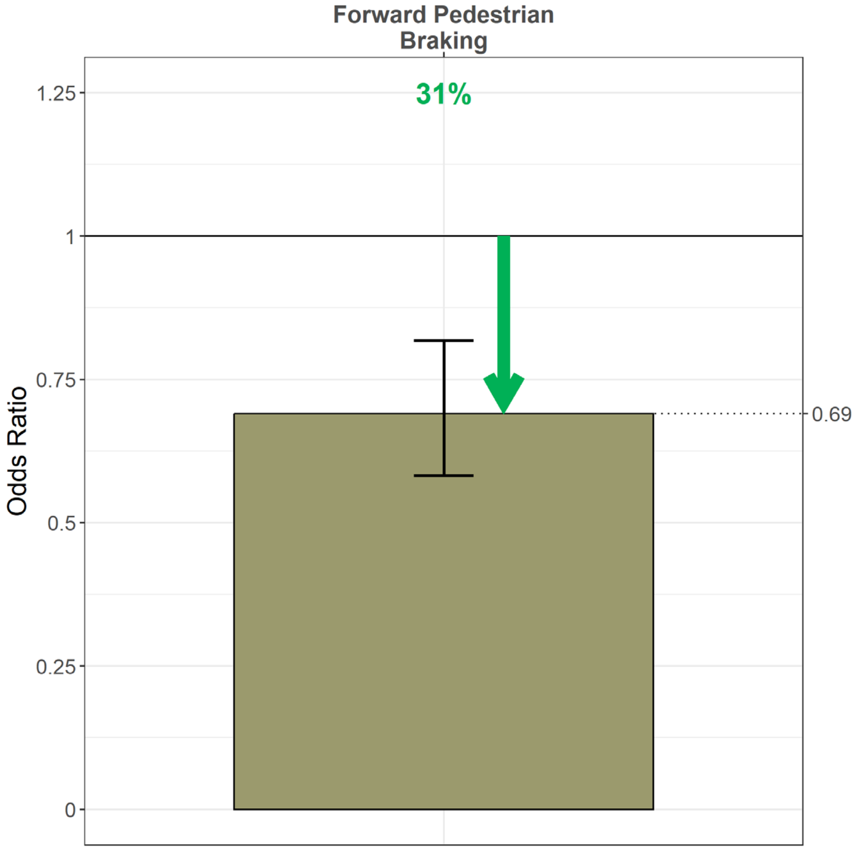

Figure 9 Estimated adjusted odds ratios and percent reductions in odds (i.e., system-relevant crashes) for the front pedestrian braking crash prevention system

Discussion

High-Level Summary of GM Advanced Driver Assistance System (ADAS) Feature Effectiveness

Table 17 summarizes the estimated effectiveness of ADAS features designed to address forward or lateral crashes. Percent effectiveness is relative to the system-relevant crash types that the feature is designed to address. Results for the current MY18-22 analysis are shown in the second column, whereas results from the two most recent GM ADAS feature effectiveness analyses (MY13-20 and MY17-21) are shown in the two rightmost columns. The results from this updated GM ADAS feature effectiveness analysis are generally similar to those observed across previous analyses, except for the LDW feature, which is being phased out by GM and is being replaced by the LKA with LDW feature. In the current effort and the MY17-21 effort, the LDW feature did not produce significant benefits, which is attributed to the changes which have occurred across model years in the LDW-equipped penetrations across vehicle types. LDW effectiveness was a small but significant 4% in the MY 13-20 analysis.

In the current analysis, the forward collision systems were found to be quite effective at reducing rear-end striking crashes, with the more automated AEB features producing greater benefit than the Camera FCA feature (which only provides alerts to the driver). Radar/fusion AEB systems was 49% effective, with camera-based AEB estimates lower at 40% effective. In contrast, the camera FCA feature was found to be 16% effective on rear-end striking crashes.

There was also a significant interaction between the type of forward collision prevention system and vehicle type. Similar to that found in earlier analyses, the most notable differences seem to occur in the AEB systems where larger vehicles (trucks and large SUVs) have lower system benefits than smaller vehicles (sedans and small/medium SUVs).

The FPB feature was observed to reduce pedestrian crashes by 31%, which is somewhat higher than the MY17-21 estimate of 23% (though within the confidence interval from that study). Despite the known limitations of this feature under nighttime conditions, no significant interactions with light condition were identified in this analysis, which could be related to the relatively low sample of pedestrian crashes.

Lateral systems were generally less effective than forward collision systems, but the more automated LKA with LDW feature produced significant reductions in roadway departure, same-direction sideswipe, and opposite-direction sideswipe crashes (the latter of which includes head-on crashes) by 8%, 10%, and 13%, respectively (all significant). More generally, this pattern of lane departure countermeasure results emphasizes the importance of measuring the effects of such countermeasures using crash types that distinguish between single- versus multi-vehicle crashes. Since the role of the vehicle equipped with the countermeasure in multiple-vehicle lane departure crash cases is less clear (e.g., the other vehicle could very well have left its lane and caused the crash), effectiveness estimates for single vehicle road departures may provide a more accurate assessment of lane departure countermeasure effectiveness.

For lane-change crashes, the LCA (with SBZA) feature was 12% effective. Side Blind Zone Alert (SBZA) alone, which has substantially lower detection ranges than LCA, was not found to be significant, consistent with previous findings.

Table 17 Estimated percent reductions in system-relevant crashes for GM Advanced Driver Assistance System (ADAS) features related to forward and lateral crashes. (Note AEB includes FCA and shaded green cells denote statistically significant effects.)

GM ACTIVE SAFETY FEATURE	GM MY18-22 Crashes (CURRENT ANALYSIS)	GM MY17-21 Crashes	GM MY13-20 Crashes
FORWARD COLLSISION			
Camera Forward Collision Alert (FCA)	16%	14%	20%
Radar/Fusion AEB with ACC (Adaptive Cruise Cruise)	49%	49%	45%
Camera AEB	40%	40%	40%
Front Pedestrian Braking (FPB)	31%	23%	23%
LANE DEPARTURE - SAME DIRECTION SIDESWIPE			
Lane Departure Warning (LDW)	-8%	-5%	4%
Lane Keep Assist (LKA) with LDW	8%	8%	10%
LANE DEPARTURE - OPPOSITE DIRECTION SIDESWIPE (INCLUDES HEAD-ON CRASHES)			
Lane Departure Warning (LDW)	14%	9%	5%
Lane Keep Assist (LKA) with LDW	10%	7%	8%
LANE DEPARTURE - SINGLE VEHICLE ROAD DEPARTURE			
Lane Departure Warning (LDW)	-3%	-5%	8%
Lane Keep Assist (LKA) with LDW	13%	15%	17%
LANE CHANGE			
Side Blind Zone Alert (SBZA)	-7%	-4%	7%
Lane Change Alert (LCA) with SBZA	12%	15%	16%

Table 18 shows the results for the ADAS features aimed at addressing backing crashes. Backing features are generally bundled such that more advanced features also include the less advanced features. For example, RAB, the most automated backing feature examined, is bundled with RCTA, RPA, and either RVC or SV. In recent model years, all vehicles have some type of rear-crash-prevention system, so it is no longer possible to use “no backing system” as a reference category. For this year, analyses were done using RVC as the reference category and the estimates were adjusted by 34%, the most recent estimate of RVC effectiveness (over no system), to make the numbers comparable to previous years. Overall a distinct stack-up effect is observed under which RPA, RCTA, and RAB significantly reduced backing crashes by 48%, 59%, and 83%, respectively (relative to having no system).

It should also be noted that relative to other crash types observed here, backing crashes are known to be under-represented in police-report databases as they often occur off public roads (e.g., on private property or in parking lots) or do not reach reporting thresholds (e.g., minor crashes not causing property damage or simply not reported to the police). Consequently, with respect to the number of backing crashes being reduced by backing features in the field, there are likely substantially more "property damage only" crashes that are not being captured in police report data collection.

Furthermore, it should also be noted that although GM offers features that are relevant to low-speed forward parking crashes (e.g., Front and Rear Park Assist), the inconsistency of parking crash coding across state crash databases did not allow a reasonable evaluation of effectiveness levels for such features in reducing such forward parking crashes.

Table 18 Estimated percent reductions in system-relevant (target) crashes for GM Advanced Driver Assistance System (ADAS) features related to backing crashes. (Note shaded green cells denote statistically significant effects.)

GM ACTIVE SAFETY FEATURE	GM MY18-22 Crashes (CURRENT ANALYSIS)	GM MY17-21 Crashes	GM MY13-20 Crashes
BACKING (note more advanced backing features generally include less advanced backing features)			
Rear Vision Camera (RVC)	Reference[11]	34%	32%
Rear Vision Camera Mirror (RVC Mirror)		27%	33%
Rear Park Assist (RPA, Front & Rear PA or Automatic PA 2)	48%	49%	41%
Rear Cross Traffic Alert (RCTA) with RVC/ Surround Vision (SV)	59%	62%	59%
Reverse Automatic Braking (RAB) with RVC/SV & RPA & RCTA	83%	85%	83%

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[11] Note that the backing system estimates use the 34% estimated effectiveness for RVC as a correction factor to ensure comparability with the estimates from previous studies.

Table 19 Summary of effectiveness of forward collision and lane departure-related GM Advanced Driver Assistance System (ADAS) features for the injury-focused analysis. (Note AEB includes FCA and shaded green cells denote statistically significant effects.)

GM ACTIVE SAFETY FEATURE	GM MY18-22 (CURRENT ANALYSIS)	GM MY18-22 Injury-Focused (CURRENT ANALYSIS)	GM MY17-21	GM MY17-21 Injury-Focused
FORWARD COLLISION				
Camera Forward Collision Alert (FCA)	16%	28%	14%	25%
Radar/Fusion AEB with ACC (Adaptive Cruise Control)	49%	52%	49%	57%
Camera AEB	40%	51%	40%	53%
LANE DEPARTURE - SAME DIRECTION SIDESWIPE				
Lane Departure Warning (LDW)	-8%	-2%	-5%	1%
Lane Keep Assist (LKA) with LDW	8%	5%	8%	9%
LANE DEPARTURE - OPPOSITE DIRECTION SIDESWIPE (INCLUDES HEAD-ON CRASHES)				
Lane Departure Warning (LDW)	14%	-2%	9%	-1%
Lane Keep Assist (LKA) with LDW	10%	9%	7%	2%
LANE DEPARTURE - SINGLE VEHICLE ROAD DEPARTURE				
Lane Departure Warning (LDW)	-3%	-11%	-5%	-6%
Lane Keep Assist (LKA) with LDW	13%	19%	15%	22%

Table 19 presents the effectiveness estimates for the injury-focused analyses next to those for all crashes (also in Table 17), for comparison purposes. In addition, the corresponding injury-focused results from the MY 17-21 analysis are provided for reference. Across all front collision systems examined in these injury-focused analyses, effectiveness for injury crashes is similar or higher than for all crashes. This improved effectiveness, when restricting the analysis to crashes that police report as more severe, provides compelling and important evidence that even when crashes are not prevented the reduction in impact speed due to alerting the driver or automatic braking can reduce injury risk. This mitigation is likely responsible for the higher effectiveness levels for injury crashes. That is, it is likely that avoided crashes are typically those that would have been less severe (i.e., involved lower relative speeds). This pattern of findings also suggests that some rear-end striking crashes that might have otherwise involved reported K-, A-, or B-injuries without FCA and AEB are potentially being shifted to C-injury or property damage-only crashes.

In the lateral collision injury-focused analysis, the only significant effect observed was for LKA with LDW on single vehicle road departure crashes, which as discussed above, can be more straightforward to interpret than two-vehicle same and opposite direction sideswipe crashes (where the role of the equipped vehicle in these crashes is less clear). This effectiveness is higher than for all crashes.

Concluding Remarks: Working Toward a Zero Crashes Vison

The current effort not only quantifies the substantial crash reduction and crash mitigation (injury reduction) benefits afforded by a wide variety of production GM ADAS features, but also identifies potential strategies for moving closer toward a Zero Crashes vision. These include offering ADAS features that provide some degree of automated control (in addition to alerts), since such features were found to consistently outperform their less advanced "alert only" counterparts (e.g., AEB versus FCA, LKA with LDW versus LDW only). The results also highlighted the need to address lane departure and lane change crashes at higher levels of effectiveness, the former of which is likely related to lower customer use of the LKA with LDW and LDW features.

When evaluating Zero Crashes vision progress, it should be remembered that overall crash reduction and crash mitigation benefits are determined by the prevalence of the system-relevant crash in the entire crash population, the feature effectiveness (which incorporates feature usage), and feature penetration across the entire fleet (not just the GM portion of the fleet). For example, based on Swanson et al. (2019)'s analysis of a national dataset of police-reported crashes, the current set of features examined have the maximum potential (i.e., if 100% effective and globally available) to address approximately 55.4% of all police-reported crashes in the US and 60.3% of fatal crashes (based on crash type). If we further assume that the entire US fleet were equipped with the GM radar/fusion AEB, LKA (with LDW), LCA (with SBZA) and RAB (with RPA and RCTA) features examined here at their estimated effectiveness rates shown in Table 17, approximately 33.6% of addressable police-reported crashes, and 19.1% of all police-reported crashes, are estimated to be prevented.[12]

More generally, there remain significant opportunities for moving toward zero crashes beyond improving or expanding the ADAS features examined here, including addressing seat belt use, driver behavior choices (e.g., speeding and impairment due to alcohol or other drugs, drowsiness, or distraction), and additional crash configurations (e.g., intersection crashes). Going forward, we recommend continuing this series of ADAS feature effectiveness studies, leveraging additional state crash databases as they become available to researchers, and exploring the use of telematics-based data (such as GM's OnStar low-level EDR and AACN data). Telematics data could enhance understanding of feature usage surrounding the crash (including feature usage more generally) and potentially enable more timely access to crash data automatically generated by the vehicle. This telematics-based crash data collection approach can be contrasted with state agency police report data, which have approximately 1- to 2-year delays due to availability, but also provide more detailed data surrounding crash circumstances. Finally, we also recommend using these large-scale field effectiveness estimates for informing New Car Assessment Program (NCAP) decision-making and feature content decision-making and planning.

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[12] These calculations are derived from the 2021 Crash Report Sampling System and the crash typology devised by Swanson, et al. (2019). For this calculation assume that: radar/fusion AEB applies to all rear-end crash types (20-24); LKA with LDW applies to drifting (17), opposite direction (18-19) and road departure (4-5) crashes; LCA with SBZA applies to lane change crashes (16); RAB (with RPA and RCTA) applies to the road departure backing (6) and back into vehicle (13) crash types.

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