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COST OF ADVANCED DRIVER ASSISTANCE SYSTEMS (ADAS) REPAIRS

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ABSTRACT

Advanced driver assistance systems (ADAS) have become more commonplace in vehicles across all price points. Even newer base models typically contain some form of ADAS, such as automatic emergency braking.

This work provides perspective on cost associated with repairing current model year vehicles of identical make and model with ADAS. The 2023 Ford F-150, 2023 Nissan Rogue, and 2023 Toyota Camry are included within this work. In 2018, the AAA Automotive Engineering team evaluated the 2018 model year versions of these vehicles for the same purpose as this study; however, it should be noted that results are not directly comparable due to differences in standard equipment, changes in labor costs, and methodology.

Research Questions and Key Findings:

1. What are the typical cost differences associated with frontal collision repair?
   The average cost of replacing ADAS components in a minor front collision repair was $1,540.92, or 13.2% of the average total repair estimate of $11,708.29.

2. What are typical cost differences associated with side mirror repairs?
   The average cost of replacing ADAS components in a side mirror replacement was $1,067.42, or 70.8% of the average total repair estimate of $1,507.55.

3. What are typical cost differences associated with minor rear collision repair?
   The average cost of replacing ADAS components in a minor rear collision repair was $684.63, or 40.9% of the average total repair estimate of $1,698.24.

4. What are typical cost differences associated with windshield replacement?
   The average cost of replacing ADAS components with the new windshield and performing the necessary calibration was $360.00, or 25.4% of the average total repair estimate of $1,439.78.

ADAS parts, labor to remove and replace them, and necessary labor for component aiming and system calibration represents 37.6% of the averaged costs of the four repair scenarios presented in this report for the three vehicles evaluated. ADAS component prices vary for several reasons discussed in the report.

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I. INTRODUCTION

Advanced Driver Assistance System (ADAS) features have been available for the better part of the past decade with overall prevalence increasing with each model year. Twenty automobile manufacturers voluntarily agreed to include automatic emergency braking (AEB) on all cars and light trucks by September 2022. In December 2022, NHTSA (National Highway Traffic Safety Administration) reported that 15 of the 20 automakers that volunteered had equipped 95% of their vehicles with AEB [1]. Additionally, NHTSA released a proposal of new rule making (NPRM) on May 31, 2023, on strengthening ADAS rules to require automatic emergency braking on all new passenger cars and light trucks, for it to be effective at speeds up to 62 miles per hour in avoiding crashes, and to require pedestrian AEB, including requiring that AEB recognize and avoid pedestrians at night [2].

AAA Automotive Engineering's research in 2018[1] evaluated the impact on repair costs from ADAS components in common repair scenarios using three vehicles each of which contained an entry level trim that was mostly free of ADAS. However, ADAS is largely ubiquitous on current model year vehicles including "base models," which are typically equipped with a host of ADAS features including adaptive cruise control, collision warning, automatic emergency braking, and lane departure warning, as standard equipment. As a result, it is not possible to compare the cost of repairing a vehicle with none or few ADAS features to a vehicle of identical make and model equipped with all available ADAS as was done in 2018. Instead, this work uses four common repair scenarios to determine the portion of the overall repair cost attributable only to the ADAS components and related labor.

II. ADAS SENSORS AND THE DRIVER ASSISTANCE FUNCTIONS THEY SUPPORT

A. ADAS Sensors

Three basic types of ADAS sensors are discussed in this report. AAA, as an advocate for automobile consumers, partnered with the Center for Automotive Research and Michigan Tech to develop material that explains the strengths, weaknesses, and complementarity of the sensors that enable ADAS systems.[2] The implications of cost, sensor robustness to weather and light levels, the range of operations from color sensitivity to speed detection, resolution, and range are explored in the published report [3].

1. Radar Sensors

Radar sensors (millimeter wave radar sensors) are used to gauge distances to objects in front of, behind, and in some cases, to the side(s) of vehicles. Radar sensors detect objects at a distance and can provide an instantaneous and accurate distance to the object. This is vital information used to support ADAS features including automatic emergency braking, adaptive cruise control, cross-traffic alert, and blind spot monitoring. Radar sensors continue to function accurately in all lighting conditions, and in poor weather conditions such as rain or fog.

[1] AAA Newsroom at https://newsroom.aaa.com/2018/10/new-vehicle-technologies-double-repair-bills-minor-collisions/

[2] https://www.mtu.edu/mtri/research/project-areas/transportation/sensors-platforms/benchmarking-sensors/

2. Ultrasonic Sensors

Ultrasonic sensors (sonar sensors) are used to gauge shorter distances compared to radar. Consumers will recognize these as the four circles (about the diameter of a nickel) on the rear and sometimes front bumper covers. Ultrasonic sensors assist with parking the vehicle and avoiding objects in front of, behind, and in some cases, to the side(s) of vehicles. The information they provide primarily supports ADAS features including parking assistance (and automated parking). Ultrasonic sensors are inputs to rear view systems, i.e., the green-yellow-red guidelines superimposed on the driver information screen when reversing the vehicle. Automated parking and rear view require additional input from camera(s). Ultrasonic sensors continue to function accurately in all lighting conditions, and poor weather conditions such as rain or fog. They are sensitive to anything covering the sensor surface, including snow or ice buildup. Ultrasonic sensors may be used as secondary inputs to blind spot monitoring and adaptive cruise control systems as noted in this report. Replacement ultrasonic sensors are often ordered pre-painted to match the vehicle color when a vehicle is still relatively new. This is due to the importance of the paint thickness and composition for the accuracy of the distance information provided by the sensor.

3. Camera Sensors

The cameras used to support ADAS functions differ from dash cams and other “picture” cameras due to the high-powered microprocessors and complex algorithms that convert the continuously changing analog image (what is “seen”) to digital data that is used as critical input to many ADAS systems. These include adaptive cruise control, collision warning, automatic emergency braking, lane departure warning, lane keeping assistance, 360° camera views, adaptive lighting that enables automatic high beams, and traffic sign recognition. Camera sensors are vulnerable to glare from rising or setting sun or other high-intensity light sources, intense reflections, and any water, ice, dirt or other debris that partially or fully blocks the lens of the camera sensor. Many consumers will be familiar with a rear-view image that is useless when the rear camera lens is wet or otherwise occluded. Automotive engineers use a variety of methods to minimize when camera sensors cannot provide reliable information. This includes the use of rain sensing windshield wiper systems that clear glass in front of the camera mounted near the rearview mirror. Other camera sensors, including those mounted behind the front grill, on the rear decklid or tailgate, or made part of the side mirrors or B-pillar are more susceptible to environmental interference. If a camera sensor cannot provide quality information to the ADAS or other systems it supports, the affected system will inform the driver that it is not available until conditions improve. This alert is often communicated by a message on the driver information center or icon in the instrument panel.

B. ADAS Functions Supported by ADAS Sensors

Auto manufacturers continue to expand the number of driver assistance features and functionalities supported by a limited number of ADAS sensors. ADAS system development has moved away from one sensor for one system. The small suite of sensors supports an increasing number of functionalities where the data transmitted by each sensor is utilized by an increasing number of control units to enable a wide range of ADAS features. The sensors and functions listed in Figure 1 are not comprehensive for the vehicles evaluated. This report is not comprehensive to all types of ADAS sensors and functions. Figure 1 summarizes the ADAS functions supported by the ADAS sensors affected in the four repair scenarios used in this report.

ADAS Functions Supported by ADAS Sensors*

	Front Radar Sensor (Distance Sensor)			Ultrasonic Sensor(s) Front Bumper Cover/Grill Rear Bumper Cover			Camera in Front Bumper Cover/Grill			Side View Camera			Camera near Rear View Mirror		
2023 Model Year															
	Nissan Rogue	Toyota Camry	Ford F150	Nissan Rogue	Toyota Camry	Ford F150	Nissan Rogue	Toyota Camry	Ford F150	Nissan Rogue	Toyota Camry	Ford F150	Nissan Rogue	Toyota Camry	Ford F150
Adaptive Cruise Control	■	■	■		■								■	■	■
Collision Warning	■	■	■	■									■	■	■
Collision Braking Automatic Emergency Braking (AEB)	■	■	■										■	■	■
Lane Departure Warning		■											■	■	■
Lane Keeping Assist	■	■											■	■	■
Lane Keeping Assist 2													■	■	■
Blind Spot Detection (side)															
Rear View															
360° Camera							■	■	■	■	■	■			
Park Assist				■	■	■									
Adaptive Lighting Automatic High Beam													■	■	■
Adaptive Lighting 2 Automatic Headlamp Leveling															
Adaptive Lighting 3 Adaptive Front Lighting															
Traffic Sign Recognition	■												■		■
Front Cross Traffic															
Rear Cross Traffic															

* Sensors and functions listed are not comprehensive to what may be available on individual vehicles.

■ Nissan Rogue ■ Toyota Camry ■ Ford F150

Figure 1: ADAS functions supported by ADAS sensors Source AAA

Utilization of these three core sensor types by different automakers is mostly uniform. Note that Toyota makes use of the ultrasonic sensor mounted behind the front grill for adaptive cruise control while Nissan and Ford do not use this sensor in the 2023 Rogue and F-150, respectively. Similarly, Nissan makes use of the front radar sensor for traffic sign recognition in addition to input from the camera mounted near the rear-view mirror, while Ford relies only on the camera near the rear-view mirror for this ADAS feature.

III. TERMINOLOGY AND LABOR RATES

Both mechanical and body repair on automobiles are specialized fields with a plethora of abbreviations and technical jargon. This section provides an overview of terms and abbreviations commonly used in collision repair estimates and related service information. Readers familiar with the automotive repair industry can skip ahead to the section on Collision Repair Costs.

A. Explanation of Labor Times and Rates

Collision repair is estimated and billed using a range of labor rates, which vary according to the type of work performed, the skill level required, and specialized equipment needed. On a collision repair estimate, labor

hour amounts are commonly followed by alpha-codes that indicate the expected rate of compensation for each line item.

Collision repair estimates often denote mechanical components with a small (m) and structural components with a small (s). If there is no indicator, the component is a body or sheet metal part. This distinction is associated with the type of service professional that will perform the repair task(s). Parts are lower case; labor is upper case. Frame, Mechanical, Diagnostic, Electrical, and Glass labor are marked with F, M, D, E, and G to the right of the labor hours. Miscellaneous operations are noted as taxable or non-taxable, marked with T or X. This includes wheel alignments and sublets, e.g., when an ADAS calibration is sublet to a dealership service department. Consumers are most familiar with the hourly labor rate from the service department they patronize for maintenance and (mechanical) repair, e.g., brake service, engine running concerns, or water pump replacement. These service departments can be a dealership or an independent/aftermarket (AM) business. The labor coding for this type of mechanical labor is M.

Labor rates for body, paint, body prep, and mechanical are fairly uniform between AM and dealerships. A survey of mechanical labor rates (M) in service departments throughout Michigan is summarized in Figure 2. Due to the convergence of AM and dealership labor rates, they are not separated in this report. A labor operation to calibrate ADAS components may be sublet to either dealership or AM facilities. The determining factors are access to the necessary specialized equipment and trained personnel familiar with the procedure(s). This is most often available at a dealership for the vehicle make but may also be an accumulation of tools and talent at an aftermarket facility that specializes in ADAS repairs and calibration procedures. Consumers can generally rely on the practices of a DRF collision repair facility—one that enables one-stop repair estimating and completion of all repairs for insurance claims—as a guide for where different aspects of a collision repair are completed. Some ADAS calibrations or aiming procedures may be done in-house, while others—particularly if they require expensive special equipment or facilities—may be sublet to a dealership or specialized aftermarket shop.

Michigan

	Average Mechanical Rate		
	2018	**2022**	**2023**
	(D-I)/D	(D-I)/D	(D-I)/D
Dealership	$82.61	$87.62	$94.74
Independent	$78.30	$86.59	$94.16
	5.5%	**1.2%**	**0.6%**

Mechanical labor rate (**M**) for dealerships is slightly higher than independents, but the gap is trending smaller

Figure 2: Dealership vs. Independent/Aftermarket mechanical (M) labor rate comparison Source AAA

Both Independent/Aftermarket and Dealership collision repair centers have labor rates that are lower than mechanical labor for body shop/collision repair labor operations. This includes sheet metal (m), paint (p), and paint prep/supply (s) labor. A survey of sheet metal (body) labor rates (M) in collision centers (dealership and independent/aftermarket) throughout Michigan is summarized in Figure 3.

Michigan

	Average Sheet Metal Rate		
	2018	2022	2023
	(D-I)/D	(D-I)/D	(D-I)/D
Dealership	$41.51	$46.48	$53.14
Independent	$42.96	$49.10	$53.97
	-3.4%	-5.3%	-1.5%
	Sheet metal labor rate (body labor) for independents is higher than dealerships, but the gap is small		

Figure 3: Dealership vs. Independent/Aftermarket sheet metal (m) labor rate comparison Source AAA

B. Source for Repair Estimates

Collision repair estimates were prepared for the four hypothetical damage scenarios by professional auto insurance estimators in two locations: Southern California and Michigan. Both sources used CCC One estimating software [4], which is used by approximately 80% of automobile insurance and collision repair facilities.

Labor rates used in calculations for this report are an average of the labor rates used in estimates from the two sources. The labor rate used for sheet metal (body labor) is $75.00 per hour, and the rate for mechanical labor is $110.00 per hour.

C. Labor Charges Common to Modern Vehicle Collision Repair

1. Pre and Post Scan

Many auto manufacturers have published statements and guidelines on how repairs are to be done on their vehicles. If a manufacturer requires a diagnostic scan of the vehicle's computerized systems before and after collision repairs, this requirement is included in the initial repair estimate. Automobile insurance estimators are familiar with these requirements and follow manufacturer's guidelines in most instances. Position statements on pre and post repair scans from Nissan, Toyota, and Ford are summarized in Figure 4.

	Pre-Scan		Post-Scan	
	Recommended	REQUIRED	Recommended	REQUIRED
Nissan	1996 - 2007	2008 MYO	1996 - 2007	2008 MYO
Toyota	--	1996 MYO	--	1996 MYO
Ford	1996 - 2010	2010 MYO	1996 - 2010	2010 MYO

Figure 4: Diagnostic scan requirements for collision repair Source I-CAR. "MYO" model year onward

Variations in manufacturer statements include Ford/Lincoln defining a collision as, “damage that exceeds minor outer body panel cosmetic distortion.” Similarly, but open to interpretation from Toyota is, “Repairers should perform a ‘Health Check’ diagnostic scan since a capable scan tool is the only way to identify and document DTCs (Diagnostic Trouble Code). It is necessary for repairers perform a ‘Health Check’ diagnostic scan before and after every repair if a vehicle has sustained damage because of a collision.” These potential gray areas in manufacturer requirements support working with a professional insurance claim adjuster and the vehicle owner doing his/her own research where possible. Personal research is not as challenging as it might sound. An internet search that includes make/model/year of the vehicle along with “ADAS components damaged in front [substitute for your situation] collision” provides a good start to learning more about the advanced driver safety systems on your vehicle and the calibration procedures that may be required to bring the vehicle back to full functionality.

2. Wheel Alignment

Many collisions can cause some type of suspension damage, and that means wheel alignment will be necessary. For ADAS equipped vehicles, these systems need to know what direction the vehicle is travelling down the road to accurately make safety corrections and predictions.

Vehicles equipped with ADAS, especially lane keeping assistance and automatic emergency braking, need to be properly aligned with how the vehicle is traveling down the road. This ensures the vehicle thrust line, an imaginary centerline drawn lengthwise through the car, points straight down the road when the steering wheel is centered. ADAS sensors are then calibrated to be in alignment with the vehicle’s thrust line.

Cameras and sensors use different inputs from the vehicle, such as inputs from the steering angle sensor. If the steering angle sensor is adjusted during a wheel alignment, the forward-facing camera, which controls the lane departure warning, may think the steering wheel is turned. This can signal the vehicle to correct the steering to stay on the road, even though the vehicle is traveling between the lines. That leads to a requirement to calibrate the forward-facing camera, which may include all cameras in a 360° view camera system.

3. Calibration of ADAS Components and Systems

Almost all ADAS sensors require calibration and some, such as forward-facing radars and cameras mounted behind the windshield, require extremely precise aiming. A tiny misalignment on the vehicle will aim the sensor significantly off axis 100 or more feet down the road.

Calibration cannot be ignored. Sensors that are out of alignment generate faulty information that will cause ADAS to operate improperly or not at all—creating a safety hazard. In addition, out-of-calibration sensors may cause a warning light or message on the instrument panel or driver information screen and/or set a diagnostic trouble code (DTC) in the vehicle’s computer memory. This DTC is what the pre-repair scan checks for, and what is expected to be cleared up when the post-repair scan is done.

ADAS sensor calibration is a precision process that requires specialized information from the vehicle manufacturer, training, tools, and even physical facilities that can be extremely expensive. Exact procedures vary with the vehicle and sensor type, but most are both complex and time consuming. While some sensors can be calibrated in the shop, others require that a vehicle be driven under specific conditions, and many must undergo both processes.

IV. COLLISION REPAIR COSTS SCENARIOS

A. Repair Scenario #1: Frontal Collision

Repairs associated with a minor frontal collision were examined. In this scenario, the vehicle has been in a forward collision that impacted its front bumper/grill. The following ADAS sensors are commonly mounted to the front bumper or grill and could be damaged in this type of scenario.

- **Radar sensors**: Longer-range sensors used by automatic emergency braking (AEB) and adaptive cruise control systems.
- **Ultrasonic sensors**: Short-range sensors used by parking assistance systems.
- **Front cameras**: Used for surround-view and parking assistance systems.

For repair cost calculations, it is assumed that these sensors need to be replaced as part of the collision repair. Once replaced, a calibration procedure is typically required. Repair cost calculations are based on the manufacturer's repair procedure for the specific vehicle being examined.

1. Front Radar Sensor

Front radar sensors are about the size of a deck of cards and are typically mounted immediately behind the vehicle's front grill. The 2023 Ford F-150 uses two front radar sensors (one left and one right) at a part cost of $392.22 each. The chart below assumes replacement of both front radar sensors with necessary brackets and mount plates for the F-150 repair scenario. Overall, the cost of calibration is less in 2023. This is attributable to ADAS calibration becoming more commonplace in the repair industry. Labor times are more consistent and rely on published times instead of how long a provider requests for the task. Repair costs attributable to the front radar sensor(s) are detailed in Figure 5.

	$75.00	collision repair body labor rate		$110.00	dealership mechanical labor rate	
Front Distance Sensor (Radar)	PARTS	LABOR HOURS SPECIFIC TO ADAS PART R&R	LABOR COST SPECIFIC TO ADAS PART R&R	LABOR HOURS FOR CALIBRATION	LABOR COST FOR CALIBRATION	TOTAL[1]
2023 Nissan Rogue (includes bracket)	$1,128.04	0.2	$15.00	1.6	$176.0	$1,319.04
2023 Toyota Camry	$384.15	0.2	$15.00	1.6	$176.0	$575.15
2023 Ford F150 (LF & RF radars + plates & brackets)	$1,147.16	1.2	$90.00	0.50	$55.00	$1,292.16
2023 AVERAGE	$886.45	0.5	$40.00	1.2	$135.67	$1,062.12

[1]Add $69.99 for four-wheel thrust angle alignment. If multiple ADAS components are replaced, only one alignment charge.

Figure 5: Front radar sensor replacement and calibration costs Source AAA, CCC, I-CAR

Data from repair estimates revealed an unexpected variation. The cost of the radar sensor for the 2023 Nissan Rogue is $928.82, if the vehicle was assembled in the United States; however, if the vehicle was assembled in Japan, the cost of the front radar sensor is $1,559.95, an increase of 68% in the cost of the repair part.

2. Front Around View Camera

Forward-facing camera sensors are about the size of a walnut and are typically mounted immediately behind the vehicle's front upper/center grill. Repair costs attributable to the front around view camera are detailed in Figure 6.

	$75.00	collision repair body labor rate		$110.00	dealership mechanical labor rate	
Front Around View Camera	PARTS	LABOR HOURS SPECIFIC TO ADAS PART R&R	LABOR COST SPECIFIC TO ADAS PART R&R	LABOR HOURS FOR CALIBRATION	LABOR COST FOR CALIBRATION	TOTAL[1]
2023 Nissan Rogue	$363.10	0.2	$15.00	3.3	$360.0	**$738.10**
2023 Toyota Camry	$238.16	included	$0.00	3.3	$360.0	**$598.16**
2023 Ford F150	$326.92	0.1	$7.50	3.3	$360.00	**$694.42**
2023 AVERAGE	$309.39	0.2	$7.50	3.3	$360.00	**$676.89**

[1]Add $69.99 for four-wheel thrust angle alignment. If multiple ADAS components are replaced, only one alignment charge.

Figure 6: Front around view camera sensor replacement with calibration costs Source CCC and I-Car

B. Repair Scenario #2: Side Mirror Replacement

In this scenario, the vehicle's side mirror has been knocked off or damaged to the point that it that it must be replaced. The accident scenario includes damage to the side/rear-facing camera that is part of the ADAS. It is common for side mirrors to have cameras facing the rear and side of the vehicle that are used by various ADAS systems, including lane departure warning and lane keeping assistance.

This cost comparison is limited to the ADAS side-view camera, labor to remove and replace (R&R) the camera in a new mirror housing assembly, and specialized sublet labor to calibrate the camera system, which may include lane keeping assistance and/or 360° surround view.

	$75.00	collision repair body labor rate		$110.00	dealership mechanical labor rate	
Side View Camera (mirror mount)	PARTS	LABOR HOURS SPECIFIC TO ADAS PART R&R	LABOR COST SPECIFIC TO ADAS PART R&R	LABOR HOURS FOR CALIBRATION	LABOR COST FOR CALIBRATION	TOTAL[1]
2023 Nissan Rogue (with mirror cover w/camera)	$503.97	included	$0.00	3.3	$360.0	$863.97
2023 Toyota Camry (mirror assembly w/ blind spot)	$381.36	included	$0.00	3.3	$360.0	$741.36
2023 Ford F150 (mirror assembly with camera)	$1,236.92	included	$0.00	3.3	$360.00	$1,596.92
2023 AVERAGE	$707.42	NA	$0.00	3.3	$360.00	**$1,067.42**

[1]Add $69.99 for four-wheel thrust angle alignment if repair involves suspension repair or calibration requires adjustment of steering angle sensor.

Figure 7: Side view camera (mirror mount) replacement and calibration costs Source CCC, I-CAR

The 2023 Ford F-150 truck side-view camera is only available as part of the complete mirror assembly. Repair estimates from both sources for all three vehicles included specialized sublet labor to perform the necessary calibration.

C. Repair Scenario #3: Rear Collision

The repair scenario for ultrasonic sensor replacement is a minor impact to the rear bumper of the vehicle that resulted in damage to all four ultrasonic sensors. Ultrasonic sensors are used on the front and rear of the vehicle for parking assistance. When equipped with lane departure warning or lane keeping systems, additional ultrasonic sensors are fitted to the vehicle's sides. For the 2023 model year, the Nissan Rogue can have up to 12 ultrasonic sensors, the Toyota Camry eight, and the Ford F-150 ten.

	$75.00	collision repair body labor rate				$110.00	dealership mechanical labor rate	
Rear Ultrasonic Sensors	PARTS(individual)[1]	Total number of ultrasonic sensors possible front/rear/side	Number of sensors replaced in repair scenario	LABOR HOURS SPECIFIC TO ADAS PART R&R Individual front or side sensor, bumper cover quantity in rear	LABOR COST SPECIFIC TO ADAS PART R&R Ultrasonic Sensor (with bumper overhaul)	LABOR HOURS FOR CALIBRATION	LABOR COST FOR CALIBRATION	TOTAL[1]
2023 Nissan Rogue	$72.53	12	4	0.3	$22.50	Calibration is not required for Nissan ultrasonic (parking assist) sensors.		$312.62
2023 Toyota Camry	$237.86	8	4	0.3	$22.50	Varied information.		$973.94
2023 Ford F150 (includes retainer)	$203.08	10	4	0.3	$22.50	Calibration not included on repair estimates (in AAA research) although Ford has two		$834.82
2023 AVERAGE	$171.16	NA		0.3	$22.50	NA		**$707.13**

[1]Add $69.99 for four-wheel thrust angle alignment if repair involves suspension repair or calibration requires adjustment of steering angle sensor.

Figure 8: Rear ultrasonic sensor (1) replacement and calibration costs Source CCC and I-CAR

Research returned conflicting information on calibration requirements for ultrasonic sensors. Insurance professionals stated that calibration is not normally required or included on repair estimates involving ultrasonic sensors, and that a functional test of operation is typically conducted to confirm repair. I-CAR, a technical resource for the collision repair and auto insurance industries states that, “No calibration requirements were found” for the Nissan Rogue. Toyota service information (accessed via Mitchell One) states that, “If a park sensor is replaced, park sensor calibration is required.” To accomplish the calibration, the park sensor angle is measured using a special gauge, and the values are input to the Intelligent Clearance Sonar control module through a scan tool.

D. Repair Scenario #4: Windshield Replacement

The final repair scenario is replacement of the front windshield glass due to stone chip or other damage. On many vehicles, a front-facing camera will be mounted to the windshield. This repair scenario does not include the cost of the front facing camera mounted near the rear-view mirror; an accident scenario severe enough to damage the camera mounted near the rear-view mirror is likely to total the vehicle. These cameras are used to identify road markings and signs and to identify other vehicles and objects in the roadway ahead. They may be used by various ADAS systems, including lane keeping assist, traffic sign recognition, and pedestrian detection, among others.

When the windshield is replaced, the camera must be transferred to the new windshield and requires precise positioning to function properly. In many cases, original equipment manufacturer (OEM) glass is required (as opposed to aftermarket) to ensure that it meets the proper specifications. This repair includes the cost of the replacement windshield and installation, as well as the labor costs to transfer the camera and perform calibrations as required.

Windshield replacement is a common repair procedure that has become an industry unto itself. Most repair facilities, both independent and dealers, sublet windshield replacement to outside specialists who come on-site and do the job at a predetermined price. ADAS cameras and other components mounted to the inside of windshields have created challenges for this business model because when a car is equipped with a camera sensor behind the windshield, the replacement glass must meet strict standards for clarity and freedom from distortion. Location pins, mounting brackets, and rigorous specifications for the shade pattern (black dots at top and around perimeter) are part of OEM glass specifications for ADAS applications. A replacement windshield that has not been designed for use with ADAS is unacceptable and can prevent proper calibration of the camera sensor.

Many automakers require or strongly suggest OEM glass when replacing the windshield on vehicles with windshield mounted ADAS cameras. For ADAS applications, some large aftermarket glass installers have sourced windshields from automakers or their original equipment manufacturers. The windshield installer is responsible for ensuring that the replacement glass does not interfere with ADAS operation on the vehicle.

	$75.00	collision repair body labor rate		$110.00	dealership mechanical labor rate	
Windshield Camera Sensor	Windshield OEM Glass	LABOR HOURS SPECIFIC TO ADAS PART R&R	LABOR COST SPECIFIC TO ADAS PART R&R	LABOR HOURS FOR CALIBRATION	LABOR COST[1] FOR CALIBRATION	TOTAL
2023 Nissan Rogue	$814.98	0	$0.00	3.3	$360.0	$1,174.98
2023 Toyota Camry	$596.30	0.3	$22.50	3.3	$360.0	$978.80
2023 Ford F150	$541.53	0.0	$0.00	3.3	$360.00	$901.53
2023 AVERAGE with OEM glass	$650.94	0.1	$7.50	3.3	$360.00	**$1,018.44**

[1] Labor costs for windshield replacement reflect industry norm of sublet to a glass replacement company. OEM glass is used for ADAS applications.

Figure 9: Windshield replacement costs specific to ADAS components Source CCC and I-CAR

Manufacturer specific statements regarding windshield replacement for the 2023 model vehicles included in this research are summarized below.

a) Nissan Rogue

- Do not remove the lane camera unit bracket and the cover bracket from windshield glass. The lane camera unit bracket and the cover bracket must be replaced together with windshield glass as an assembly.

b) Toyota Camry

- Toyota states that systems that could be affected if Toyota genuine parts are not used are the lane departure alert system, forward recognition camera system, dynamic radar cruise control system, pre-collision system or automatic high beam system. If an aftermarket glass is installed, there is the possibility that the black ceramic border may not allow the camera to see through it properly. In addition, the aftermarket glass may be missing the brackets necessary for mounting the camera.
- Many of the newer models are now equipped with a forward recognition camera, which is part of the adaptive cruise system. When the windshield is replaced, the camera unit will need to be calibrated.

c) *Ford F-150*

- The original glass used on Ford Motor Company vehicles is designed and built to provide optimum fit, function, safety, and structural integrity. The quality, performance, and safety of aftermarket replacement windshield and side glass may not meet Ford Motor Company's exacting specifications and can result in key safety features not functioning properly and reduced customer satisfaction in the performance of their vehicle. For these reasons, Ford Motor Company does not approve the use of aftermarket windshield or side replacement glass. Only by using Ford Original Equipment Carlite replacement glass can you be assured of the fit, function, safety, and structural integrity of the repair.
- Advanced Driver Assistance Systems (ADAS) such as Lane-Keeping, Pre-Collision Assist with Automatic Braking, Evasive Steering Assist, and Auto High-Beam Headlamps use images from a camera mounted to the windshield. Windshields equipped with cameras have integrated camera brackets that allow for precise attachment and positioning of the camera and are designed to have optical quality that is compatible with the camera. Aftermarket windshields cannot duplicate the precise location of the camera attachment brackets and often contain distortion that adversely affects the camera's operation, which can result in improper ADAS system operation.

V. KEY FINDINGS

Primary research questions and findings:

A. What are typical cost differences associated with frontal collision repair?

The cost of front collision repairs that is attributable to ADAS components averages 13.2% of the total repair cost for the three 2023 model vehicles evaluated.

The average cost of replacing ADAS components in a minor front collision repair was $1,540.92, or 13.2% of the average total repair estimate of $11,708.29.

	Repair Scenario #1: Front impact			
	Total Repair Estimate	Front Radar	Front Camera	ADAS % of Total Repair
2023 Nissan Rogue	10209.09	1319.04	738.10	20.2%
2023 Toyota Camry	10270.37	575.15	598.16	11.4%
2023 Ford F-150	14645.42	697.88	694.42	9.5%
Average	**$ 11,708.29**	**$ 864.02**	**$ 676.89**	**13.2%**

Figure 10: Front impact scenario: ADAS % of total repair cost Source AAA

B. What are typical cost differences associated with side mirror repairs?

The cost of side mirror repairs (replacement) that is attributable to ADAS components averages 70.8% of the total repair cost for the three 2023 model vehicles evaluated.

The average cost of replacing ADAS components in a side mirror replacement was $1,067.42, or 70.8% of the average total repair estimate of $1,507.55.

	Repair Scenario #2: Side Mirror Damaged		
	Total Repair Estimate	Side-view Camera	ADAS % of Total Repair
2023 Nissan Rogue	1583.53	863.97	54.6%
2023 Toyota Camry	1028.81	741.36	72.1%
2023 Ford F-150	1910.30	1596.92	83.6%
Average	**1507.55**	**1067.42**	**70.8%**

Figure 11: Side mirror damage scenario: ADAS % of total repair cost Source AAA

C. What are typical cost differences associated with minor rear collision repair?

The cost of minor rear collision repair that is attributable to ADAS components averages 40.9% of the total repair cost for the three 2023 model vehicles evaluated.

The average cost of replacing ADAS components in a minor rear collision repair was $684.63, or 40.9% of the average total repair estimate of $1,698.24.

	Repair Scenario #3: Rear Impact		
	2023 Total Repair Estimate	Ultrasonic Sensor (4 Replaced)	ADAS % of Total Repair
2023 Nissan Rogue	1782.75	290.12	16.3%
2023 Toyota Camry	1733.41	951.44	54.9%
2023 Ford F-150	1578.67	812.32	51.5%
Average	**$ 1,698.28**	**$ 684.63**	**40.9%**

Figure 12: Rear impact scenario: ADAS % of total repair cost Source AAA

D. What are typical cost differences associated with windshield replacement?

The cost of windshield glass replacement that is attributable to ADAS components averages 25.4% of the total repair cost for the three 2023 model vehicles evaluated.

The average cost of relocating ADAS components to the replacement windshield and performing the necessary calibration was $360.00, or 25.4% of the average total repair estimate of $1,439.78.

	Repair Scenario #4: Windshield Replacement		
	Total Repair Estimate	ADAS Calibration	ADAS % of Total Repair
2023 Nissan Rogue	1687.40	360.00	21.3%
2023 Toyota Camry	1371.95	360.00	26.2%
2023 Ford F-150	1259.98	360.00	28.6%
Average	**1439.78**	**360.00**	**25.4%**

Figure 13: Windshield replacement scenario: ADAS % of total repair cost Source AAA

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