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ADA TRAFFIC JAM EVALUATION

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ABSTRACT

Active Driving Assistance (ADA) systems [1],which are Level 2 (L2) Advanced Driver Assistance Systems (ADAS), have the ability to automatically provide steering and acceleration/deceleration support in certain driving situations, while requiring the driver to remain fully engaged and supervising the system. ADA technology has continued to expand its capabilities, and many systems are now designed to function in low-speed high-traffic scenarios.

This project evaluated five vehicles with ADA systems designed to operate in traffic congestion situations and operate at speeds down to a full stop. Vehicles underwent naturalistic evaluation, being driven normally in accordance with owner's manual instructions on limited-access highways in routes and times chosen to promote high-traffic situations. Each vehicle was driven 342 miles and 16.2 hours on average, with GPS data, video, and audio being continuously recorded to document traffic conditions, vehicle behavior, and driver observations. Abnormal or inadequate behavior by ADA systems was recorded and quantified.

Research Questions:

1. How do ADA systems of new passenger vehicles perform in real-world, high-traffic driving?
2. How does the performance of hands-off ADA systems compare to hands-on ADA systems?

Key Findings:

1. In total, notable events were recorded every 3.2 miles (9.1 minutes) on average, with drivers having to intervene 85% of the time. The most common type of event was inadequate response by the automated system to vehicles cutting into the lane ahead, occurring every 8.6 miles (24.4 minutes) on average. These events are inherently challenging, particularly because they often provide little time to react. The second most common event was inadequate lane centering, occurring every 11.3 miles (32.2 minutes).
2. Overall, notable events occurred three times as often for hands-on ADA systems (every 2.3 miles or 6.7 minutes) than for hands-off ADA systems (every 7.2 miles or 20.1 minutes) on average. It was also found that hands-off systems asked the driver to place their hands back on the wheel once every 5.5 miles or 15.3 minutes on average.

Recommendations:

1. Evaluated ADA systems frequently encountered situations that required drivers to intervene. Drivers utilizing ADA or other driver assistance systems should be careful to maintain awareness and the ability to quickly take full control of the vehicle at all times.
2. With respect to high-traffic driving, manufacturers should seek to improve ADA performance, particularly related to cut-ins response and lane centering behavior.
3. Manufacturers should seek to increase the overtness of alerts related to deactivation of ADAS features to ensure drivers are aware when features are or are not active.

GLOSSARY

Adaptive Cruise Control (ACC): Cruise control that also assists with acceleration and/or braking to maintain a driver-selected gap to the vehicle in front. Some systems can come to a stop and continue while others cannot [1].

Active Driving Assistance (ADA): Simultaneously uses Lane Centering Assistance and Adaptive Cruise Control features. It is considered a level 2 (L2) ADAS feature, and the driver must constantly supervise this support feature and maintain responsibility for driving [1] [2].

Advanced Driver Assistance System (ADAS): A collection of technologies designed to enhance vehicle safety. The systems utilize a variety of sensors with software to assist drivers in the operation of their vehicles, aiming to reduce the likelihood of accidents caused by human error.

Lane Centering: Also referred to as “Lane Centering Assistance,” provides steering support to assist the driver in continuously maintaining the vehicle at or near the center of the lane [1].

LiDAR: “Light detection and ranging”. Uses lasers to measure distance via reflected light, similar to the function of radar. In this context, this technology is used to produce three-dimensional maps utilized by some ADAS technology.

Traffic Jam Assist: This or similar terminology is commonly used to refer to ADAS features that automatically control acceleration, braking, and steering in low-speed, stop-and-go traffic situations. These systems can automatically decelerate to a stop and accelerate from a stop. Their operation may be limited to low speeds (commonly 25 mph or less) or they may operate up to highway speeds. These systems fall under the definition of Level 2 ADAS or “Active Driving Assistance”.

CONTENTS

I. Background 6
II. Introduction 6
III. Vehicle Selection & Preparation 7
A. ADA System Requirements 7
B. Test Vehicles 7
C. Test Vehicle Preparation 7
IV. Test Equipment 8
V. Methodology 9
A. Objective 9
B. Driving Routes & Timing 9
C. Data Recorded 10
D. Test Procedure 10
1) Pre-test Preparation: 10
2) Start of Test Drive: 11
3) During Test Drive: 11
4) End of Test Drive: 12
E. Data Analysis 12
VI. Test Results & Analysis 13
A. Overall Results 13
B. Comparison of Hands-on and Hands-off Systems 15
VII. Recommendations 17
VIII. References 1
IX. Approvals 19
X. Appendix A: Test Vehicle Information 20
XI. Appendix B: Maps of Driving Routes 21
XII. Appendix C: Table of defined Event Types 25
XIII. Appendix D: Test Results by Vehicle 26

I. BACKGROUND

ADAS (Advanced Driver Assistance Systems) refers to modern safety and convenience features that use advanced technology (like cameras and other sensors) to detect objects and obstacles and assist the driver. SAE defines ADAS in levels from 0 to 5 [2]. Level 1 systems control one component of driving (steering or braking/acceleration) and includes automatic emergency braking and lane keeping assistance. Active Driving Assistance systems (ADA), which is the subject of this evaluation, refers to systems that provide steering and brake/acceleration support, but requires the driver to be fully engaged in driving and supervising these features. In practicality, ADA systems are a combination of two level 1 ADAS features operating simultaneously: lane centering and adaptive cruise control.

Currently available ADA systems fall into two categories: hands-on and hands-off. Hands-on systems require the driver to continue holding the steering wheel while the ADA system is functioning. These systems rely on on-board sensors (like camera and radar) to detect and react to the driving environment. Hands-off systems allow the driver to take their hands off of the steering wheel in most conditions while the ADA system is active, though in specific conditions the driver may be asked to place their hands back on the steering wheel. These systems use on-board sensors as well, but also rely on LiDAR-mapped roads. For this reason, these systems only operate on specific highways that have been mapped by the vehicle’s manufacturer.

As ADA technology has advanced, systems have become capable of handling more driving scenarios. Specifically, in recent years more systems have added the ability to operate in low-speed, high-traffic scenarios. Many systems have the ability to come to a complete stop on their own and resume driving when traffic begins to move. This study is intended to focus on low-speed, high-traffic driving situations, because these situations challenge newer capabilities for ADA systems.

II. INTRODUCTION

As Active Driving Assistance (ADAS) technology continues to grow, the types of driving situations in which they are designed to operate expands. Traffic jam situations are one area where more systems have added capability in recent years. The systems evaluated in this study are capable of automatically controlling acceleration, braking (to a complete stop), and steering under driver supervision in low-speed, high-traffic scenarios.

The operational domain and specific function of these systems varies among different vehicle manufacturers. Some systems are intended only for lower-speed driving, while others operate continuously from a full stop to highway speeds. Some systems are hands-on, while others are hands-off. Some systems are intended to operate on any road as long as specific conditions are met, while others are designed to only operate on designated highways.

This project evaluated five vehicles with ADA systems designed to operate in traffic congestion situations and operate at speeds down to a full stop. Vehicles underwent naturalistic evaluation, being driven normally on limited-access highways in routes and times chosen to provide high-traffic situations. Any abnormal or inadequate behavior by the ADA system was recorded, particularly events in which the driver had to take control of the vehicle.

III. VEHICLE SELECTION & PREPARATION

A. ADA System Requirements

All vehicles tested in this study were equipped with systems meeting the following requirements:

- Automatically controls acceleration, deceleration, and steering within the driving lane.
- Operates on limited-access highways (minimum).
- Capable of coming to a complete stop.
- Operates up to a speed of 25 mph (minimum).
- Representation of hands-on and hands-off systems (minimum 2 of each tested)

B. Test Vehicles

In addition to the above requirements for the ADA systems, new 2024 or newer model year vehicles were selected for testing based on availability and to provide a mix of vehicle manufacturers and models with significant U.S. sales. To that end, no more than one model from any manufacturer was tested. Also, three hands-on and two hands-off ADA systems were evaluated. Tested vehicles are listed below, with hands-on and hands-off ADA systems marked as such.

- 2024 Ford F-150 Platinum SuperCrew 4WD (hands-off)
- 2024 Honda Accord LX Sedan (hands-on)
- 2024 Lexus RX 450h+ Luxury (hands-off)
- 2024 Mazda CX-30 2.5 Turbo Premium Plus (hands-on)
- 2024 Volkswagen Atlas SE AWD w/ Technology Package (hands-on)

C. Test Vehicle Preparation

Upon receipt, test vehicles were inspected and confirmed to be in working order with no check engine lights or warning messages on the dash. Vehicles were taken to dealerships for the following services:

- Tire and brake system inspection
- Four-wheel alignment
- ADAS calibration
- Software update to latest version

IV. TEST EQUIPMENT

Figure 1: Photo of test vehicle interior during testing, showing touch screen and cameras. Image source: AAA.

Each test vehicle was instrumented with the following equipment, used to continuously record data during testing.

- **Datalogger: VBOX Video HD2 Datalogging Unit (1)**
  One datalogging unit was used to continuously record and store multiple time-synched data inputs.
- **Touch Screen Interface: VBOX MFD Touch Display (1)**
  A touch screen interface was used to allow the driver to mark notable events during testing, allowing for efficient post-test analysis.
- **GPS: 25 Hz Low Profile GNSS Antenna (1)**
  A GPS antenna was positioned centrally on the roof of the vehicle to record vehicle position, velocity, and acceleration data.
- **Cameras: VBOX Video 1080p Camera (2)**
  One camera was positioned on the dash of the test vehicle facing forward through the windshield to record near driver-view video of events during testing. A second camera was positioned facing the instrument cluster to record any alerts received during testing.
- **Microphone: VBOX Video HD2 Mono Microphone (1)**
  A microphone was positioned near the driver's seat to allow the driver to dictate information about events that occurred during testing.
- **Brake Pedal Tape Switches: Tapeswitch Foot Switch (1)**
  A normally-open, momentary-contact foot switch was placed on the brake pedal to capture brake pedal depressions. Data was used when reviewing event data to verify whether the driver manually applied the brakes.
- **Throttle Pedal Pressure Sensor: Ohmite Resistive Analog Force Sensor (1)**

Flat resistive force sensor was placed on the throttle pedal to measure applied force. Data was used when reviewing event data to verify whether the driver pressed the throttle pedal.

- **2-way Radio (1)**

  A 2-way radio was used to communicate with other test drivers to coordinate driving routes and timing.

V. METHODOLOGY

A. Objective

The purpose of this project was to evaluate the performance of ADA systems of various new passenger vehicles in real-world, low-speed, high-traffic highway driving conditions. Vehicles were evaluated naturalistically on public roadways while various data were recorded. Test personnel were instructed to drive the vehicles normally in accordance with owner's manual instructions and to mark any notable events (events related to ADA performance, specifically) and dictate relevant information into the microphone. Information about all notable events were analyzed to quantify system performance.

B. Driving Routes & Timing

All testing was performed on limited-access highways in the greater Los Angeles, CA, area. This area was chosen due to consistent high-traffic conditions and the abundance of roadways on which ADA systems are capable of operation (particularly in the case of the hands-off ADA systems). Driving routes varied by test segment, featuring a variety of highways. Routes were selected to provide a variety of conditions (such as direction, sun exposure, road surface condition, overpasses and tunnels, and time of day) while also promoting high-traffic conditions. Testing was performed on weekdays, focusing on mornings and afternoons to provide consistent traffic patterns. All test vehicles were driven along the same routes simultaneously, with vehicles entering and exiting the highway together. However, test vehicles remained separated in traffic.

Test Segment		Route Description	Approx. Local Time	
Date	Segment		Start	End
10/21/2024	Monday AM	110 South to 110 N to 101 North to 101 South repeated two times.	8:45 AM	11:00 AM
10/21/2024	Monday PM	10 West to 10 East.	2:05 PM	3:00 PM
10/22/2024	Tuesday AM	110 South to 110 N to 101 North to 101 South repeated two times.	8:05 AM	10:00 AM
10/22/2024	Tuesday PM	110 North to 5. Loop 110 South to 110 North twice, then to 5 South.	2:25 PM	4:00 PM
10/23/2024	Wednesday AM	10 West to 10 East to 10 West to 10 East to 10 West to 405 South.	8:00 AM	11:30 AM
10/23/2024	Wednesday PM	405 North to 405 South repeated three times. Then 405 North to 10 East	1:15 PM	3:45 PM
10/24/2024	Thursday AM	10 West to 10 East, repeated twice. Then 10 West.	8:20 AM	11:40 AM
10/24/2024	Thursday PM	405 South to 405 North repeated twice. Then 405 North to 10 East.	1:15 PM	3:15 PM
10/25/2024	Friday AM	110 South to 105 West to 405 North to 101 South to 5 South to 710 South to 105 West to 110 North.	8:10 AM	10:40 AM

All routes consist of highways in the greater Los Angeles area. Route maps can be found in the appendix.
Note that there are periods within these timeframes in which vehicles exited the test route, such as exiting to switch highway directions or when taking breaks. Events were not recorded during these periods.

Figure 2: Schedule and descriptions of driving routes. Image source: AAA.

Inherent differences in driver behavior (particularly drivers' specific perceptions and tolerances for driving behavior in certain situations) have the potential to cause variability when quantifying the performance of ADA systems in a real-world setting. For this reason, the six test drivers (one for each test vehicle) were rotated through test vehicles according to the following schedule. Full details of the driving route and schedule can be found in Appendix B.

Day	Austin	Brion	Megan	Josh	Minh	Richard
Monday AM	Buick	Ford	Honda	Lexus	Mazda	Volkswagen
Monday PM	Ford	Honda	Lexus	Mazda	Volkswagen	NA
Tuesday AM	Ford	Honda	Lexus	Mazda	Volkswagen	NA
Tuesday PM	Honda	Lexus	Mazda	Volkswagen	NA	Ford
Wednesday AM	Honda	Lexus	Mazda	Volkswagen	NA	Ford
Wednesday PM	Lexus	Mazda	Volkswagen	NA	Ford	Honda
Thursday AM	Lexus	Mazda	Volkswagen	NA	Ford	Honda
Thursday PM	Mazda	Volkswagen	NA	Ford	Honda	Lexus
Friday AM	Volkswagen	NA	Ford	Honda	Lexus	Mazda

Figure 3: Schedule of driver rotation during test week. Image source: AAA.

C. Data Recorded

The following data was recorded continuously during test drives, utilizing the equipment described previously.

- **GPS:** Position (lat/long), elapsed distance, speed, acceleration, heading, UTC time, elapsed time
- **Video**: Camera 1 - forward through windshield; camera 2 - instrument cluster
- **Audio**: Microphone near instrument cluster to record driver dictations
- **Pedals:** Throttle pedal force (via resistive force sensor) and brake pedal depression (via normally open switch)
- **Event Markers:** Occurrence of events marked on data timeline via touch screen buttons

D. Test Procedure

1) Pre-test Preparation: Before test drives, drivers familiarized themselves with the test vehicle and the function of its ADA system, particularly the initialization steps, control of any adjustable settings, and familiarization with alerts and icons related to the ADA system. Drivers also familiarized themselves with the designated route for that test segment.

Drivers started the test vehicle, powered on the datalogging equipment, and verified it was operating correctly. The adjustable following distance for the ADA system was verified to be in the specified setting (noted below) prior to starting the test drive. For all but one test vehicle, the following distance was set at the closest setting, because it was found in pre-testing drives that higher settings promoted excessive cut-ins by other drivers. For the Lexus RX, the hands-free ADA system is fixed to the second-closest following distance, so this setting was used instead.

2) Start of Test Drive: Dataloggers were initiated to record data and all vehicles departed from the base facility together, driving towards the designated highway entrance for the driving route. Once on the highway and in the appropriate driving lane, drivers would initialize the vehicle's ADA system and set the maximum speed according to the speed limit. The ADA system would remain on for the duration of the test drive until the test route was completed and they had exited the highway. Upon entering the highway, drivers moved into lane 3 (third lane from the left) as soon as safely possible, allowing a minimum of one non-test vehicle between test vehicles.

Drivers would remain in lane 3 continuously during test drives until it was necessary to switch lanes, such as exiting from one highway to another. Note that in road sections with a special lane to the far left (such as express or carpool lanes), test vehicles remained in the third lane from the left counted from the first "non-special" lane. In certain scenarios it was deemed that a different lane (other than lane 3) was preferable, particularly in areas with abnormal interchanges. This change was initiated by the lead vehicle, communicated to the other test drivers via hand-held radio, and all test vehicles moved into the new lane as soon as it was safe to do so.

3) During Test Drive: During test drives, the responsibility of the driver was to drive safely and normally, utilizing the ADA system according to the instructions provided in the owner's manual. Drivers were instructed to allow the ADA system to control driving tasks as long as the system was operational and it was safe to do so, while maintaining awareness and the ability to immediately take control of the vehicle when necessary. For hands-off ADA systems, drivers were instructed to have their hands off of the steering wheel until necessary to take control, while for the hands-on ADA systems drivers were instructed to keep their hands on the steering wheel while providing a minimal amount of steering input.

During test drives, drivers were tasked with marking notable events using programmed buttons on the datalogger's touch screen interface. Notable events included all events in which the driver deemed it necessary to take back full control of the vehicle (steering, brake, or throttle input) and all events in which the ADA system's behavior in deviated from its normal operation or what would be considered normal driving behavior. Six buttons were used to categorize notable events into groups for efficient data analysis:

- **"Adjacent Lane":** Used to mark events that involved interactions with vehicles from adjacent lanes. Most commonly, this meant vehicles moving from an adjacent lane into the test vehicle's lane ahead.
- "**Deactivation":** Used to mark deactivation of ADA functionality, including loss of lane centering, adaptive cruise control, hands-off functionality, or any combination.
- "**Lane Centering":** Used to mark events related to lane centering functionality (excluding deactivations).
- **"Lead Following":** Used to mark events related to the adaptive cruise control functionality (excluding deactivations).
- **"Kudos":** Used to mark events in which the driver felt that the ADA system performed particularly well considering the conditions.
- **"Other Events":** Used to mark events that did not fit the descriptions of the other marker groups.

After the occurrence of a notable event, once the driver deemed it safe to do so according to the driving conditions, the driver pressed the appropriate button on the touch screen, which placed a marker at that timestamp in the continuous data log. Drivers would then audibly dictate information about the event, including a brief description of the event, description of interacting vehicles, and any other information they – deemed relevant.

4) End of Test Drive: Upon completion of the test route, drivers exited the highway and returned to the base facility. After parking the vehicle and turning off the datalogging equipment, drivers completed a test form in which they were asked to provide feedback on the performance of the ADA system during that test segment.

E. Data Analysis

Once testing was completed, personnel reviewed the data files using the VBOX Test Suite software from RACELOGIC, Ltd. This software allowed for all recorded values to be viewed simultaneously, including time, position, speed, video, and event markers.

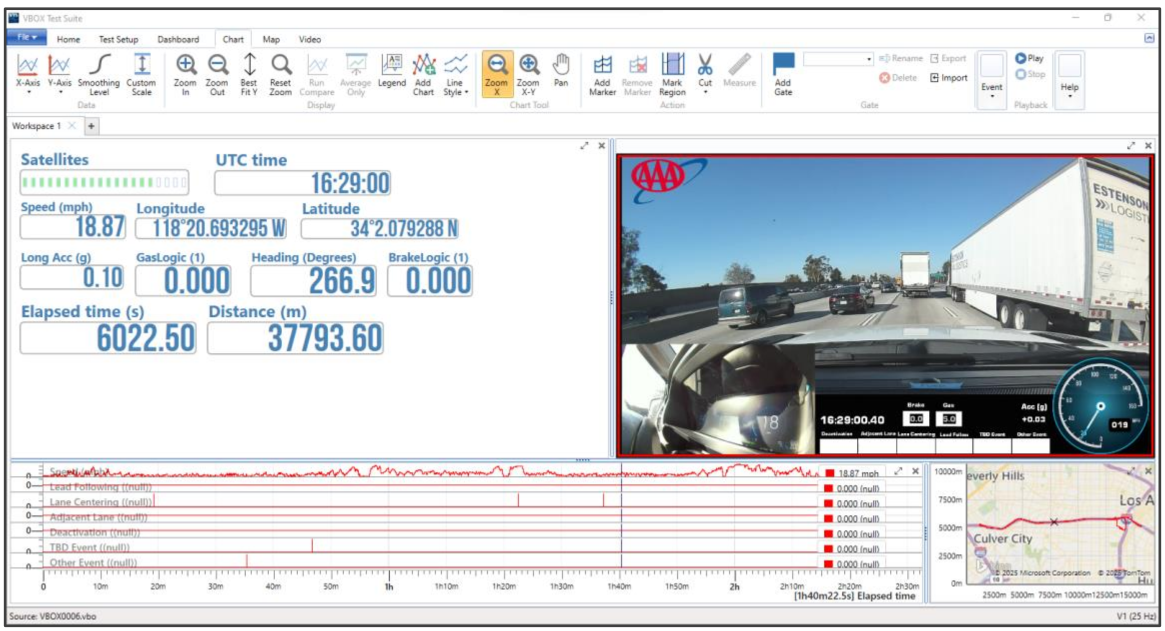

Figure 4: Example of data analysis using VBOX Test Suite software. Image source: AAA.

Personnel reviewed each data file and recorded specified information for each marked event into a data table. Once input, recorded data was reviewed by a second person, and identified errors were corrected. For each event, the following information was recorded:

Event Type	Description
File Name	Name of the data file that the event was recorded in.
Test vehicle	Brand of the test vehicle.
Driver	Name of the driver.
Date	MM/DD/YY
AM/PM	Specifies either the morning or afternoon driving segment for that day.
Event Button	The touch interface button associated with the type of event that occurred.
Event Type	More specific categorization of events (details provided in appednix).
Driver Intervened?	Whether or not the driver took back control of the vehicle by applying brakes, pressing throttle, or manually steering.
Time	UTC Time provided by GPS. Converted to local time.
Position	Latitude and longitude as recorded by GPS.
Highway Information	Highway name, and nominal direction for the occurrence of the event. Confirmed by video footage and GPS position
Sun Position	Recorded as vertical and horizontal position (in degrees) of the sun. Calculated using online tool based on date, time, and location.
Vehicle Heading	Vehicle heading in degrees from GPS.
Vehicle Speed	Vehicle speed in MPH from GPS.
Interacting Vehicle	Brief description of interacting vehicles when applicable, such as during a cut-in event.
Lane Marker Condition	Brief description of the condition of lane markings, particularly whether they were worn, faded, or missing. (Subjective)
Road Curvature	Whether or not there was a significant curvature to the road at the occurece of the event. (Subjective)
Description of Event	Short description of the event based on video and driver dictation.

Figure 5: Table of information recorded for each marked event. Image source: AAA.

VI. TEST RESULTS & ANALYSIS

A. Overall Results

Once all event information was recorded and reviewed for all test vehicles, results were compiled for analysis. For the purpose of quantifying the performance of tested ADA systems during test drives, it was necessary to define specific categories of events. First, “notable events” are defined for this analysis as all events in which the ADA system did not adequately handle the driving situation as determined by the driver. These are behaviors by the ADA system that the driver determined were “abnormal” or unsafe, and includes both situations in which the driver intervened by taking over control of the vehicle and situations where the ADA system was allowed to maintain control through the entirety of the event. Note that this includes deactivations to adaptive cruise control and/or lane centering function. However, this does not include deactivations of the hands-off functionality, which is only relevant to the vehicles with hands-off ADA systems.

Event Type	All	Intervened	
Cut-in response inadequate	199	179	89.9%
Lane centering inadequate	151	110	72.8%
No resume after stop	71	71	100.0%
Lane centering &/or ACC deactivation	57	55	96.5%
Inadequate deceleration	43	30	69.8%
Other Events	12	6	50.0%
Total	**533**	**451**	**84.6%**

Figure 6: Total counts of notable events - all test vehicles. Image source: AAA.

The table above provides total counts of notable events observed during testing for all test vehicles, broken down by event type. It provides counts for all notable events and for notable events in which the driver intervened, along with the percentage of events in which the driver intervened. Notable event results for individual vehicles can be found in Appendix C.

The total count of notable events (including all test segments and test vehicles) was 533, with drivers intervening in 451 of those (85%). The event type with the highest rates of occurrence was inadequate cut-in responses at 199 (more than one-third of all events), with 90% of those requiring the driver to intervene. The second highest event type was inadequate lane centering at 151 (more than one quarter of all events), with 73% of those requiring driver intervention. These two event types account for the majority of notable events at 66%. Other prevalent event types included ACC function not resuming after coming to a stop, deactivation of lane centering and ACC functions, and inadequate deceleration in response to vehicles ahead.

In total, the five test vehicles traveled 1,708.2 miles and 80.9 hours over five days of testing (average speed of 21.1 mph). To better quantify the prevalence of notable events during test drives, the distance and time driven were divided by event counts to produce average intervals between notable events in miles and minutes, respectively. Presenting these results in the form of rate of occurrence may make it easier to understand their significance.

Event Type	All		Intervened	
Event occurred once every ...	miles	minutes	miles	minutes
Cut-in response inadequate	8.6	24.4	9.5	27.1
Lane centering inadequate	11.3	32.2	15.5	44.1
No resume after stop	24.1	68.4	24.1	68.4
Lane centering &/or ACC deactivation	30.0	85.2	31.1	88.3
Inadequate deceleration	39.7	112.9	56.9	161.9
Other Events	142.3	404.7	284.7	809.3
Total	**3.2**	**9.1**	**3.8**	**10.8**

Figure 7: Average distance and time intervals between notable events (all test vehicles). Image source: AAA.

a) In total (all test vehicles) notable events occurred every 3.2 miles or 9.1 minutes on average, with drivers having to intervene by braking, steering, or accelerating every 3.8 miles or 10.8 minutes. The most frequently occurring event type was inadequate response to vehicles cutting into the lane in front, with drivers having to apply the brakes to avoid collision once every 27.1 minutes on average. Drivers had to intervene due to inadequate lane centering events once every 15.5 miles or 44.1 minutes.

The AAA Foundation for Traffic Safety's 2023 American Driving Survey found that Americans drove 29.1 miles and 60.7 minutes each day on average [3]. While not all Americans travel in the type of high-traffic conditions tested in this study on a daily basis, it is reasonable due to the typical distances driven that they should expect to have to intervene due to incidents multiple times a day on average if using these types of systems.

B. Comparison of Hands-on and Hands-off Systems

While each of the systems evaluated differed slightly based on manufacturer, the tested ADA systems can be classified into two distinct types: hands-on and hands-off. Differences between these types of system include not only their operation, but also the technology they use to function.

Hands-on systems require the driver to keep their hands on the steering wheel while the system is operating. These typically have a steering wheel torque sensor to detect that the driver is holding the wheel, and will alert the driver and eventually disable the ADA functions if not detected. These systems rely on on-board sensors (such as camera and radar) and are not limited to specific roads on which they can operate. Three of the five vehicles tested had hands-on ADA systems: Honda Accord, Mazda CX-30, and Volkswagen Atlas.

Notable Events - Hands-On Systems	Tot Miles 1019.7	Tot Hrs 48.8
Event Type	Total	Intervened
Vehicle cut-in response inadequate	153	137
Lane centering inadequate	121	90
No resume after stop	70	70
Lane centering &/or ACC deactivation	47	45
Inadequate deceleration	37	24
Other events	9	4
Total	**437**	**370**

Figure 8: Counts of notable events for evaluated hands-on ADA systems. Image source: AAA.

Hands-off systems allow the driver to take their hands off of the steering wheel while the ADA system is operating in normal conditions. In certain driving situations, these systems may ask the driver to place their hands back on the steering wheel. In addition to using on-board sensors, these systems also typically rely on mapped roads to operate. For this reason, both of the hands-off ADA systems tested were limited via GPS to approved highways. All of the roads on which vehicles were tested for this study were confirmed to be approved for both hands-off vehicles. Two of the vehicles tested had hands-off ADA systems: Ford F-150 and Lexus RX 450h+.

Notable Events - Hands-Off Systems	Tot Miles 688.5	Tot Hrs 32.2
Event Type	All	Intervened
Vehicle cut-in response inadequate	46	42
Lane centering inadequate	30	20
Lane centering &/or ACC deactivation	10	10
Inadequate deceleration	6	6
Other events	3	2
No resume after stop	1	1
Total	**96**	**81**

Figure 9: Counts of notable events for evaluated hands-off ADA systems. Image source: AAA.

Once again, results were converted to frequency of occurrence for comparative purposes. Distance and time driven were divided by event counts to produce average intervals between notable events in miles and minutes, respectively.

Notable Events - Hands-On Systems	All		Intervened	
Event occurred once every ...	miles	minutes	miles	minutes
Vehicle cut-in response inadequate	6.7	19.1	7.4	21.4
Lane centering inadequate	8.4	24.2	11.3	32.5
No resume after stop	14.6	41.8	14.6	41.8
Lane centering &/or ACC deactivation	21.7	62.3	22.7	65.0
Inadequate deceleration	27.6	79.1	42.5	121.9
Other events	113.3	325.2	254.9	731.6
Total	**2.3**	**6.7**	**2.8**	**7.9**

Figure 10: Average distance and time intervals between notable events (hands-on systems). Image source: AAA.

Notable Events - Hands-Off Systems	All		Intervened	
Event occurred once every ...	miles	minutes	miles	minutes
Vehicle cut-in response inadequate	15.0	42.0	16.4	45.9
Lane centering inadequate	22.9	64.3	34.4	96.5
Lane centering &/or ACC deactivation	68.8	193.0	68.8	193.0
Inadequate deceleration	114.7	321.6	114.7	321.6
Other events	229.5	643.3	344.2	964.9
No resume after stop	688.5	1929.8	688.5	1929.8
Total	**7.2**	**20.1**	**8.5**	**23.8**

Figure 11: Average distance and time intervals between notable events (hands-off systems). Image source: AAA.

Overall, the rate of occurrence of notable events was much lower for the hands-off systems. For hands-off systems, drivers had to intervene every 8.5 miles or 23.8 minutes. For the hands-on systems, drivers had to intervene once every 2.8 miles or 7.9 minutes on average - three times as often. For both hands-on and hands-off systems, the most common type of event was inadequate response to cut-ins, however these occurred roughly twice as often for the hands-on systems. Likewise, the second most common event for both was inadequate lane-centering. Drivers of vehicles with hands-on systems had to intervene due to inadequate lane centering three times as often as for hands-off systems.

As mentioned before, when counting deactivations in the above results, deactivations of the hands-off functionality were not counted. These are instances when the ADA features (lane keeping and adaptive cruise control) continue to function but the driver is asked to place their hands back on the steering wheel, and they only pertain only to hands-off ADA systems. The reason that hands-off ADA systems ask the driver to place their hands on the steering wheel is typically not explicitly indicated by the ADA system, but they often occurred in situations with worn or low visibility lane markers, road curves at higher speeds, or other abnormal or “difficult” conditions.

Loss of hands-off function were excluded from the count of deactivations because the functions of ADA continue to operate (lane keeping and adaptive cruise control) and because these events are not comparable to hands-on systems. However, examination of these events does add value when discussing hands-off systems on their own. Over the course of 688.5 miles and 32.2 hours of driving, hands-off functionality was lost 126 times. In other words, drivers of vehicles with hands-off ADA systems were asked to place their hands on the steering wheel every 5.5 miles or 15.3 minutes.

VII. RECOMMENDATIONS

The task of driving is highly variable and complicated, especially in high traffic situations. While ADA systems have the ability to handle the task of driving for limited amounts of time in specific circumstances, the results of this study show that current ADA systems are frequently met with situations that they cannot handle in real-world driving. However, as drivers are relieved of some driving tasks by ADAS functionality, they may be prone to be less attentive. This combination could lead to a higher risk for drivers in those situations that the ADA system cannot handle on its own. Therefore, drivers must remain attentive and ready to take full control of the vehicle at all times, even when not physically engaged in the task of driving.

For manufacturers of ADA technology, these results suggest that the highest-priority area for improvement is response to cut-in situations. Situations in which another vehicle cuts into the lane ahead are inherently challenging, particularly because they often provide little time to react. However, in high-traffic scenarios, they are a common occurrence, and they have a high likelihood of resulting in a collision if mishandled.

Lane centering is another area to prioritize for improvement, particularly in high-traffic situations. The severity of these events varied greatly, from systems driving off-center in the lane to systems steering out of the lane towards other vehicles. In high-traffic scenarios with nearby vehicles ahead and to the side it is common that lane markers are less visible than they would be normally, which may contribute to poor lane centering performance. It was found that the hands-off systems, which can only operate on approved roads, performed significantly better than hands-on systems in this regard, though lane centering issues were still relatively common.

Another notable area for improvement is the means used to notify the driver when features are active or non-active. These systems often respond to changing driving conditions by intentionally stopping the function of certain features (such as lane centering) to allow the driver to take back control. This is done when it does not detect the necessary conditions for operation.

Though variable by vehicle, it was observed that the icons and/or sounds used to alert the driver of deactivations can go unnoticed - particularly when the driver is actively looking at the road. This can lead to dangerous situations in which the ADA system has given full driving duties back to the driver while the driver believes it is still operating. Effort should be made to improve the overtness of alerts to make it clear when the driver needs to take back full control.

These scenarios are far from the only potential areas for improvement. Other common events included inadequate braking in response to obstacles and slowing traffic ahead, misidentification of lead vehicles, and frequent deactivation of lane centering and adaptive cruise control features.

VIII. REFERENCES

[1] American Automobile Association, "Clearing the Confusion: Common Naming for Advanced Driver Assistance Systems," July 2022. [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://newsroom.aaa.com/wp-content/uploads/2023/02/Clearing-the-Confusion-One-Pager-New-Version-7-25-22.pdf. [Accessed May 2025].

[2] SAE International, "SAE J3016 Levels of Driving Automation," January 2019. [Online]. Available: https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic. [Accessed May 2025].

[3] X. &. S. R. Zhang, "American Driving Survey: 2023," American Foundation for Traffic Safety, Washington, D.C., 2024.

IX. APPROVALS

		Date	Signature
Group Manager, Automotive Research Center, ACE	Megan McKernan		
Project Lead—AAA Inc.	Austin Shivers		
Director of Research—AAA Inc.	Greg Brannon		

X. APPENDIX A: TEST VEHICLE INFORMATION

	2024 Ford F-150	2024 Honda Accord	2024 Lexus RX 450h+	2024 Mazda CX-30	2024 Volkswagen Atlas
Date Received	10/14/2024	10/11/2024	10/14/2024	10/16/2024	10/11/2024
VIN	1FTFW7LD6RFA44482	1HGCY1F22RA008419	JTJCJMGA9R2008645	3MVDMBEY8RM600290	1V2HR2CA6RC531092
License Plate	DF 48298	9JLU815	9JJK481	9HRP795	9H0Z521
Odometer Before Testing	4,185	14,688	8,049	8,156	15,621
Odometer After Testing	4,637	15,206	8,551	8,637	16,108
Vehicle Color	White	Silver	Gray	Polymetal Gray Metallic	Silver
Hands ON/OFF	Hands OFF	Hands ON	Hands OFF	Hands ON	Hands ON
Tire Info	Grabber 275/50/R22	Kinergy GT 225/50/R17	Bridgestone 235/50/R21	Bridgestone 215/55/R18	Kumho 255/50/R20
Tire Pressure (PSI)	35	33/32	33	38/36	36
Fluid Levels Verified?	Yes	Yes	Yes	Yes	Yes
Brake Pads & Rotors Condition	Good	Good	Good	Good	Good
Software up to date?	Yes	Yes	Yes	Yes	Yes

Figure 12: Table of test vehicle information. Image source: AAA.

XI. APPENDIX B: MAPS OF DRIVING ROUTES

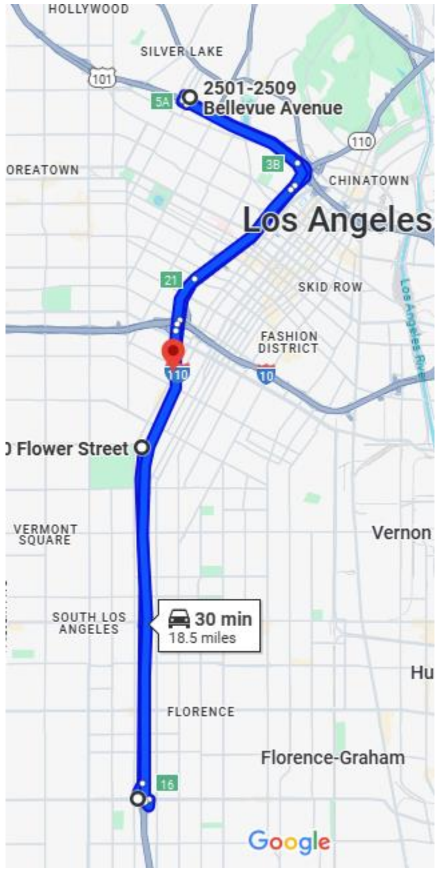

Figure 13: Map of Monday AM Driving Route. Image source: AAA.

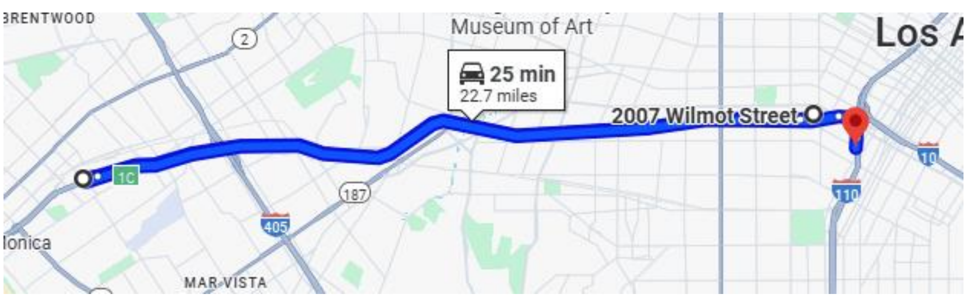

Figure 14: Map of Monday PM Driving Route. Image source: AAA.

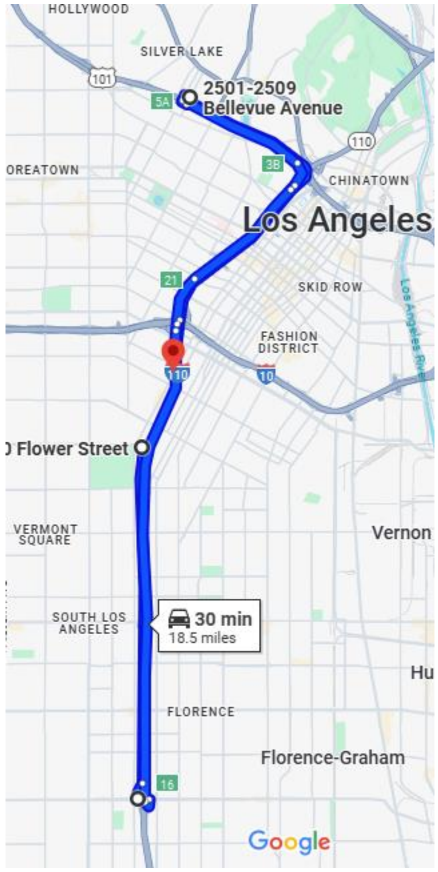

Figure 15: Map of Tuesday AM Driving Route. Image source: AAA.

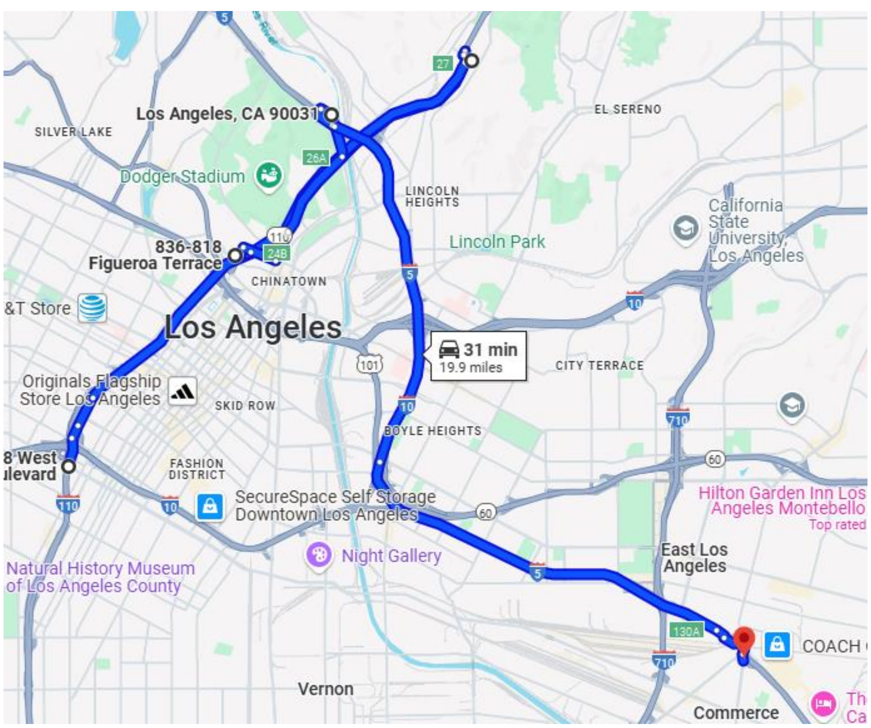

Figure 16: Map of Tuesday PM Driving Route. Image source: AAA.

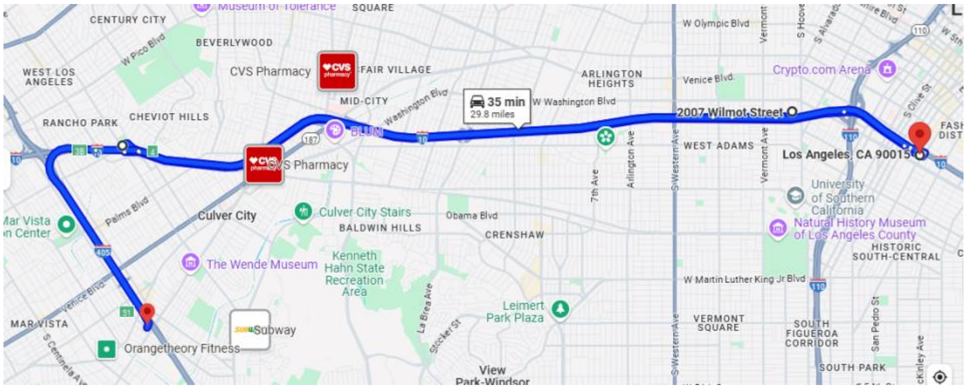

Figure 17: Map of Wednesday AM Driving Route. Image source: AAA.

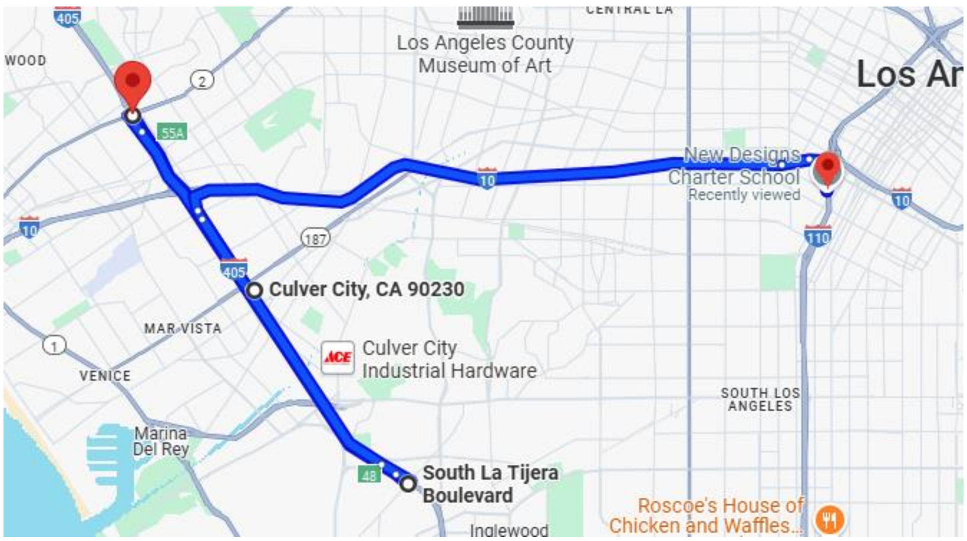

Figure 18: Map of Wednesday PM Driving Route. Image source: AAA.

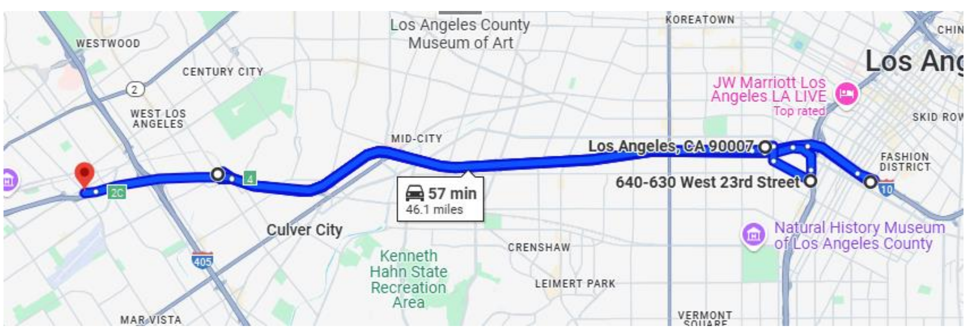

Figure 19: Map of Thursday AM Driving Route. Image source: AAA.

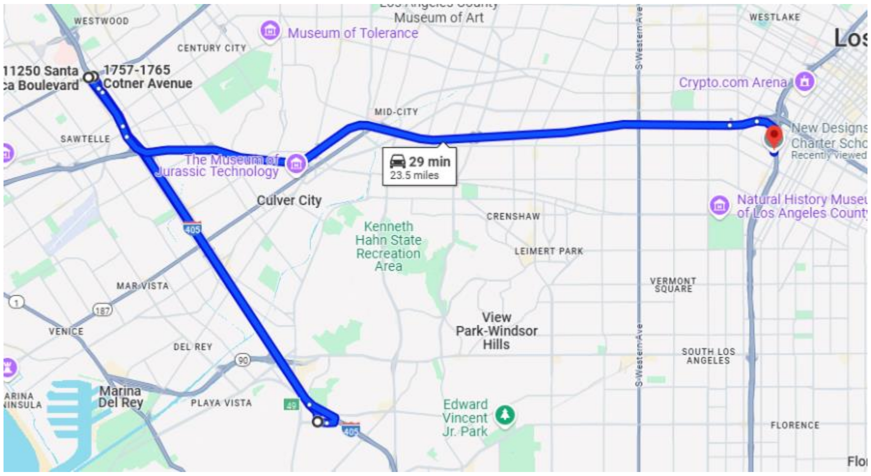

Figure 20: Map of Thursday PM Driving Route. Image source: AAA.

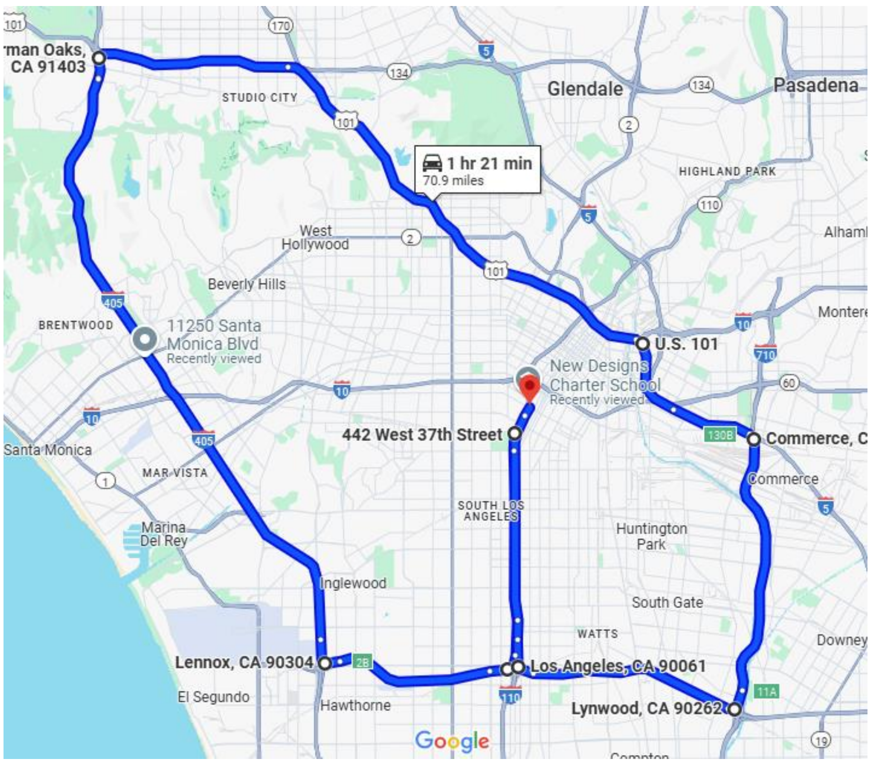

Figure 21: Map of Friday AM Driving Route. Image source: AAA.

XII. APPENDIX C: TABLE OF DEFINED EVENT TYPES

Event Button	Event Type	Driver Intervened?	Description
Adjacent Lane	Cut-in response inadequate	Either	L2 system performed in a way not "normal" and/or safe in response to a vehicle cutting into lane ahead.
Adjacent Lane	Merge-in problem	Either	L2 system performed in a way not "normal" and/or safe in a situation where test vehicle drive lane was merging with another lane.
Deactivation	ACC and lane centering deactivated	Y	Both the adaptive cruise control and lane centering functions deactivated as determined by icons and/or alerts.
Deactivation	ACC deactivated	Y	Adaptive cruise control function deactivated as determined by icons and/or alerts.
Deactivation	Hands-off deactivated	Y	For hands-off L2 systems, the driver was notified to place hands on steering wheel.
Deactivation	Lane centering deactivation	Y	Lane centeringfunction deactivated as determined by icons and/or alerts.
Kudos	ACC performed well	N	Adaptive cruise control function performed well in seemingly difficult situation.
Kudos	ACC resumed after stop	N	Adaptive cruise control function resumed after coming to complete stop for some amount of time.
Kudos	Cut-in response good	N	L2 system performed well in seemingly difficult situation in which a vehicle cut into lane ahead.
Kudos	Lane centering performed well	N	Lane centering function performed well in seemingly difficult situation.
Kudos	Slowdown response good	N	Adaptive cruise control performed well in response to sudden slowdown in lane ahead.
Kudos	Worked in tunnel	N	L2 functions continued working through tunnel.
Lane Centering	Lane centering inadequate	Either	Lane centering function performed in a way not "normal" and/or safe for the situation.
Lead Following	Inadequate acceleration	Either	Accelerated in a way not "normal" and/or safe for the situation.
Lead Following	Inadequate deceleration	Either	Decelerated in a way not "normal" and/or safe for the situation.
Lead Following	No resume after stop	Y	Adaptive cruise control function did not resume after coming to complete stop for some amount of time.
Lead Following	Unnecessary deceleration	Either	Decelerated without a vehicle or other obstruction in lane ahead to necessitate such.
Other Event	Driver Override	Y	The driver overrode the L2 system for a reason not related to L2 performance.
Other Event	Hands-off deactivated due to driver inattention	Y	Driver was notified to place hands on steering wheel due to perceived inattention based on driver monitoring.
Other Event	Not significant	Either	Events marked by the driver that do not fit into other defined categories and are deemed non significant.
Other Event	Notification	N	Driver marked instance of a notification not related to a notable driving event.
Other Event	Other	Either	Events marked by the driver that do not fit into other defined categories.

Figure 22: List of defined event types used for categorizing test data. Image source: AAA.

XIII. APPENDIX D: TEST RESULTS BY VEHICLE

2024 Ford F-150 Platinum	Tot Miles 337.8	Tot Hrs 16.0
Event Type	Total	Intervened
ACC and lane keeping deactivated	0	0
ACC deactivated	0	0
Inadequate acceleration	0	0
Inadequate deceleration	3	3
Lane centering deactivation	8	8
Lane centering inadequate	20	14
Merge-in problem	2	2
No resume after stop	1	1
Unnecessary deceleration	1	0
Vehicle cut-in response inadequate	17	16
Total	**52**	**44**

Figure 23: Total counts of notable events - Ford F-150. Image source: AAA.

2024 Honda Accord LX	Tot Miles 345.3	Tot Hrs 16.3
Event Type	Total	Intervened
ACC and lane keeping deactivated	0	0
ACC deactivated	1	1
Inadequate acceleration	0	0
Inadequate deceleration	4	4
Lane centering deactivation	7	7
Lane centering inadequate	60	56
Merge-in problem	0	0
No resume after stop	7	7
Unnecessary deceleration	0	0
Vehicle cut-in response inadequate	40	36
Total	**119**	**111**

Figure 24: Total counts of notable events - Honda Accord. Image source: AAA.

2024 Lexus RX450h+	Tot Miles 350.7	Tot Hrs 16.1
Event Type	Total	Intervened
ACC and lane keeping deactivated	0	0
ACC deactivated	0	0
Inadequate acceleration	0	0
Inadequate deceleration	3	3
Lane centering deactivation	2	2
Lane centering inadequate	10	6
Merge-in problem	0	0
No resume after stop	0	0
Unnecessary deceleration	0	0
Vehicle cut-in response inadequate	29	26
Total	**44**	**37**

Figure 25: Total counts of notable events - Lexus RX. Image source: AAA.

2024 Mazda CX-30 2.5 Turbo	Tot Miles 344.2	Tot Hrs 16.4
Event Type	Total	Intervened
ACC and lane keeping deactivated	2	2
ACC deactivated	0	0
Inadequate acceleration	7	4
Inadequate deceleration	12	6
Lane centering deactivation	37	35
Lane centering inadequate	35	15
Merge-in problem	0	0
No resume after stop	60	60
Unnecessary deceleration	0	0
Vehicle cut-in response inadequate	65	57
Total	**218**	**179**

Figure 26: Total counts of notable events - Mazda CX-30. Image source: AAA.

2024 Volkswagen Atlas SE	Tot Miles 330.1	Tot Hrs 16.2
Event Type	Total	Intervened
ACC and lane keeping deactivated	0	0
ACC deactivated	0	0
Inadequate acceleration	2	0
Inadequate deceleration	21	14
Lane centering deactivation	0	0
Lane centering inadequate	26	19
Merge-in problem	0	0
No resume after stop	3	3
Unnecessary deceleration	0	0
Vehicle cut-in response inadequate	48	44
Total	**100**	**80**

Figure 27: Total counts of notable events - Volkswagen Atlas. Image source: AAA.