# Review the State-of-the-Art Studies on the Public's Perception of Advanced Driver Assistance Systems and Assess the Actual Performance

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RESEARCH & DEVELOPMENT

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**FINAL REPORT**

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**16. Abstract**

Advanced Driver Assistance Systems (ADAS), particularly the transitional ADAS (tADAS) that fall between SAE Level 2 and Level 3, are becoming increasingly prevalent in vehicles on the road. Despite their growing presence, public understanding of these systems remains limited, with widespread misconceptions. This study reviews the current state of research on public perception, user behavior, and the real-world performance of tADAS technologies. Findings reveal persistent misperceptions among users and non-users (i.e., other road users), including confusion about system capabilities, misuse beyond the intended Operational Design Domain (ODD), and inadequate understanding of safety features. The project examined studies on tADAS developed by Tesla, Ford, and General Motors (GM), incorporating independent research and official safety assessments by organizations such as the Insurance Institute for Highway Safety (IIHS), the Euro New Car Assessment Programme (NCAP), and the National Highway Traffic Safety Administration (NHTSA). Survey and field data show that users frequently overestimate system autonomy, and that branding and interface design contribute to driver complacency and misuse. Non-users—such as pedestrians and cyclists—also express safety concerns, but their perspectives remain underexplored in formal studies. The report identifies critical research gaps and provides actionable recommendations to support safer deployment, more accurate user education, and better policy responses for the next generation of ADAS technologies.

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# EXECUTIVE SUMMARY

Advanced Driver Assistance Systems (ADAS), particularly transitional ADAS (tADAS) operating between SAE Levels 2 and 3, are increasingly available in modern vehicles. These systems offer features like hands-free driving and automated lane changes. However, significant public misunderstanding persists about their capabilities and safe use.

## Objectives

This research, conducted for the North Carolina Department of Transportation (NCDOT), aimed to:

- Review existing studies on users' misperceptions and misuse of tADAS.
- Examine non-users' perceptions and concerns, including other drivers, pedestrians, and cyclists.
- Assess the actual safety performance of tADAS systems on the market.

## Methodology

The study combined:

- A literature review of academic papers, government reports, and industry publications.
- Analysis of safety evaluations by organizations like the Insurance Institute for Highway Safety (IIHS), the Euro New Car Assessment Programme (NCAP), and the National Highway Traffic Safety Administration (NHTSA).
- Examination of Original Equipment Manufacturer (OEM) safety reports, especially from Tesla and General Motors (GM).
- Review of survey data on user behaviors and attitudes.
- Exploration of public discussions on social media and online forums.

## Key Findings

- Widespread Misunderstanding: Many drivers believe tADAS systems are fully autonomous, leading to misuse outside intended conditions.
- Branding and Interface Gaps: Marketing terms such as "Autopilot" and "Full Self-Driving" contribute to confusion. System interfaces often provide subtle or unclear warnings, causing users to misinterpret alerts as malfunctions.
- Safety Performance Varies: Independent assessments found gaps in driver engagement and safety safeguards. Tesla's systems showed higher rates of misuse, while GM's Super Cruise demonstrated more disciplined usage. However, public safety data remain limited, likely due to restricted access to OEM data.
- Non-User Concerns Understudied: Vulnerable road users (e.g., pedestrians, cyclists) express concerns about how tADAS-equipped vehicles recognize and respond to them. Yet, formal research on these perspectives is scarce.

## Recommendations

- Broaden research beyond Tesla to include other OEMs' tADAS systems.
- Improve public communication about tADAS capabilities and limitations.
- Develop methods to capture non-user perspectives, including through social media.
- Explore policy and legal measures to address misuse, such as enforcement challenges related to driver inattention.

In summary, while tADAS technologies hold promises for enhancing driving comfort and safety, persistent misconceptions, misuse, and research gaps present significant challenges. Addressing these issues is essential for safer deployment and public confidence in advanced vehicle technologies.

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# 1    Introduction and Objectives

Advanced Driver Assistance Systems (ADAS) are increasingly common across vehicle models and are primarily designed to assist—rather than replace—drivers. Most commercially available systems fall under SAE Level 1 or 2, with very few reaching SAE Level 3. However, there are persistent misperceptions about these systems—particularly transitional ADAS (tADAS) products that fall between SAE Level 2 and Level 3 and offer enhanced automation features such as hands-off driving (e.g., General Motors (GM)'s Super Cruise) or auto navigation (e.g., Tesla Full Self-Driving (Supervised)). Many users and non-users mistakenly believe these systems are fully autonomous, even though they still require constant driver supervision.

Such misperceptions can lead to serious safety consequences. ADAS users may engage in inappropriate behaviors such as hands-free driving, misuse the system beyond its intended Operational Design Domain (ODD), or fail to monitor the driving environment. These behaviors were linked to crashes, near-misses, and fatalities (NHTSA, 2024a; NHTSA, 2024b; NHTSA, 2025). The impact is not limited to the users themselves—vulnerable road users (VRUs), such as pedestrians and cyclists, may also be at increased risk due to misperceptions of ADAS. Moreover, these myths may negatively influence public acceptance of future technologies, including SAE Level 4 and Level 5 autonomous vehicles such as autonomous shuttles.

Therefore, it is critical to understand misperceptions and misuse of tADAS among both users and non-users. However, research on these issues remains limited.

The **objective** of this study is to review the state-of-the-art research and practice on:

1. Users' misperception and misuse of tADAS;
2. Non-users' misperceptions and concerns related to tADAS; and
3. The actual performance of tADAS systems, in terms of safety and capability.

In this study, **transitional ADAS (tADAS)** refers to systems that operate between SAE Level 2 and Level 3. These products offer more automation—such as automatic lane change, hands-off operation, and automatic navigation—than basic SAE Level 1 systems.

# 2    Automation Level of ADAS

This section reviews the automation levels of ADAS and discusses the confusion arising from the naming practices used by Original Equipment Manufacturers (OEMs) in their marketing, which may contribute to public misperception and misuse.

## 2.1    SAE Automation Levels

The United States Department of Transportation (USDOT) and the National Highway Traffic Safety Administration (NHTSA) have adopted the Society of Automotive Engineers (SAE) (J3016) levels of driving automation. Specifically, SAE Level 2 and Level 3 definitions are as follows:

- "Level 2 (L2): You Drive, You Monitor. You, as the driver, are responsible for driving the vehicle. When engaged, the system can perform steering AND acceleration/braking."

- "Level 3 (L3): System Drives, You Must Be Available To Take Over Upon Request. When engaged, the system handles all aspects of the driving task while you, as the driver, are available to take over driving if requested. If the system can no longer operate and prompts the driver, the driver must be available to resume all aspects of the driving task."

There is a significant functional leap between Level 2 and Level 3 in the allocation of responsibility between the system and the driver.

## 2.2  *The Gray and Confusing Zone: Transitional ADAS (tADAS)*

Many systems currently on the market offer features beyond "*basic*" Level 2 (i.e., Adaptive Cruise Control and lane keeping) but not yet Level 3, such as hands-off driving, automated lane changes, and navigation-based automation. Various informal terms have emerged to describe these in-between systems, such as *Level 2+* (Mobileye, 2020), *enhanced Level 2*, or *Level 2-point-something*. These labels reflect the growing complexity of ADAS. However, none of these terms have been standardized or formally adopted by SAE, USDOT, or used on OEM web pages.

## 2.3  *OEM Practices and Global Variations*

It is worth noting that OEMs rarely specify SAE automation levels on their product webpages. Instead, their product web pages focus on listing functions (e.g., Navigate on Autopilot, Auto Lane Change) and very often use brand-specific terms. This practice may lead to inconsistency and contribute to misinterpretation among users and the broader public.

Notably, the European Union permits Level 2 systems with hands-off capabilities (e.g., Ford BlueCruise, BMW Highway Assistant) and still classifies them as Level 2.

Social media and public discussions sometimes use automation levels, but misuse is very widespread—for example, incorrectly treating Adaptive Cruise Control as Level 2.

## 2.4  *Summary*

ADAS functionalities vary largely, and so do the corresponding automation levels. SAE automation levels are not broadly used by OEMs or in social media and public discussions. The big functional gap between Level 2 and Level 3 requires a finer-scale classification to help the public better understand the capabilities and limitations of these transitional ADAS technologies.

## 3  Transitional ADAS (tADAS) Systems on the Market

This section reviews ten commonly available tADAS from six major manufacturers, focusing on key dimensions including automation functionalities, safety features, Operational Design Domains (ODDs), pricing models, and deployment across vehicle platforms; see *Appendix 1* for more details.

Most tADAS systems offer similar core functionalities between SAE Level 2 and Level 3, with drivers still required to supervise vehicle operations. Typical features include hands-free steering (autosteer), automated lane changing—either initiated by the driver or the system—and automatic parking. Some systems provide optional advanced features such as auto navigation (such as Tesla's Full Self-Driving (Supervised)).

The ODD for most systems is generally limited to controlled-access highways, with a few extending to state highways. Tesla's Full Self-Driving (Supervised) is currently the only tADAS that allows operation on city streets. For ODD enforcement, most systems use geofenced and pre-defined compatible maps. Tesla's Autopilot and Full Self-Driving (Supervised) are not geofenced.

The cost of tADAS usually ranges between $500-$1200 per year, mostly offered via subscription.

A more detailed review of ADAS from Tesla is provided below, which has received a lot of discussion in the media and public forums.

Currently, Tesla markets two primary ADAS packages:

- Autopilot (standard)
- Full Self-Driving (Supervised) (subscription-based)

Another product—Enhanced Autopilot—was previously offered but is no longer available for purchase. However, Tesla vehicles on the road are still equipped with this version, and the system remains operational. Table 1 summarizes the key features of these typical packages.

Tesla's webpage does not specify SAE automation levels for its ADAS products. However, per NHTSA investigation (EA22002), Autopilot has been categorized as SAE Level 2.

Tesla's ADAS systems have changed over time. Some product variants are no longer offered for purchase but are still in use. Therefore, Tesla vehicles currently in operation may be running different versions of ADAS software and features. The company has removed descriptions of earlier product versions from its official site, which may affect users' ability to reference or compare systems across time.

Table 1. Key Features of Tesla Autopilot, Enhanced Autopilot, and Full Self-Driving Service

| *System* | **Function at Level 2+ (beyond basic Level 2)** | **Webpage with SAE Level** | **Features mentioned by OEM** | **Price** | **OEM** |
|---|---|---|---|---|---|
| **Autopilot** | No | No | - Traffic-Aware Cruise Control<br>- Autosteer | Free | Tesla |
| Enhanced Autopilot | Yes | No | - Navigate on Autopilot<br>- Auto Lane Change<br>- Autopark<br>- Dumb Summon<br>- Actually Smart Summon | No longer available.<br>It used to cost $6,000 (one-time purchase). | |
| **Full Self-Driving (supervised)** | Yes | No | - All of Enhanced Autopilot<br>- Autosteer on City Streets<br>- Traffic and Stop Sign Control | $8,000 (one-time purchase) or $99.00 per month. Requires hardware like Full Self-Driving computer 3.0 or above. | |

## 4    Official Test and Assessment of tADAS

This section summarizes key official evaluations of transitional ADAS (tADAS) conducted by major safety organizations, including the Euro New Car Assessment Programme (NCAP), the Insurance Institute for Highway Safety (IIHS), and NHTSA. These assessments examine system functionality, driver engagement, safety safeguards, and emergency fallback procedures.

### 4.1    IIHS Rating

IIHS launched a program in 2024 to provide partial automation safeguard ratings (IIHS, 2024). This program evaluates how effectively a system keeps the driver engaged and how it responds when the driver fails to remain attentive.

The IIHS assessment focuses on five key areas: Driver Monitoring, Attention Reminder, Emergency Procedures, Driver Involvement, and Safeguard Features, which are weighted to provide the overall

rating. Each system is rated as Good, Acceptable, Marginal, or Poor. Ratings apply to specific vehicle models and system versions at the time of evaluation.

The initial round of testing included 14 systems from nine manufacturers, notably including the commonly used tADAS systems reviewed in this study: Tesla Autopilot and Full Self-Driving (Beta), Ford BlueCruise, and GM Super Cruise. The results revealed widespread shortcomings. Overall, most systems were rated "Poor" or "Marginal." For Driver Monitoring, Ford BlueCruise received an "Acceptable" rating, and most others received "Poor." For Attention Reminders, performance varied significantly across systems. For Safeguard Features, GM Super Cruise was rated "Good," but most systems were rated "Poor." For Emergency Procedures, most systems were rated "Acceptable." A detailed snapshot is provided below.

| | Overall rating | Driver monitoring | Attention reminders | Emergency procedures | Driver involvement | | | Safety features |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | | Lane change | ACC resume | Cooperative steering | |
| General Motors Super Cruise 2023-24 GMC Sierra | M | P | G | G | P | A | P | G |
| Ford BlueCruise 2021-24 Ford Mustang Mach-E | P | A | G | M | G | M | G | P |
| Tesla Autopilot, Version 2023.7.10 2021-23 Tesla Model 3 | P | P | P | A | G | P | P | P |
| Tesla Full Self-Driving (Beta), Version 2023.7.10 2021-23 Tesla Model 3 | P | P | A | A | P | P | P | P |

Figure 1. IIHS Ratings for the GM Super Cruise, Ford BlueCruise, Tesla Autopilot, and FSD

*4.2* *Euro NCAP*

Euro NCAP is a leading independent vehicle safety evaluation organization. It has conducted major campaigns to assess the real-world performance of ADAS technologies.

Among its efforts, the most relevant to transitional ADAS (tADAS) are the 2018 Automated Driving Test and the 2020 Assisted Driving Test. Most systems evaluated were not tADAS (except for Tesla Autopilot) but rather simpler versions. More recent tADAS products were not included in these evaluations. Nevertheless, the results still provide a valuable reference for understanding tADAS performance.

Euro NCAP's 2018 Automated Driving Test assessed the state-of-the-art highway assist systems and examined their underlying design strategies. The evaluation included systems such as the Ford Co-Pilot360, Mercedes-Benz Active Distance Assist DISTRONIC, and Tesla Autopilot. The findings (Euro NCAP, 2020) emphasized that "state-of-the-art technology is far from being automated and no system offered assistance across the full range of tests: the driver needs to be vigilant at all times and fully in

control of the vehicle." It found that the systems improved comfort and reduced driving stress under routine conditions, but in challenging scenarios (cut-in and cut-out) an alert driver is needed to avoid collisions. The tested systems were classified as driver assistance features—not autonomous functions—and Euro NCAP highlighted the importance of passive and active safety systems as critical backups.

For Tesla Autopilot, the evaluation noted that it provided a high level of support in braking and steering, which improved comfort but also resulted in driver over-reliance. The name "Autopilot" was considered misleading, and misuse beyond its Operational Design Domain (ODD) was not strictly enforced. While the system is technically capable, it delegates too much control to the vehicle and lacks effective driver engagement mechanisms, increasing the risk of misuse and over-trust in real-world conditions. Notably, these findings from Euro NCAP are consistent with NHTSA's investigation report (NHTSA, 2024b).

Euro NCAP's 2020 Assisted Driving Test assessed ADAS systems with a focus on balancing automation support and driver engagement. The assessment protocol evaluated systems in two areas: Assistance Competence (balance between driver engagement and vehicle assistance) and Safety Backup. Systems were rated in four overall performance categories: Entry, Moderate, Good, and Very Good. The evaluation included Ford Co-Pilot360, Mercedes-Benz Active Distance Assist DISTRONIC, and Tesla Autopilot (as of 2020). All were classified as SAE Level 1 or 2. Mercedes-Benz DISTRONIC achieved the highest score with a good balance between vehicle support and driver engagement, and Ford Co-Pilot360 is second with a solid score. For Tesla Autopilot, it received a "Moderate" rating with 36% for assistance competence and 95% for safety backup. The evaluation highlighted multiple concerns. Euro NCAP found the "Autopilot" name inappropriate, and the promotion material suggests system automation. Although the system was clear, there was no head-up display. Tesla's driver monitoring system relied only on steering wheel input, with no camera-based monitoring. Additionally, the system resisted driver steering input and then disengaged, limiting opportunities for cooperative driving.



Figure 2. Euro NCAP Evaluation (left: Tesla Autopilot; right: Ford Co-Pilot360) (Euro NCAP, 2020)

### 4.3    NHTSA Investigation

NHTSA has investigated the Tesla Autopilot and is currently investigating Ford BlueCruise. There are no other NHTSA investigations related to other tADAS.

### Tesla

NHTSA investigated Tesla's Autopilot system under EA22002, which was closed in 2024. The investigation was triggered by a series of crashes where Tesla vehicles operating in Autopilot mode collided with stationary vehicles, including emergency responders.

The Office of Defects Investigation (ODI) identified a critical safety gap: Tesla's weak driver engagement system, when paired with Autopilot's permissive operating capabilities, "led to foreseeable misuse and avoidable crashes." In response to NHTSA's investigation, Tesla issued a recall (23V838) described "the prominence and scope of the system's controls may be insufficient to prevent driver misuse" and proposed a remedy to "improve the effectiveness of driver warnings and to reduce mode confusion." ODI is currently following up via a recall query (RQ24009) to assess the effectiveness of Tesla remedy 23V838.

In EA22002, ODI also provided an assessment of the SAE Level 2 market. It identified Tesla as an outlier in the SAE L2 market, featuring a mismatch between weak driver engagement enforcement and permissive system operability. Autopilot's design can discourage driver involvement, while others are more cooperative. Autopilot "invited GREATER driver confidence" compared to peer Level 2 products. The term "autopilot" may result in overconfidence in vehicle capability, while peer products use more conservative names like "assist," "sense," or "team."

### Ford

NHTSA opened an Engineering Analysis (EA25001) (NHTSA, 2025) to investigate Ford's BlueCruise system, following two fatal collisions. Preliminary findings indicate that the Adaptive Cruise Control of BlueCruise is programmed to intentionally ignore stationary objects when the vehicle is traveling at speeds over 62 mph, a setting that may contribute to crash risk in certain highway scenarios. The investigation is currently ongoing.

## 4.4   *OEM Safety Reporting/Analysis Outcomes*

This subsection synthesizes the safety reports and research findings on the safety performance of tADAS from the engineering perspective, such as performance indicated by incident rates.

### Tesla

Since Q3 2018, Tesla has voluntarily published quarterly safety reports to document crash involvement across its fleet, distinguishing crash rates between vehicles operating with and without Autopilot and associated active safety features.

Tesla's Q4 2024 Vehicle Safety Report (Tesla, 2025) presents the following crash rates:

- With Autopilot engaged: 1 crash per 5.94 million vehicle miles traveled (VMT)

- Without Autopilot engaged: 1 crash per 1.08 million VMT

- U.S. national average[1]: approximately 1 crash per 0.7 million VMT

However, independent analyses and federal reviews have raised concerns. Specifically, Goodall's study noted that the crash rate without Autopilot appears higher than expected (Goodall, 2024). NHTSA's investigation report on Tesla Autopilot (NHTSA, 2024b) noted that Tesla failed to detect or report certain crashes. Tesla relies on telematics-based reporting, which may miss some crashes (e.g., reporting fails in case of no cellular connectivity or antenna damage).

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[1] This is used in the Tesla report, but its source is unclear. Notably, NHTSA's accident reporting system focuses on fatalities instead of crashes, and thus the measurements are not comparable with Tesla's measures. However, we extracted the police-reported traffic crashes and VMT in 2023 (NHTSA, 2025), which results in 1 traffic-reported crashes per 1.89 million VMT.
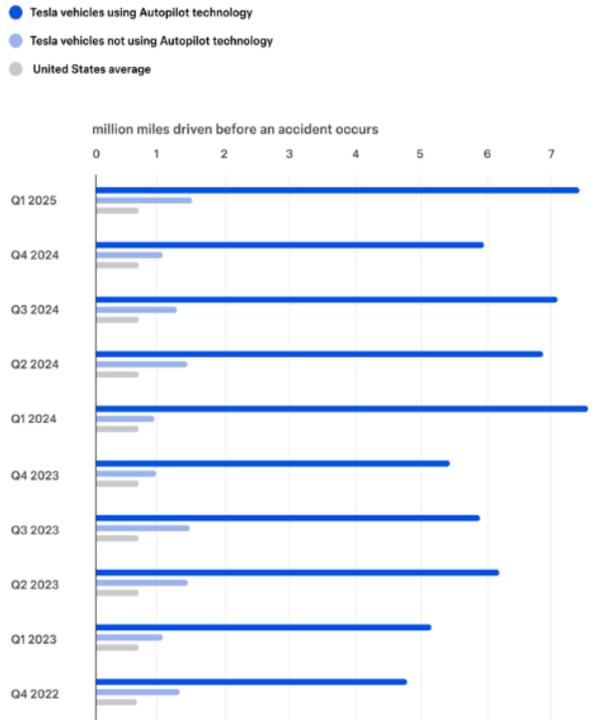
**Miles Driven Per One Accident**

- Tesla vehicles using Autopilot technology
- Tesla vehicles not using Autopilot technology
- United States average

million miles driven before an accident occurs

Figure 3. Tesla Q4 2024 Vehicle Safety Report

### GM Super Cruise

A few studies co-authored by GM (Llaneras et al., 2024; Leslie et al., 2025) examined the safety performance of GM Super Cruise and found no significant difference in incident rates compared to other conventional ADAS (e.g., Adaptive Cruise Control). The findings suggest that, based on available data, Super Cruise performs similarly to conventional ADAS in terms of crash involvement or incident frequency.

### Summary

Public analysis of tADAS safety performance remains very limited. The review found that Tesla is the only tADAS OEM that provides regular safety reports to the public, and no other studies on incident rates were found beyond a few on GM Super Cruise, mentioned above. The scarcity of research is likely due to restricted access to system usage data, which is often held only by OEMs. For example, several studies (Llaneras et al., 2024; Leslie et al., 2025) on GM Super Cruise used detailed information such as system status, travel location, and time, combined with crash data—none of which is publicly available. Currently, the detailed system information and status of tADAS in vehicles are not routinely captured in police crash reports. These limitations make meaningful public analysis extremely difficult.

# 5 User Misperception and Misuse

## 5.1 Overall Status

Research on user misperception and misuse of tADAS systems has received increasing attention in the research community. Some rigorous studies have been conducted to understand how drivers interact with the systems. Findings have consistently confirmed the existence of misunderstanding and inappropriate use (e.g., Nordhoff et al., 2023; Mueller et al., 2024; Winter et al., 2025; Linja et al., 2022; Lin et al., 2018). However, it is important to note that the majority of existing studies focus on Tesla products, particularly Autopilot and Full Self-Driving (Beta). There is limited research on other tADAS, such as Ford BlueCruise or GM Super Cruise.

## 5.2 Evidence from Literature

A growing body of literature provides solid and consistent evidence that users often misinterpret system capabilities and use tADAS features beyond their intended design. For example, one study (Nordhoff et al., 2023) found that Tesla drivers "became complacent over time" while using Autopilot. This was associated with failures to monitor the system and engagement in risky behaviors, such as hands-off driving. The study also reported instances of intentional violations of the system's intended use.

Survey-based studies further highlight confusion across systems. In one study (Mueller et al., 2024), a substantial percentage of users reported treating their SAE Level 1 or Level 2 systems as self-driving: 53% of Super Cruise users, 42% of Autopilot users, and 12% of ProPILOT Assist users. Similarly, an American Automobile Association (AAA) national survey (AAA, 2025) found that 40% of Americans mistakenly believed that systems with names like Autopilot, ProPILOT, or Pilot Assist could fully drive the vehicle on their own, suggesting that branding plays a role in public misunderstanding.

There is also documented evidence (Mueller et al., 2025) of a disconnect between system design and user beliefs. For example, users with hands-free options mistakenly assumed that hands must always be on the wheel, while users of hands-on-required systems incorrectly believed that hands-free was allowed. In addition, research (Morando et al., 2021) observed that drivers became less attentive during tADAS use and spent more time on non-driving-related activities.

## 5.3 More detailed analysis of user misperceptions and misuse

Multiple factors appear to contribute to misperceptions of tADAS, including marketing terms used by OEMs, coverage of tADAS incidents in public media, and the design of attention monitoring and alert systems meant to ensure driver engagement. Marketing terms may mislead the public into having overconfidence in tADAS (Liu et al., 2021). For instance, Tesla's branding of Autopilot and Full-Self Driving conveys a misleading impression that these systems require little to no monitoring, and only in 2025 has the FSD system been rebranded to Full-Self Driving (Supervised) to stipulate the requirement for continuous monitoring. Media attention also contributes to misunderstandings. Results of one survey indicate that negative media exposure and word of mouth contribute to higher perceived risk and anxiety towards autonomous vehicles (Zhu et al., 2024). In March 2025, YouTuber and engineer Mark Rober received significant attention for his video, titled "*Can You Fool A Self-Driving Car?*", in which he tested Tesla's performance in the detection of a camouflaged wall blocking the road (Rober, 2025). However, the video has been criticized for its misleading title, as the demonstration did not involve self-driving technology (Autopilot was used, not FSD) and primarily demonstrated differences between camera systems and LiDAR in obstacle detection (Templeton, 2025).

Another factor that may contribute to misperceptions of tADAS is the design of the tADAS themselves. For instance, users may misinterpret warnings and lockouts as system malfunctions rather than intentional safety interventions (Mueller et al., 2024). If users do not understand why the system initiates these events (i.e., inattention), they may further fail to correct their misuse behavior.

The following sub-sections examine two of the most studied tADAS on the market—Tesla's Autopilot and FSD, and GM's Super Cruise—with additional details on their interface design.

### *Tesla Autopilot and Full Self-Driving (Supervised)*

In addition to official evaluations by IIHS, Euro NCAP, and Tesla's safety reports on the FSD system, there is a growing body of OEM-adjacent research, academic studies, and user-generated content that sheds additional light on real-world performance and user behavior that may not be fully captured in formal tests.

**Driver Behavior and Misperception.** Studies and observations confirm that drivers frequently operate Tesla's Autopilot and FSD outside their intended Operational Design Domain (ODD), including city centers, intersections, construction zones, and periods of inclement weather, despite explicit instructions against such use. Analyses of YouTube and forum commentary reveal intentional testing of FSD in unsupported contexts, such as dense urban areas or in challenging environmental conditions (Winter et al., 2025). This behavior is partly enabled by the absence of geofencing or automated restrictions within Tesla's system design (Nordhoff et al., 2023; Mueller et al., 2024). However, another significant influence is the users' misunderstandings of system capabilities and boundary conditions. Mueller et al. (2024) found that 42% of Autopilot users (alongside 53% of Super Cruise users) reportedly felt safe leaving automation unattended. Some drivers even mistake temporary suspensions for system failures, interpreting safety disengagements as lockout errors. This false sense of autonomy coincides with a general overestimation of system capabilities. Such overconfidence can reduce the likelihood of timely intervention during system errors or transitions.

**Safety and Fatigue Perception.** The influence of Tesla's FSD on fatigue is somewhat paradoxical: whereas some users report heightened stress due to the demand for constant vigilance, others describe the experience as "boring" due to the infrequent demand for interaction. In the case of the latter, prolonged periods of zero-intervention driving may foster inattention and undermine a driver's ability to intervene in time-critical moments (Metz Tech, 2024; Nordhoff et al., 2023). Interestingly, studies involving drivers with disabilities reveal that perceived workload with Autopilot or FSD is comparable to that of manual driving, though these drivers remained on heightened alert near work zones or unusual road layouts (Xu et al., 2022; Xu et al., 2023). This suggests that some drivers may regulate attentiveness when aware of system limitations, while others may not.

**Interface and Feedback Gaps.** Tesla's human-machine interface (HMI) design has also received criticism from users and researchers alike. Alerts, such as navigation updates or system warnings, typically appear briefly on the center screen in small, text-heavy bubbles, making them difficult to notice or read, especially for visually impaired users or conditions of high attentional demand (Xu et al., 2022; Xu et al., 2023). Drivers must decide between attending to these notifications at risk of the driving situation and attending to the road at the expense of the alert. Such design choices can diminish the usability and present a vulnerability to road safety. There is also evidence of inconsistent handling of driver inputs. For example, attempts to reposition the vehicle within the lane (e.g., to avoid debris or improve buffer distance) are sometimes resisted by the system before it eventually relinquishes control, and this may slow driver response in critical moments (Euro NCAP, 2018).

**Road and Environment Perception Failures.** Tesla's FSD has demonstrated perceptual limitations in identifying and reacting to real-world road features. User feedback across forums highlights persistent challenges with detecting non-standard road environments such as parking lots, driveways, cones, or temporary construction barriers (Linja et al., 2022; Lin et al., 2018). Autosteer was shown in crash analyses to remain engaged even in low-traction environments such as wet roads, resulting in loss of control and road departure (NHTSA, 2024). These limitations can compromise the system's performance in suburban, commercial, or low-speed settings, which are not well represented in test scenarios. The preliminary rollout of FSD version 13 included a feature where the vehicle would slowly creep forward at intersections in anticipation of a green light, a maneuver reminiscent of the informal "California stop."

After public and regulatory concerns, Tesla was forced to remove this feature, underscoring the risks of behavior-based automation tuning (East Coast Tesla, 2024; Boudette, 2022).

Overall, independent OEM-oriented findings highlight that while Tesla's FSD system delivers novel capabilities, its real-world safety and usability are undermined by misconceptions, incomplete driver education, interface design, and perceptual edge-case failures as revealed by public research. These insights support the need for stronger constraints on system use, improved driver training, and transparent performance boundaries to reduce the risk of misuse and misunderstanding.

### *GM Super Cruise*

GM began developing its hands-free driver assistance system, Super Cruise (GM Authority, n.d.), in the early 2010s as part of its broader commitment to autonomous vehicle technology. The system was first announced in 2013 and debuted on the 2018 Cadillac CT6, positioning GM among the first automakers to offer hands-free driving on compatible highways. Super Cruise combined LiDAR map data, real-time GPS, cameras, radar sensors, and an infrared driver attention system to ensure both accuracy and safety. In 2019, Super Cruise added automatic lane change, and its coverage grew to over 200,000 miles of divided highways in North America, which doubled to more than 400,000 miles by 2023. GM also extended the technology across its vehicle lineup, including Chevrolet, GMC, and Buick models. Notably, Super Cruise is also available in most GM's trucks, such as the Chevrolet Silverado (Burns Chevrolet, 2023).
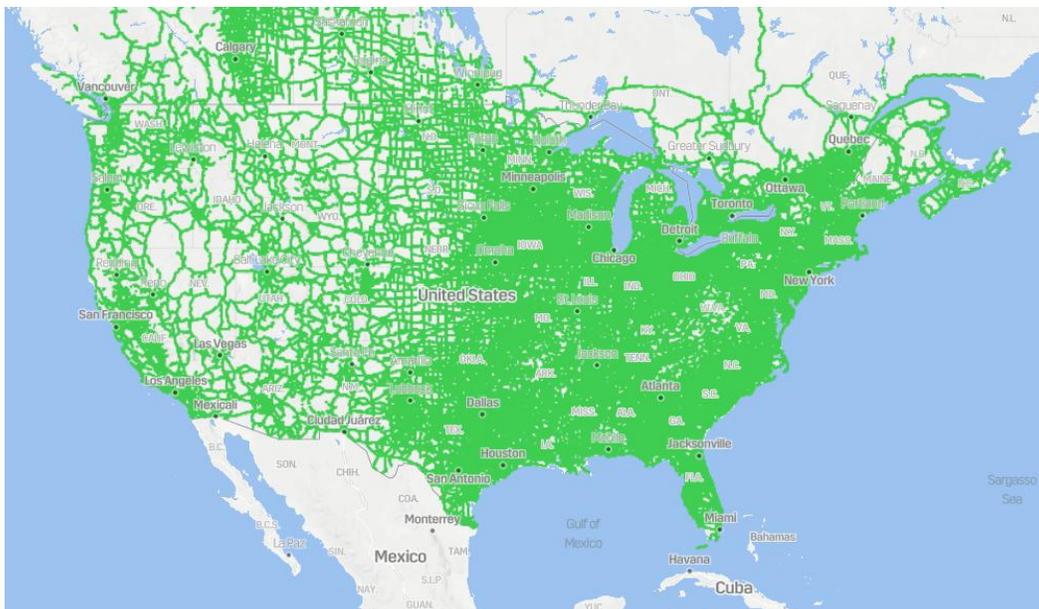


Figure 4. Super Cruise Compatible Roads (Cadillac. (n.d.), retrieved May 23, 2025)

Super Cruise operates only on predefined compatible roads, including controlled-access highways and select state highways. However, many users remain confused about the system's ODD. Mueller et al. (2024) found that some users incorrectly equate hands-free mode with full autonomy and report system lockouts after disengaging from proper usage protocols. They also reported that 53% of Super Cruise users felt safe leaving the system unattended, despite clear documentation emphasizing continuous driver supervision. Users frequently misinterpret warning triggers and lockouts as system malfunctions, rather than as designed safety interventions—highlighting a need for more intuitive feedback mechanisms.

Despite the system's robust design, Mueller et al. (2024) found that its hands-free nature encouraged visual-manual distractions, with users more likely to engage in multitasking compared to users of other systems like ProPILOT Assist or Autopilot. Additionally, while Super Cruise uses an infrared driver monitoring system to track head and eye position, Mueller et al. (2024) identified vulnerabilities: no alerts are triggered if the camera is blocked or if the driver's face is obscured, leaving a potential blind spot in the system's ability to detect disengagement.

That said, Super Cruise's escalating alert design during driver disengagement was generally well understood. In cases where the system shut down and could not be reactivated, 70% of users understood the reason for the lockout, suggesting transparency in communication and protocol (Mueller et al., 2024).

ODD adherence among Super Cruise users is generally high. Survey data from Mueller et al. (2024) show that 95% of usage occurred on free-flowing highways, with very limited use in intersections, traffic signals, or adverse weather conditions—indicating strong user alignment with intended operational conditions. However, limitations still exist in certain environments, such as work zones, poorly marked intersections, and in cases of sun glare or connectivity lapses, which may temporarily disable the system.

In contrast, findings from Llaneras et al. (2024) and Leslie et al. (2025) — both co-authored by researchers affiliated with GM—provide additional insights into real-world Super Cruise usage. They found that Super Cruise is typically activated on predictable, low-complexity roads and that usage patterns generally reflect greater discipline than those observed among Tesla users.

In a focused study of Super Cruise's Lane Change on Command feature, Llaneras et al. (2024) and Leslie et al. (2025) reported that drivers consistently performed over-the-shoulder and mirror glances before lane changes, regardless of whether the maneuver was automatic or manual. Notably, this conscientious behavior persisted across experience levels and over 10 days, suggesting that some safety habits remain intact even in the presence of automation. Still, the researchers cautioned that observer presence might have contributed to heightened driver vigilance, and further research under naturalistic conditions is needed.

They also found that braking under Super Cruise was smoother than with manual or traditional Adaptive Cruise Control (ACC) use, with fewer instances of hard braking. Furthermore, no Advanced Automatic Crash Notification (AACN) events were recorded on Super Cruise roads, pointing to a possible reduction in severe crash outcomes.

Overall, Mueller et al. (2024) found that many Super Cruise users misunderstood its capabilities, with over half believing it can operate unattended. The hands-free design encouraged distractions, and the driver monitoring system had detection gaps. Still, most users stayed within the intended ODD.

In contrast, GM-affiliated studies (Llaneras et al., 2024; Leslie et al., 2025) showed more disciplined usage, with drivers maintaining safety behaviors during automated lane changes and smoother braking patterns. No severe crash events were reported on Super Cruise roads.

## 6 Non-User Perceptions and Concerns

Because users of ADAS share the road with non-ADAS drivers, bicyclists, and pedestrians, any safety vulnerability presented by tADAS can undermine the safety of these other road users. There is ample anecdotal and investigative evidence indicating that tADAS can have implications for non-users. For example, in 2023, a teen student in North Carolina was injured when a driver using Tesla Autopilot failed to stop for a school bus despite the bus's flashing warnings and the visibility of the pedestrian (ABC11). News sources document a rash of instances in which Tesla vehicles crash into emergency vehicles due to an apparent failure of Autopilot to recognize or avoid these objects.

Surveys of vulnerable road users have found mixed attitudes toward autonomous vehicles. Notably, such surveys either use "autonomous vehicles" generally (with no specific automation level) or explicitly focus on self-driving cars. One survey of pedestrians and bicyclists in Pittsburgh found a generally positive

leaning, with respondents reporting positive experiences such as autonomous vehicles following the rules of the road, driving defensively, and yielding to other road users more frequently (Rahman et al., 2021). However, negative perceptions centered on safety and trust, and perceptions were found to depend on familiarity with ADAS technology. Another survey on bicyclists found that trust in self-driving cars depended on broader attitudes toward technology, and a subsequent focus group found that major concerns included the reliability of the self-driving cars in detecting vulnerable road users and the presence of signals that made clear the system's recognition of those users (Luger-Bazinger et al., 2023).

In addition to isolated crash reports and surveys, there are ongoing discussions in online communities regarding tADAS use and impacts. For instance, our informal search on social media revealed concerning issues, such as failure to recognize signs for school zones. In addition to ADAS users, discussions also involve non-user perspectives, including online communities dedicated to non-vehicular road use (e.g., running and cycling) and negative sentiment towards vehicles (see some examples in Table 2). These communities have raised concerns about how ADAS and autonomous vehicles interact with vulnerable road users. However, these conversations remain limited in volume, and to our knowledge, they have not been formally studied.

Table 2. Example of Negative Sentiment Toward ADAS Vehicles Found in Online Communities

| Site | ADAS | Thread title | Positive experiences | Negative experiences | Notes | Non-user |
|------|------|--------------|----------------------|----------------------|-------|----------|
| Reddit | Tesla FSD | FSD 30 Day Trial | Handles construction zones fine. Performs zipper merges fine, responds quicky to things (before user notices them). | Failure to get into the target lane. Failure to handle specific traffic light. | | |
| Reddit | Tesla FSD | "Tesla's Cyclist Conundrum" | - | "I refuse to use FSD on city streets", "barely use it on the highway" | Reports being both Tesla owner and cyclist, 49 upvotes | Yes |
| Reddit | Tesla FSD | "Tesla's Cyclist Conundrum" | - | [of FSD beta testers] "Whether I am in my car, motorcycle, or bicycle I do not WANT these people next to me on the road." | 67 upvotes | Yes |
| Reddit | Tesla FSD | "Tesla's Cyclist Conundrum" | Suggests beta testing on open roads is a necessity due to simulations being unrealistic | "I'll never use self driving as it makes me a nervous wreck." | Reports being both Tesla owner and cyclist | Yes |
| Reddit | Tesla FSD | FSD Tries to drive over a curb and enter a bike-only lane | | FSD couldn't recognize bike-only lane | 3yr ago | Yes |
| Tesla Motors Club (TMC) | Tesla FSD | FSD 11.3.6 Fail - no stopping for school bus | | FSD didn't stop for school bus, didn't recognize school zones | May- August, 2023 | |
| Tesla Motors Club (TMC) | Tesla FSD | FSD having more fails than 4 months ago | | "I just don't use FSD, and instead use the standard ADAS stuff, most of which works OK for my needs: In my experience, its safer, more consistent, more reliable. FSD has tried to kill me; ADAS has not." | Feb 6, 2025 75-yr poster | |

In summary, while there are numerous real-world examples showing that tADAS can negatively affect non-users, formal research is extremely limited. Comments from non-users are scattered across online communities, but there are no dedicated mechanisms for non-users to provide input or raise safety concerns.

## 7    Research Gaps and Recommendations

Based on our review, this project has identified key research gaps from the perspectives of tADAS users, non-users, and the broader society. Corresponding recommendations have been developed, as summarized in the table below.

Table 3. Identified Research Gaps and Recommendations

| Perspective | Research Gaps | Recommendations |
|---|---|---|
| **ADAS Users** | 1. Research on users' mental models of tADAS (e.g., what capabilities and limitations, how they work) is missing.<br>2. Most studies focused exclusively on Tesla, with very limited research on other tADAS. | 1. Directly investigate users' knowledge of their ADAS and how that deviates from the actual system capabilities.<br>2. Expand research on other tADAS and identify common and system-specific patterns of misperception/misuse. |
| **Non-user** | 1. There is no research examining the perspectives of non-user drivers who interact with tADAS-users, and little research examining the perspectives of vulnerable road users.<br>2. No research has leveraged social media to study attitudes and misconceptions of vulnerable road users towards tADAS.<br>3. Research on non-users' mental models—including their assumptions about the capabilities and limitations of tADAS compared to actual system behavior—remains unknown. | 1. Develop methods and tools for collecting and analyzing commentary from social media, particularly from non-user perspectives.<br>2. Use these tools to further study non-user sentiment and mental models of tADAS. |
| **Society** | 1. Societal implications of tADAS misuse remain underexplored. For example, how should law enforcement respond to misuse, such as DUI, while using Autopilot/FSD or violations of driver engagement requirements? | 1. To study legal and enforcement responses to tADAS misuse.<br>2. To develop policy and training guidelines for law enforcement on handling the misuse of tADAS. |

# 8    Implementation and Technology Transfer Plan

Findings from this study will support NCDOT in developing policies, educational materials, and safety initiatives related to transitional ADAS (tADAS). The following steps are proposed for implementation and technology transfer:

- **Policy Development:** Share insights with NCDOT divisions to inform policies on driver education, enforcement protocols, and infrastructure planning for vehicles equipped with tADAS.

- **Public Education:** Develop clear, accessible materials to educate drivers and the general public on the capabilities and limitations of tADAS systems, helping reduce misuse and misperceptions.

- **Collaboration with OEMs:** Engage with automakers to promote standardized terminology and clearer communication about system limitations to users and non-users alike.

- **Research Dissemination:** Present findings at conferences, workshops, and through NCDOT channels to facilitate knowledge sharing among transportation professionals, law enforcement, and stakeholders.

- **Future Research:** Use identified gaps as a foundation for new projects, particularly focusing on non-user perspectives and policy frameworks for managing tADAS-related safety concerns.

Together, these actions aim to improve road safety, enhance public understanding, and ensure that the deployment of advanced vehicle technologies aligns with North Carolina's transportation goals.

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# 10 Appendix

Appendix 1: List of Common tADAS

| Make | System | Function at Level 2+ (beyond basic SAE Level 2) | Manufacturer claim on SAE Level | Manufacturer site | Features mentioned by manufacturer | ODD information from manufacturer | Price | Available in trucks? |
|------|--------|------|------|------|------|------|------|------|
| Tesla | Autopilot | No | No mention on manufacturer's site | https://www.tesla.com/support/autopilot | - Traffic-Aware Cruise Control<br>- Autosteer | - Tesla's webpage only lists info on Autopilot and Full Self-Driving (Supervised), no distinction of other versions/names. | Free | Available in Cybertrucks |
| Tesla | Enhanced Autopilot | Yes | No mention on manufacturer's site | https://www.tesla.com/support/autopilot | - Navigate on Autopilot<br>- Auto Lane Change<br>- Autopark<br>- Dumb Summon<br>- Actually Smart Summon | | No longer available. It used to cost $6,000 (one-time purchase). | |
| Tesla | Full Self-Driving (supervised) | Yes | No mention on manufacturer's site | https://www.tesla.com/support/autopilot | - All of Enhanced Autopilot<br>- Autosteer on City Streets<br>- Traffic and Stop Sign Control | | $99.00 per month. Requires hardware like Full Self-Driving computer 3.0 or above. | Available in Cybertrucks |
| Ford | Co-Pilot360 | No | No mention on manufacturer's site | https://www.ford.com/technology/driver-assist-technology/ | - Pre-Collision Assist<br>- Blind Spot Assist<br>- Reverse Brake Assist<br>- Adaptive Cruise Control | | | Available in some trucks, including the F-150, Ranger, and Maverick |

| Make | System | Function at Level 2+ (beyond basic SAE Level 2) | Manufacturer claim on SAE Level | Manufacturer site | Features mentioned by manufacturer | ODD information from manufacturer | Price | Available in trucks? |
|------|--------|------|------|------|------|------|------|------|
| Ford | ActiveGlide/ BlueCruise (on Lincoln) | Yes | No mention on manufacturer's site | https://www.lincolnheightslincoln.com/active-glide-en.html | Hands-free driving on compatible roads | - It has its own blue hands-free zone, zone map is not available. https://www.lincolnheightslincoln.com/active-glide-en.html | | |
| Ford | BlueCruise | Yes | Not declared on main site. Media outlet claims Level 2. | https://www.ford.com/technology/bluecruise/ | - Hands-free driving on compatible roads (1.0) <br> - In-Lane Repositioning and Lane Change Assist (1.2) <br> - Improvements of curve navigation and hands-free capability (1.3 & 1.4) <br> - Automatic Lane Change (1.5) | -It has its own map to show compatible roads, called Blue Zone network; provides navigation routes. <br> - Controlled access highways; available on 97% of controlled access highways (130,000 miles) across U.S. and Canada. https://www.ford.com/technology/bluecruise/ | 1-year plan for $495 or a One-Time Purchase for $2,495. At the end of the initial complimentary trial or included plan duration, customers can choose to purchase a monthly plan for $49.99 or an annual plan for $495. | Available on some trucks and SUV models, e.g., Mustang Mach-E SUVs, F-150 |

| Make | System | Function at Level 2+ (beyond basic SAE Level 2) | Manufacturer claim on SAE Level | Manufacturer site | Features mentioned by manufacturer | ODD information from manufacturer | Price | Available in trucks? |
|---|---|---|---|---|---|---|---|---|
| General Motors (GM) | Super Cruise | Yes | No mention on manufacturer's site | https://www.gmc.com/connectivity-technology/super-cruise | - A hands-free driver assistance system for use on compatible roads<br>- Driver Attention Assist<br>- Enhanced Automatic Parking Assist | -It has its own map to show compatible roads.<br>- Includes controlled access highways and some state highways; compatible roads are shown on their map but hard to read; no navigation routes provided.<br>https://www.gmc.com/connectivity-technology/super-cruise | Super Cruise Package: $2,950. | Available on some trucks and SUV models, including Chevy trucks |
| Mercedes-Benz | Drive-Pilot | Yes | Claims certified Level 3 on manufacturer webpage | https://www.mbusa.com/en/owners/manuals/drive-pilot | Hands-free driving on compatible roads | - Clear lane markings, approved freeways<br>- Moderate/heavy traffic, speeds under 40 MPH<br>- Daytime lighting, clear weather<br>- Driver visible to camera above driver's display<br>- No construction zones | | |

| Make | System | Function at Level 2+ (beyond basic SAE Level 2) | Manufacturer claim on SAE Level | Manufacturer site | Features mentioned by manufacturer | ODD information from manufacturer | Price | Available in trucks? |
|---|---|---|---|---|---|---|---|---|
| BMW | Driver Assistance | Yes | No mention on manufacturer's site | https://www.bmwusa.com/explore/driver-assistance-safety-features.html | - Highway Assistant: hands-free driving at speeds up to 85 mph on controlled-access highways; includes Active Lane Change, allowing you to confirm suggested lane changes<br>- Distance Control: set desired distance from lead vehicle<br>- Steering Assistant: lane centering, ability to read lane markings<br>- Lane Change Assistant: automatically changes lanes and adjusts speed as needed<br>- Active Blind Spot Detection<br>- Forward Collision Mitigation<br>- Lane Keeping Assistant<br>- Drive Recorder<br>- High Beam Assistant<br>- Emergency Stop Assistant<br>- Backup Assistant<br>- Maneuver Assistant | - Only controlled access highways<br>-It has its own map to show compatible roads, called Highway Assistant Availability Map. https://bmwusanews.com/HighwayAssistantAvailabilityMap | | |

| Make | System | Function at Level 2+ (beyond basic SAE Level 2) | Manufacturer claim on SAE Level | Manufacturer site | Features mentioned by manufacturer | ODD information from manufacturer | Price | Available in trucks? |
|---|---|---|---|---|---|---|---|---|
| Hyundai/Kia /Genesis | Highway Driving Assist 2 (HDA2) | Yes (auto lane change on highway) | No mention on manufacturer's site | https://www.hyundaiusa.com/us/en/safety#:~:text=Lane%20Following%20Assist%20(LFA)%20helps,for%20feature%20details%20and%20limitations. | - Highway Lane Change Assist function helps change lanes after you switch turn signal and if the function judges that lane change is possible. | | | |