AI & SOCIETY (2023) 38:983–993
https://doi.org/10.1007/s00146-022-01442-x

STUDENT FORUM

The importance of transparency in naming conventions, designs, and operations of safety features: from modern ADAS to fully autonomous driving functions

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Received: 30 July 2021 / Accepted: 24 March 2022 / Published online: 16 April 2022

Abstract
This paper investigates the importance of standardising and maintaining the transparency of advanced driver-assistance systems (ADAS) functions nomenclature, designs, and operations in all categories up until fully autonomous vehicles. The aim of this paper is to reveal the discrepancies in ADAS functions across automakers and discuss the underlying issues and potential solutions. In this pilot study, user manuals of various brands are reviewed systematically and critical analyses of common ADAS functions are conducted. The result shows that terminologies used to describe ADAS functions vary widely across manufacturers and sometimes do not reflect their fundamental functions intuitively. Operational conditions and control procedures also vary across the selected models under this study. Due to this lack of consensus across the industry, drivers are not aware or well informed about ADAS functions in their vehicles, leading to a very low utilization rate and may lead to misuse of those functions. This paper provides insightful suggestions for the transport industry, Artificial Intelligence (AI) experts, and regulators to design frameworks and guidelines in governing the naming convention, operating conditions, control procedures, and information disclosure of ADAS. Such guidelines can be the foundations for regulating future AI-based self-driving functions.

Keywords ADAS · Autonomous vehicles · Operating conditions · Regulation · Standards · Transparency

1 Introduction

It is believed that fully autonomous vehicles are still at least a decade away (Litman 2017). There are many social, ethical, technical, infrastructural, and regulatory challenges in the journey between partially autonomous and fully autonomous vehicles (Dosen, Aroozoo and Graham 2017; Vrščaj, Nyholm and Verbong 2020). The Society of Automotive Engineers (SAE) has defined various automation levels from no driving automation (level 0) to fully automated (level 5) (SAE International 2021). In automotive electronics, advanced driver-assistance systems (ADAS) is a rapidly growing segment as it is a proven technology in reducing on-road accidents. Automotive industry experts believe that by 2025, all the modern vehicles on road will have at least one ADAS function (Shirokinskiy, Bernhart and Keese 2021). According to the US National Highway Traffic Safety Administration (NHTSA), 94% of the accidents are related to human negligence (Dosen, Aroozoo and Graham 2017). Driverless cars are envisioned to reduce the number of crashes, pollution, and energy consumption (Bagloee et al. 2016). Currently, there is no standard nomenclature of ADAS function across car manufacturers (Shirokinskiy, Bernhart and Keese 2021). It is anticipated that if ADAS technology is properly deployed and utilised, it has the potential to reduce the number of crashes by between 50 to 90%, depending on the adoption rate (Boelhouwer et al. 2018).

One of the revolutions in automation was the adoption of fully automated elevators. It took about fifty years for

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the technology to prevail and for the masses to accept it (Post 2020). There is a consensus that today's elevators are safe. We believe that there is a high level of similarity to the development and adoption of ADAS technologies in the automotive industry. This leads to questions on whether semi- or fully ADAS may follow the same adoption trend. However, from the technological point of view, there are significant differences. While both are autonomous systems, elevators are designed for operating in a confined environment with mostly constant parameters. In contrast, ADAS needs to tackle dynamic environmental factors and unpredictable human behaviours, which makes it hard to achieve the same safety level and gain the trust of the general public. It is expected that it will still take many years for the public to fully embrace autonomous safety features in automobiles (Litman 2017).

Another example, which represents the other extreme, is the adoption of autonomous functions in modern aviation. Unlike elevators, autopilot functions in modern planes were designed to tackle a dynamic environment, including headwind, tailwind, crosswind, and turbulence. Modern ADAS functions comprise numerous sensors, including cameras, ultrasonic sensors, lidar, and radar, which collect data and use advanced signal processing and control algorithms to predict and prevent accidents. For fully autonomous vehicles in the future, it is believed that machine learning techniques will be used to further minimise human interventions (Eliot 2017). While they share a similar technological framework, it is worth noting that planes and autopilot systems are designed to be operated by highly qualified and experienced pilots (Civil Aviation Safety Authority 2021). Pilots are well informed of the functions and limitations of the planes, while there is no special requirement and training for drivers of vehicles with ADAS or autonomous driving functions. This imposes a potential hazard. In Table 1, the similarities and differences among elevators, self-driving cars, and modern planes are summarised.

As demonstrated in the previous examples, there are a number of challenges and potential risks in the adoption of ADAS and autonomous driving functions in modern cars, i.e. training requirements, system limitations, and extrinsic dynamic factors including traffic conditions, pedestrians, and other road users (Litman 2017). Therefore, it becomes the prime responsibility of the automotive industry and its regulators to clearly define standards for ADAS and autonomous driving technologies so that consistency can be achieved across manufacturers. This can help to expedite Autonomous Vehicles' (AVs) design and development processes, and it can also help to gain the trust of the public and yield a higher adoption rate.

In choosing different brands of sedan cars, we have focussed on maximising the overall geographical coverage while brands sharing the same parent company have been discarded. For manufacturers with luxury vehicle divisions, car models from the more luxurious production line are selected as they are equipped with the more advanced ADAS functions. To ensure a fair comparison, the latest face-lifted sedans and their top-of-the-line versions have been selected for the study whenever possible as they are equipped with the most completed ADAS functions of their manufacturers. The study is based on data collected from the latest user manuals and/or specifications obtained from the corresponding official car manufacturers' websites at the time of writing. Table 2 shows the list of vehicles that have been selected for this study.

The paper is structured as follows. In Sect. "The development of ADAS and autonomous functions in the automotive industry", a general overview of the development of ADAS and autonomous functions in the automotive industry is presented. In Sect. "Results and analysis", details on the research approaches in conducting the survey are elaborated

Table 2 Vehicle brands and their parent organisations

Brand	Parent Organisation (Bartlett 2021)	Origin Country (Dean 2020)
BMW	BMW Group	Germany
Audi	Volkswagen AG	Germany
Tesla	Tesla Inc	America
Infiniti	Renault–Nissan–Mitsubishi Alliance	Japan
Lexus	Toyota Motor Corp	Japan
Mercedes Benz	Daimler AG	Germany
Maserati	Stellantis	Italy
Volvo	Zhejiang Geely Holding Group	Sweden
Genesis	Hyundai Motor Group	South Korea
Jaguar	Tata Motors	England

Table 1 Autonomous system—similarities and differences

Autonomous systems	Elevator	Vehicles (w/ADAS or fully autonomous)	Planes (w/autopilot functions)
Human operator/driver	A reasonable person	A reasonable person	Professional
Operational environment	A confined/static environment	A highly dynamic environment	A highly dynamic environment
Training requirements	No training required	Basic training required	Extensive training and assessments required

followed by an in-depth analysis of the findings. Factors that are limiting the wide adoption of ADAS functions are identified and further discussed in Sect. "Discussion". Based on the findings and analyses, recommendations for stakeholders and concluding remarks are provided in Sect. "Conclusion".

2 The development of ADAS and autonomous functions in the automotive industry

SAE has defined various automation levels from no driving automation (level 0) to fully automated (level 5), as indicated in (SAE International 2021). In general, the development of AV technologies can be summarised into three phases.

Phase 1: Researchers between 1960 and 2003 were mainly divided into two groups. The first group focused on the utilization of extrinsic factors such as intelligent road infrastructure (Anderson et al. 2016). The second group focused on sensing and intelligent technologies installed on the subject car (Anderson et al. 2016). During the same time, various ADAS functions were developed, such as cruise control, adaptive cruise control, and lane-keeping assist (Shaout, Colella and Awad 2011). For example, adaptive cruise control was first developed by Toyota in 1998 and laser-based technology was used due to its compact form factor and low cost. A year later in 1999, Jaguar developed their adaptive cruise control system and they preferred to use radar-based technology because of its long range (Shaout, Colella and Awad 2011). Over the years, automakers used different technologies to implement their own ADAS functions. Due to a lack of consensus across the manufacturers, automakers used different functions and names for marketing their brand (American Automobile Association 2019). The lack of standardisation imposes many challenges in the adoption and utilization of ADAS functions which are further presented in Sect. "Discussion".

Phase 2: From 2003 to 2007, the U.S. Defence Advanced Research Projects Agency (DARPA) provided numerous support and technical challenges to motivate academics and industry to accelerate the development of ADAS functions and AVs (Anderson et al. 2016). In a competition held in 2004, the best contesting vehicle could only complete 12 km out of a 230 km course without being involved in a collision. This indicates the inadequacies of the technology at that time (Carnegie Mellon University 2004). By 2007, the competition had moved into urban areas, where six AVs were able to reach the finish line. The outcomes marked the technological readiness of AV technologies (DARPA 2008). However, the mass deployment of AVs in uncontrolled areas remains a controversial topic.

Phase 3: 2007 – Current. The DARPA competitions further attracted tech giants, such as Google, to invest in AVs. In many years of Google's on-road experiments, only one incident occurred, on 14 February 2016, that was due to the fault of the AV (Bagloee et al. 2016). Currently, Google AVs are accompanied by trained AV pilots who take control only in unexpected and extremely complex driving situations. The pilot will also step in during unfavourable weather conditions, on unpaved roads, near-crash sites, and road works (Anderson et al. 2016).

3 Results and analysis

The objective of this pilot study is to elaborate on the importance of standardising the naming convention of the technologies and informing drivers on the operating conditions of various ADAS functions available in modern vehicles. The outcomes of this study will help stakeholders in the automotive industry in developing guidelines and frameworks to govern the naming and information disclosure of artificial intelligence (AI)-based autonomous driving functions in the future. To understand the problem, we surveyed user manuals systematically and conducted critical analyses of ADAS functions found in modern sedans from different automotive brands. This information is summarised in Table 3. The analytical processes are further elaborated as follows.

i. The process begins with searching for ADAS functions in each brand's user manuals with keywords mentioned in the American Automobile Association (AAA) report (American Automobile Association 2019).
ii. Due to different marketing naming conventions and usage of technical terminologies, sections around the keywords in the manuals were studied manually to categorise the natures of the functions.
iii. The categorised ADAS functions have been further classified into Active or Passive functions based on the (ANCAP 2021; Traffic Injury Research Foundation 2021). To maintain the generality of this study, only common functions appearing in reports of industry regulatory bodies, namely NHTSA, AAA, and Australian New Car Assessment Program (ANCAP) are chosen (American Automobile Association 2019; ANCAP 2021; National Highway Traffic Safety Administration (NHTSA) 2020).
iv. ADAS functions that directly act on behalf of the driver on the road and assist the driver in making complex driving decisions are retained for analysis and the rest of the functions are discarded.
v. Afterwards, ADAS functions with electronic controllers are retained for comparisons and analyses and the rest of the functions are discarded.

Table 3 Comparison of ADAS functions across different selected car models. The corresponding operating conditions/limitations are stated inside square brackets

	BMW 7 Series (BMW 2019)	Mercedes S Class (Mercedes Benz 2021)	Audi A8 (Audi 2020)	Tesla Model S (TESLA 2021)	Infinity Q50 (Nissan Motor Co. 2020)	Lexus Ls500 (Lexus 2020)	Genesis G70 (Genesis 2021)	Volvo S60 (Volvo 2021)	Maserati Quattroporte (Maserati 2021)	Jaguar XF (Jaguar Land Rover 2021)
Collision Avoidance	Front Collison Mitigation [Above 5 km/h]	Active Brake Assist [Above 7 km/h]	Audi Pre-Sense [Above 30 km/h]	Collision Avoidance Assist [10–150 km/h]	Predictive Forward Collision Warning [Above 5 km/h]	Pre-Collision System [5-180 km/h]	Forward Collision Avoidance Assist [Above 10 km/h]	Collision Avoidance [60-140 km/h]	Forward Collision Warning [2-250 km/h]	Collision Avoidance [5-180 km/h]
Adaptive Cruise Control	Active Cruise Control with Stop and Go Function [30–180 km/h]	Active Distance Assist DISTRONIC [20–210 km/h]	Adaptive Cruise Assist [above 30 km/h]	Traffic Aware Cruise Control [0*–150 km/h] *when behind another vehicle	Intelligent Cruise Control [32-144 km/h]	Dynamic Radar Cruise Control (vehicle to vehicle distance control) [Above 30 km/h]	Smart Cruise Control with Stop and Go Function [30–200 km/h]	Adaptive Cruise Control [30–140 km/h]	Adaptive Cruise Control [30–210 km/h]	Adaptive Cruise Control [0–200 km/h]
Cruise Control	Cruise Control [30–180 km/h]	Cruise Control [20-250 km/h]	Cruise Control [Above 20 km/h]	Traffic Aware Cruise Control [30–150 km/h]	Cruise Control [40–144 km/h]	Dynamic Radar Cruise Control (constant speed control) [Above 30 km/h]	Cruise Control [Above 30 km/h]	Cruise Control [0-200 km/h]	Cruise Control [30-210 km/h]	Cruise Control [Above 16 km/h]
Blind Spot Assist	Side Collision Mitigation [5–210 km/h]	Active blind Spot Assist [30–200 km/h]	Side Assist [Above 10 km/h]	Blind Spot Collision Warning Chime [12–140 km/h]	Blind Spot Intervention Above 60 km/h]	Blind Spot Monitor (BSM) [Above 16 km/h]	Blind Spot Collision Warning (BCW) [Above 30 km/h]	Blind Spot Information System [Above 12 km/h]	Active Blind Spot Assist [60–180 km/h]	Blind Spot Assist [64–180 km/h]
Lane Keeping Assist	Lane Departure Warning [Country specific -210 km/h]	Active Lane keeping Assist [60–200 km/h]	Lane Departure Warning [65–250 km/h]	Lane Departure Avoidance [64–145 km/h]	Lane Departure Prevention [Above 70 km/h]	Lane Tracing Assist (LTA) [Above 50 km/h]	Lane Keeping Assist [Above 64 km/h]	Lane Keeping Aid [65–200 km/h	Lane Keeping Assist [60–180 km/h]	Lane Keeping Assist [64–180]
Automatic High Beam	High Beam Assistant [Activation speed not reported]	Adaptive High Beam Assist [Above 30 km/h]	High Beam Assistant [Activation speed not reported]	High Beam Head Lights [Activation speed not reported]	High Beam Assist [Above 35 km/h]	Automatic High Beam [Above 34 km/h]	High Beam Assist [Above 40 km/h]	Active Main Beam [Above 20 km/h]	Automatic High Beam Assist [40–250 km/h]	Auto High Beam Assist [Above 40 km/h]
Adaptive Front Lighting	Adaptive Light Function [Activation speed not reported]	Active Headlamps Function [Activation speed not reported]	Adaptive Light [Activation speed not reported]	Adaptive Front Lighting System (AFS) [Activation speed not reported]	Adaptive Front Lighting System (AFS) [Above 5 km/h]	Adaptive Front Lighting System (AFS) [Above 10 km/h]	Adaptive Front Lighting System [Activation speed not reported]	Active Bending Light [Activation speed not reported]	Adaptive Driving Beam [Activation speed not reported]	Adaptive Front Lighting System [0 to maximum speed, not reporter]

Operational conditions and limitations of the selected ADAS functions among all the brands considered in this study were collected for more in-depth comparisons. Via an exhaustive search, we found that there is no consistency between manufacturers in naming their ADAS functions. There are functions that have the same purposes but are named differently and in some cases, ADAS functions names are very similar but their functions are different (Boelhouwer et al. 2020). The selection process of ADAS functions for this study is shown in Fig. 1. In the process, some of the functions were discarded as they have been regarded as out of scope, for example, Remote parking, Trailer assistance, and Fully automated parking assistance, etc. At the end of the filtering process, seven ADAS functions have been selected for further analysis, and the results are presented in Table 3.

3.1 Observations

i. We observed that terminologies used to define and describe the same or similar ADAS functions vary across the selected car models. Some of them have been replaced by trademarks or product names that do not directly reflect their fundamental functions in intuitive ways. The finding concurs with that in (American Automobile Association 2019) which stated that forty unique names were used by different manufacturers to label their collision avoidance systems. Details on the unique names used by the manufacturer to describe the ADAS function can be found in (American Automobile Association 2019).
ii. Manufacturers tend to combine multiple safety features into ADAS packages and provide buyers with high-level product names. For example, BMW Intelligent Safety includes eight different ADAS sub-functions sets (BMW 2019). Lexus Safety System + A comes with six ADAS sub-functions sets (Lexus 2020). Jaguar InControl includes eleven ADAS sub-functions sets (Jaguar Land Rover 2021). Nissan's Intelligent safety shields includes nine ADAS sub-functions sets (Nissan 2020), while Tesla Autopilot comes with thirteen ADAS sub-functions sets (TESLA 2021). Nevertheless, all the sub-functions sets of different automakers are carrying different numbers of ADAS functions. According to (Hawkins 2019) such high-level and marketing ADAS package names used by the manufacturers can be misinterpreted by motorists. Table 4 illustrates ADAS package names used by the selected car models in this study.
iii. Another observation that was not covered in previous surveys is that the operational conditions or limitations of some ADAS functions vary across the selected models as shown in Table 3. It is important for driv-

Table 4 ADAS packages of different car brands

Brand	ADAS or Equivalent Package Name
BMW (BMW 2019)	Intelligent safety
Audi (Audi 2021)	Audi pre sense
TESLA (TESLA 2021)	Autopilot
Nissan/Infinity (Nissan 2020)	Infinity safety shield
Toyota/Lexus (Lexus 2020)	Lexus safety system + A
Mercedes (Mercedes Benz 2021)	Intelligent drive*
Maserati (Maserati 2021)	Safety and driving assistant*
Volvo (Volvo 2021)	IntelliSafe
Genesis (Genesis 2021)	Safety features*
Jaguar (Jaguar Land Rover 2021)	InControl

*Package name not specified. The corresponding section heading in the manual/website has been used instead

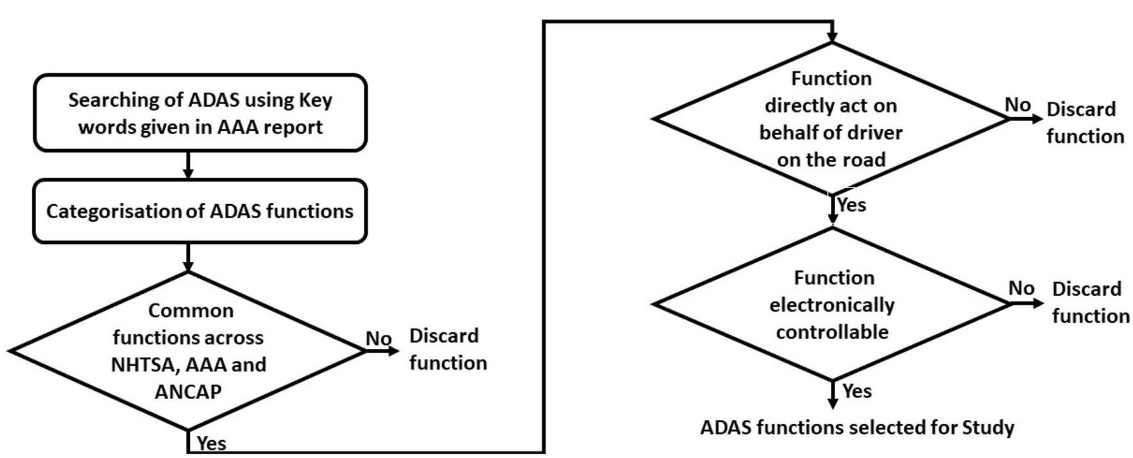

Fig. 1 Selection process ADAS functions for study

ers to acknowledge and have a clear understanding of the limitations and operational conditions of each ADAS function on their vehicles. Such discrepancies can introduce confusion for drivers. From Table 3, it is observed that the operating conditions of different ADAS functions vary even within the same model. This can create ambiguity and cause misjudgement for drivers, especially under emergencies. A typical example is adaptive cruise control which is a popular function in modern vehicles. However, the minimum and maximum speed thresholds for it to be functional are significantly different from model to model, which could be one of the root causes of the finding in (Boelhouwer et al. 2020) that reported only 26.1% of users claimed they use adaptive cruise control regularly.

iv. Control procedures are varying significantly across functions and models, including, pressing a button once, holding a button for a specific amount of time, or changing the settings via the interface on the dashboard. Warning signs and the way that they are given, including constant indicator, flashing, chimp sounds, and vibrations are also very different. All these can cause disturbances to drivers.

v. Conditional statements, such as non-favourable driving conditions, poor visibility, narrow lanes, worn lane marking, light interferences, and different levels of sensor obstructions or misalignment, introduce uncertainties and can lower a driver's confidence in utilising these functions. Key system limitations are illustrated in Fig. 2.

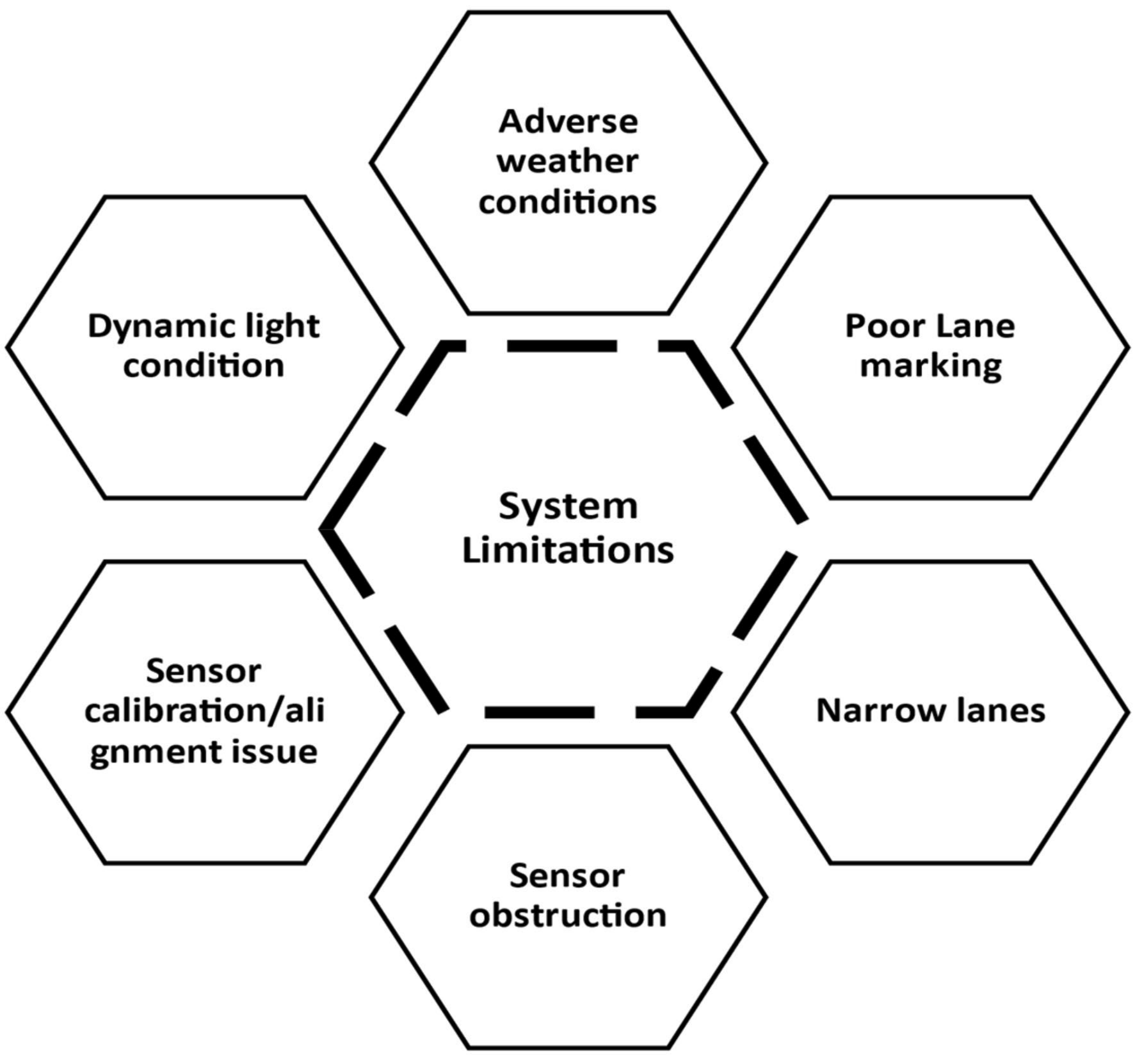

Fig. 2 Key system limitations

vi. According to ANCAP, active ADAS functions can avoid fatal accidents effectively. Active functions, such as lane-keeping assistance, blind spot intervention, adaptive cruise control, etc., all intervene and make corrective steering/braking manoeuvres under emergencies. However, the descriptions of the behaviour of the car such as the amount of steering it provides when performing those rectification actions are vague and not quantifiable. Currently, there is no suggested way for drivers to experience these actions for training purposes under safe conditions.

vii. It is also observed that there are no clear guidelines on the calibration and maintenance of ADAS functions.

4 Discussion

4.1 Different naming conventions used by automakers

It is evident from Table 3 that manufacturers use very different terminologies to describe their ADAS functions. The lack of uniformity and consistency in ADAS functions naming conventions can confuse drivers while using those functions in dynamic driving situations and may compromise the safety of road users as suggested in (American Automobile Association 2019; Boelhouwer et al. 2020). Very often car brands bundle multiple safety functions into one package and present their customers with a generic product name. According to (Hawkins 2019), autopilot or pro-pilot assists are used by two leading car manufacturers and 40% of drivers misinterpreted that the above systems have autonomous driving capabilities. Table 4 illustrates ADAS package names used by the selected car models in this study. Currently, there is no consensus or agreement between automakers and regulators on standard names to reflect ADAS functions, which makes it hard for motorists to discern, compare, or even use them. As recommended in (American Automobile Association 2019), the automotive industry needs to come up with standard terminologies for their ADAS features. Regulators need to develop rules and standards for automakers and their suppliers to follow when disclosing those essential technical details.

One of the factors which contribute to the low adoption and utilization rates of ADAS functions by drivers is the lack of intuitive naming conventions (Boelhouwer et al. 2020). The lack of uniformity in naming ADAS functions can add confusion and ambiguity for drivers while using those functions in a dynamic driving environment. It also becomes difficult for buyers to compare the ADAS functions available in different vehicles. Automotive industry regulators across the globe should come up with general rules for naming AI/ADAS functions across the industry. Based on regulations of different local authorities, manufacturers should further provide customers with proper terminology mapping. Consumers should be aware of the technology that their cars have been using so that they can make well-informed buying decisions.

4.2 Different Operating conditions and procedures

Table 3 implies that operating conditions and parameters of ADAS functions vary across selected car models. Inadequate knowledge and lack of clarity about the functional requirements of the system can lead to severe road safety issues. For AVs of SAE Level 4 or lower, there is always human intervention involved. Therefore, it is very important that automakers come up with uniform operating conditions and procedures so drivers can use those functions with confidence as variations in operating conditions can confuse the driver while using the ADAS function in a dynamic driving environment. From Table 3, it is observed that the operational speeds of some ADAS functions can vary significantly across brands. That makes it hard for human drivers to understand and remember the capability and limitations of the ADAS functions in their cars, especially for novice AV drivers. If a driver of a highly automated machine does not have a clear and accurate understanding of the capabilities and limitations of each of the ADAS functions, he/she can make wrong decisions and may wrongly rely on the technology when it is unsafe to do so. If the operating procedures of the ADAS functions are too complex, the driver may not be confident in activating and operating those ADAS functions, which leads to a low utilisation rate.

It is also essential for automotive regulators and manufacturers to design simple and consistent procedures for drivers to activate/deactivate ADAS functions. The simplicity of the procedures is crucial as drivers are often required to follow or execute them while driving or during emergencies.

Automakers should jointly design common and intuitive visualisation frameworks (warning notifications, symbols, colour and sequencing order of visual and audio indicators, etc.) to alert drivers of potential hazards. Research shows that on average, a human driver takes 1.5 s to identify a hazard and make the necessary manoeuvring adjustments to avoid a potential crash (Matheson 2019). A driver assistance system can take hundreds of milliseconds to alert the driver of potential hazards. During that time, if the driver is engaged in non-driving tasks such as accessing the in-car infotainment system, it could add hundreds of milliseconds to any reaction (Matheson 2019).

The situation can be more severe for AVs as their drivers are not expected to engage in driving, except under extreme conditions. It is worrying that AVs may not provide enough time for their drivers to react in hazardous situations.

Furthermore, as AV owners could have fewer hands-on, on-road experiences due to their reliance on self-driving functions, it can be expected that AV owners will take an even longer time to react. If there is no well-defined and consistent approach across the manufacturers on controlling those ADAS and self-driving functions in case of an emergency, the aforementioned time delays will increase the probability of a crash.

An example that resonates with the above argument is the tragedy of British Midland Flight 92 on January 8, 1989. After its take-off, its crew experienced vibration and smoke in the flight deck. Due to a lack of knowledge about the design of the new aircraft, its first officer could not assimilate the electronic instrument readings correctly and recommended that the pilot shut down the wrong engine which led to a crash (Trimble 1990). According to the investigation report, the lack of understanding about the new design of the aircraft and the non-intuitive electronic indicators are two of the major causes of this fatal disaster (Trimble 1990). This event highlighted the importance of training and understanding the behaviour of the manoeuvring system of a vehicle/vessel under emergencies.

According to the Australian Civil Aviation Safety Authority, to obtain an air transport pilot license, pilots are expected to complete at least 1500 flying hours (Civil Aviation Safety Authority 2021). However, owners of vehicles with ADAS functions or AVs nowadays are not required to go through an equivalent extensive training, which means automakers need to ensure that their control interfaces are simple, intuitive, and standardised across the industry. Automotive industry experts have a consensus that there should be training provided to AV users for them to obtain the optimal benefit from the technology (Tsapi et al. 2020). Automakers and their resellers should also ensure that the end-users are well informed and receive adequate and regular training on the functionality and operations of those ADAS and self-driving functions.

In summary, the lack of consistency in operating speed and procedures can lead to misunderstanding and misjudgement by drivers. Manufacturers should describe the operating conditions of the ADAS functions in quantifiable terms so that users can understand the level of automation and the operating conditions of each ADAS function clearly and accurately. A consensus should be developed across manufacturers on obtaining baseline operating conditions of different ADAS functions, so buyers are well informed about what provisions to expect in a dynamic driving environment and potential emergencies. A standard across automakers on control procedures of various ADAS and self-driving functions is also needed. There should be a consistent design philosophy on warning notifications, instrument cluster displays, buttons press-and-hold time, the sequencing order of visual and audio indicators, and dashboards. To facilitate this, regulatory authorities should initiate the study on the effectiveness of different control procedures and warning messages. Based on the research outcomes, automakers should produce a common design philosophy on, including but not limited to, warning notifications, instrument cluster display, button holding times, and the operating speed of various ADAS functions.

4.3 ADAS limitations and maintenance issues

Automakers have claimed that in some situations ADAS functions may not work or may work with limited capacity. However, terminologies used by vehicles manufacturers to describe the limitations are vague. For example, adverse weather conditions mentioned in their descriptions, such as rain, snow, fog, wind, glare light, or during winter, lane markings can be covered by snow, heavy rain, etc. (Neumeister and Pape 2019) have no trivial definitions. Similarly, lane markings can be ambiguous for AVs to detect in glaring light (Neumeister and Pape 2019). Another issue is related to road infrastructure e.g., narrow lanes, poor lane marking, etc. Most ADAS functions rely upon lane markings and other features of road infrastructures, however, without a clear definition of their wear and tear conditions, it is hard to interpret when ADAS would fail and require human interventions. For weather, lighting, and road conditions, automakers need to provide a scientific definition of the above situations and design quantifiable measures for each of them so that consumers can make comparisons and have a better understanding of the performance of their cars.

An example, that elaborates the importance of driver/pilot understanding on behaviours of active control systems and sensors limitation on board, is the flight incident of Air France 447. The incident happened on 1st June 2009, when the autopilot system was deactivated by the computer because the airspeed sensors called pitot tubes were blocked by ice (Bureau d'Enquêtes et d'Analyses 2012). Unfortunately, the pilots did not assimilate the problem and pulled back the control stick which forces the plane into a steep climb and caused it to stall. The plane started free-falling from the sky (Bureau d'Enquêtes et d'Analyses 2012).

This catastrophe highlights three areas that require industry experts' attention. The first one is the importance of the autonomous system operator's understanding of sensor limitations and behaviour. Sensors must be regularly cleaned and properly calibrated. But consumers are not trained for this action, so automakers and their resellers need to educate the consumer and remind them about this requirement. The cleaning and calibration process should be simple.

Automakers may need to redesign their sensors or adopt more advanced technologies.

The second point is the importance of letting the user know the behaviours of the assistive and active control system onboard. Currently, users are relying on the information available through the user manual, internet, or the trial-and-error method. Automakers should use quantifiable measures to describe the behaviours of the system under emergencies. For example, how much steering assistant would be provided when lane-keeping assist is activated and for how long. Automakers should also design ways to demonstrate that behaviour to users under safe conditions, including videos.

Thirdly, it is observed from the AF447 incident that unanticipated takeover requests are very difficult for humans to handle. Even highly qualified and well-trained pilots can panic and make wrong decisions (Bureau d'Enquêtes et d'Analyses 2012). ADAS and AVs should provide enough time for human drivers to focus on the road again before transferring the control. These systems may also need mechanisms for measuring drivers' readiness in overtaking other vehicles.

Terminologies used by the automakers to describe the limitations of the system are imprecise and cloudy, such as poor weather conditions, narrow lane marking, etc. Similarly, descriptions about the behaviours of ADAS functions in making corrective steering/braking manoeuvre are also ambiguous. Another issue is that there is no clear calibration process nor are there maintenance guidelines for ADAS functions. Manufacturers should formulate scientific definitions about the above situations and design quantifiable measures for each of them so consumers can make enhanced comparisons and have a better understanding of their cars. Automakers should also design ADAS with uniform and quantifiable corrective manoeuvring behaviours so drivers can coordinate with the systems under emergency driving conditions. Nevertheless, to ensure ADAS are operating at their peak performance, manufacturers should also provide clear and simple instructions on maintaining and calibrating the ADAS for the users.

Factors discussed in Sects. Different naming conventions used by automakers, Different Operating conditions and procedures, and ADAS limitations and maintenance issues are limiting the prevalence of ADAS functions. There are functions that are available since the mid-twentieth century, however, they are not widely used by drivers (Shaout, Colella and Awad 2011). The study in (Boelhouwer et al. 2020) shows that some ADAS functions, as shown in Table 5, have low utilisation rates. Table 5 below indicates that automakers and automotive industry regulators have a role to play to ensure uniformity in naming conventions, operating conditions, operational procedures, and system limitations of ADAS can be achieved. It is expected that by implementing the aforementioned recommendations, the driver's understanding of levels of ADAS functions can be increased which can help to increase the adoption rate of ADAS functions.

Table 5 ADAS function average regular user

ADAS Function	Function available since (Shaout, Colella & Awad 2011)	Regular user (Boelhouwer et al. 2020)
Cruise control	1960	33.3%
Adaptive cruise control	1998	26.1%
Lane keeping Assist	2001	9.8%

5 Conclusion

This pilot study aims to elaborate on the significance of standardizing the nomenclature of ADAS functions and providing transparency to car owners on the operational conditions and procedures of various ADAS functions equipped in modern vehicles. According to our findings, it is observed that there is a lack of consensus on the naming conventions across car manufacturers to describe their ADAS functions, which concur with those reported by the American Automobile Association. Furthermore, we also observed that operational conditions, operational procedures, and system limitations vary across the car models selected in this study. These inconsistencies may impose confusion upon drivers in using and maintaining ADAS on their vehicles. As some of the ADAS functions can act on behalf of drivers on the road, if they are not used properly, they can be potential hazards to their drivers and other road users. Based on our analyses and discussions, we now give some practical suggestions for all the stakeholders, including automobile manufacturers, regulation organisations, and end-users which can help the development and deployment of safer ADAS and AVs.

- *Define unified and standard naming conventions for AI/ADAS functions* – Local policymakers should define the rules to standardise the names and based on those rules automakers should perform the mapping to meet country-specific requirements.
- *Develop a uniform process for the activation and deactivation of ADAS function* – Research should be conducted to study the most effective process of activation and deactivation of ADAS functions. Based on the research outcomes, manufacturers should design the ADAS functions activation/deactivation processes accordingly.
- *Develop a consistent design philosophy for system indicators and human vehicle interaction* – Research should

be conducted to study the effectiveness of different message types on the alertness of drivers. Based on the outcome, manufacturers should design intuitive universal warning mechanisms and vehicle behaviours.

- *Develop and design quantifiable operating conditions and system limitations* – Depending on the AI technology used, and sensor types deployed by different manufacturers, quantifiable operating conditions should be disclosed to the buyers so that users can make a well-informed buying decision.
- *Develop clear and simple calibration and maintenance processes for all the sensors* – Automakers should design standard calibration processes and sensor maintenance guidelines. They should develop standardised monitoring and diagnostic mechanisms for evaluating sensor health conditions.
- *Designing of safety systems with uniform operating speed* – Local rule regulators and automakers should define the baseline operating conditions of common ADAS functions. Automakers should then design their systems and functions to fulfil those requirements.
- *Develop a better instruction sharing and training process* – Research should be conducted to study the effective and best possible training structure for AV drivers. Based on the outcomes of the research, local licensing authorities can design the training and licensing framework for AV drivers.

The suggestions mentioned above will help the relevant road transport regulatory bodies to develop guidelines in governing the naming conventions, operating conditions, control procedures, and information disclosure of ADAS. The guidelines can guide the automotive industry in deploying ADAS and AI-based self-driving functionalities. This will also allow the general public to better understand ADAS functions and leading to a higher adoption rate.

Funding Open Access funding enabled and organized by CAUL and its Member Institutions.

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Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.