# How Often are ADAS Used? Results of a Car Drivers' Survey

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*Abstract:* - Safety in automotive systems has been a major concern since the early days of vehicles on the road. In recent decades, automakers worked hard to integrate Advanced Driver Assistance Systems (ADAS) into their vehicles. The aim of the paper is twofold: *i)* investigate the ADAS evolution over time, a trend that has made current cars safer and paved the way for self-driving mobility; *ii)* investigate the users' propensity in using steering wheel controls which, as known, promise an increase in road safety. To do this, both a desk analysis and a mobility survey among Italian car drivers were performed. Survey results allowed us to investigate both the presence of these systems on board the vehicles currently used and their frequency of usage. Precisely, 60% of the respondents currently have the steering wheel controls on board their car to listen to music and/or answer calls. Of those who have these devices, about 60% (68%) of the respondents frequently (high) use steering wheel controls to answer calls (to listen to music). 82% (74%) of the drivers stated that these devices to answer calls (to listen to music) significantly improve both road safety and driving stress, (improve the overall travel experience). Furthermore, it is interesting to observe that steering wheel controls to answer calls are perceived as more useful than those to listen to music (about 8 percentage points more). Finally, among those who do not have steering wheel controls, 89% of the respondents believed they would like to have them in their next car.

*Key-Words:* - Advanced Driver Assistance Systems (ADAS); travel experience; Self-driving vehicles; driverless; Autonomous Vehicles (Avs); Automated Driving (AD); road safety; transportation planning

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## 1 Introduction

Safety in automotive systems has been a major concern since the early days of on road vehicles. Advanced Driver Assistance Systems (ADAS) have become a salient feature for safety in modern vehicles. State of the art ADAS are primarily vision based, but light detection and ranging (lidar), radio detection and ranging (radar), and other advanced-sensing technologies are also becoming popular, [1]. Recently, ADAS are also key technologies to develop autonomous vehicles (AVs), [2]. The

Society of Automotive Engineers (SAE) defines six different levels of driving automation for road vehicles, [3]. A vehicle is categorized as level zero if no systems are assisting the driver in handling steering and acceleration/deceleration and everything is handled manually by the driver. Level one vehicles consist of systems assisting the driver in handling either steering or acceleration/deceleration under certain cases with human driver input. Technologies in level two vehicles handle both steering and acceleration/deceleration under certain environments with human driver input. In general, in lower-level vehicles (levels zero to two), the driver monitors the driving environment. From level 3 onwards the role of the human driver becomes increasingly marginal and driving functions are no longer attributable to ADAS alone, as it is artificial intelligence (AI) that takes over, understands the environment, and makes the car move.

Artificial intelligence defines the transition from automated vehicles to autonomous vehicles. Automated vehicles are equipped with ADAS systems only, autonomous vehicles in addition to ADAS, exploit Artificial Intelligence to process signals/data received from a combination of sensors, cameras, radars, lidars, lasers, GPS trackers (and many others), to understand the environment and offer a response to the challenges, thus ensuring the movement of the vehicle.

According to [4], AI is just *"the science and engineering of making intelligent machines"*. In technical terms, Artificial Intelligence is a branch of information technology that allows the programming and design of both hardware and software systems that make it possible to equip machines with certain characteristics that are considered typically human such as example, visual perceptions, space-temporal and decisional, [5], [6], [7], [8].

"*AI enables technical systems to perceive their environment, deal with what they perceive, solve problems and act to achieve a specific goal. The computer receives data – already prepared or gathered through its own sensors such as a camera – processes it and responds. AI systems are capable of adapting their behaviour to a certain degree by analysing the effects of previous actions and working autonomously"*, [9].

Therefore, the advancement of artificial intelligence has truly stimulated the development and deployment of autonomous vehicles in the transportation industry. Fueled by big data from various sensing devices and advanced computing resources, AI has become an essential component of AVs for perceiving the surrounding environment and making appropriate decisions in motion, [10]. Therefore, while ADAS only support the driver with their driving task, and endeavor to avert accidents by intervening, when required, improving road safety; autonomous vehicles take over specific portions of the dynamic driving task, which are ordinarily executed by human drivers for at least part of the trip.

While autonomous vehicles are in the experimental stage, ADAS are present and are increasingly common in current vehicles. Their role in improving road safety is recognized throughout Europe to such an extent that the Regulation (EU) 2019/2144 of the European Parliament and of the Council, dated November 27, 2019, stipulates that starting from 2024, the registration of category A and B vehicles that do not have advanced safety systems on board, such as intelligent speed adaptation, interface for alcohol lock installation, driver inattention, and fatigue warning, advanced driver distraction warning, emergency stop signal, reversing detection, and event data recorder, will be prohibited.

Starting from these considerations, the aim of the paper was twofold: *i)* investigate the ADAS evolution over time, a trend that has made current cars safer and paved the way for self-driving mobility; *ii)* investigate the users' propensity in using steering wheel controls which, as known, promise an increase in road safety.

The paper is structured as follows: Section 2 reports the evolution of the main advanced driver assistance systems (ADAS) over time; Section 3 reports the results of a survey investigating how often the ADAS are used among Italian drivers. Finally, Section 4 reports the main conclusions, limitations, and future research directions.

## 2 Evolution of Advanced Driver Assistance Systems (ADAS) Over Time: Towards Self-Driving Vehicles

Modern vehicles are equipped with a variety of systems and accessories, whose number has been increasing with the introduction of each new model. Some of these features are designed to attract the attention of potential buyers or to improve comfort. Examples of such systems include advanced lighting technology, high-end infotainment systems, various driving modes, pre-setting of seats and rear-view mirrors, and so on. Others are specifically designed to improve driver and passenger safety and are generally referred to as ADAS systems (Advanced Driver Assistance System). Among the most popular ones, there are Automatic Emergency Braking (AEB), reverse cameras, frontal sensing systems, 360° cameras (surround-view), and many others.

In the space of a century, these driver assistance systems have evolved considerably, from simple devices for mechanical cruise control to solutions capable of enabling the construction of vehicles that are increasingly “software defined” that make extensive use of augmented and virtual reality and aim at fully autonomous driving.

To define the evolution of the main ADAS over time an ad hoc methodology was performed: *i)* a web-based desk search was conducted, identifying articles and websites in which the keywords, such as, “*advanced driver assistance systems*”, "*ADAS*", “*road safety devices and/or systems*” appeared in the title and/or text; *ii)* a careful analysis of the sources was conducted to identify the entry-level year of the ADAS and its main characteristics; *iii)* the single technology (ADAS) were included in a timeline Fig. **1** and discussed in the body of the text.

Probably the forerunner of driver assistance systems was the Speedostat, [11]. This was the first design of a speed control system, [12]. Patented on 22 August 1950, [13], it consisted of a speed selector on the dashboard connected to a mechanical adjustment mechanism derived from the vehicle's drive shaft. Actuated by the controller, a vacuum pump was responsible for pushing up the accelerator pedal, providing haptic feedback to the driver to signal him to slow down. Chrysler automobile was the first automaker to adopt the Speedostat in 1958, [11], [13].

Shortly after Speedostat had been successfully implemented on production vehicles, another technological revolution was at the doorstep: in 1971 was invented and patented the first electronic cruise control, which was defined as 'speed control for motor vehicles', [14]. This new electronic speed control could manage, and this was an absolute novelty, the speed of the vehicle in a ‘closed loop’, even uphill and downhill. This invention, known as cruise control, changed vehicles forever. The history of ABS (Anti-lock Braking Systems) also offers interesting insights. Similar to cruise control, ABS was initially conceived as a mechanical system. The first production vehicle equipped with an electronic ABS system was the 1971 Chrysler Imperial model, [15]. The Bendix company patented it in 1970 and Chrysler named this system 'Sure Brake', commonly known as 'anti-skid', [16]. ABS has thus become a standard feature for all car manufacturers and almost all vehicles now on the roads adopt it. The first known example of a reversing camera, mounted on the Centurion model made by Buick, dates back to 1956, [17].

This concept car had a rear-view camera whose images were shown on a television screen in the passenger compartment that was used in place of the rear-view mirror. Although it was certainly a brilliant idea, the decidedly high cost was the element that most likely held back its widespread diffusion. In fact, it is thought that this system was never fully functional.

We have to wait until 1972 to see another car equipped with a camera: in this case, it was an experimental Safety Car made by Volvo (VESC – Volvo Experimental Safety Car) to test a range of new safety features, [18]. Toyota was the first OEM (Original Equipment Manufacturer) to equip a vehicle intended for series production with a reversing camera: this was the Soarer Limited model marketed from 1991 only in Japan, [17]. In production until 1997, the system used a color screen and a CCD camera mounted on the spoiler. In 2000, the Nissan Infiniti model also featured a reversing camera. In this system, coloured lines on the LCD screen - an option available in the USA from the following year - estimated the distance to objects in the image, [19].

In 2017, Subaru and Cadillac combined a reversing camera with automatic rear emergency braking.

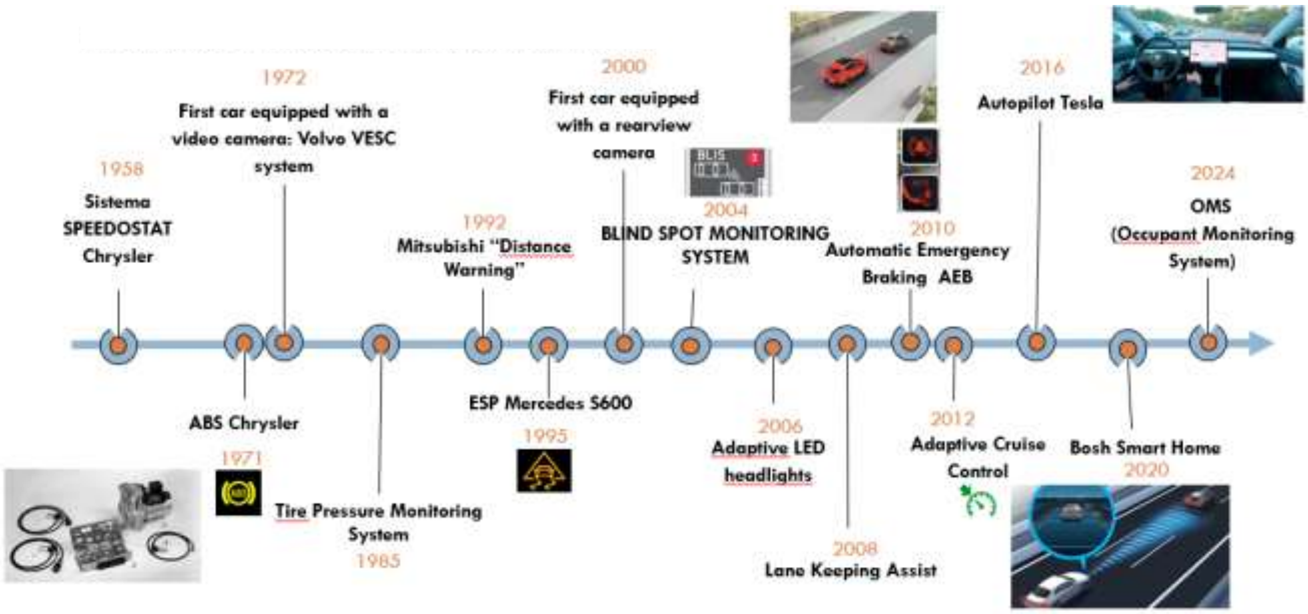


Fig. 1: Timeline: from ADAS to driving automation for road vehicles

Advanced emergency braking (AEB) can detect obstacles and brake to a complete stop to avoid or reduce the impact of a collision.

In 1992, Mitsubishi installed a laser-based system called 'Distance Warning' on its Debonair model that could warn the driver if an object was too close to the vehicle, [20]. Shortly afterwards, on the Diamante model, the same car manufacturer introduced a closed-loop system called 'Preview Distance Control'. This system acts on the accelerator to help the driver avoid collisions, thereby improving reaction time. During the 1990s, other car manufacturers became actively involved in the development of their systems. It soon became apparent that collision avoidance systems by means of frontal detection could, and should, be combined with automatic braking and cruise control systems, [17].

In 2003, Honda was the first company to propose a radar-based automatic braking system called 'Collision Mitigation Braking System', [21]. Toyota, Mercedes, and Volvo soon proposed similar developments.

The first Tire Pressure Monitoring System (TPMS), first installed on the Porsche 959, dates back to 1985, [22].

Stability control systems made their appearance in the early 1990s: Bosch introduced such a system in 1995 on the Mercedes-Benz S600 coupé, [23]. Stability control is also integrated with the ABS and traction control systems, adding additional sensors to understand how the vehicle responds to driver-led actions (via the accelerator and steering), [11]. Stability control became standard equipment in the US in 2012. Referring back to the early 2000s, Volvo introduced what it called a Blind Spot Information System for Blind Spot Monitoring (BSM) in 2003, [24].

This system warns the driver whenever a vehicle is in his or her blind spot, right or left, and provides an additional audible warning if the direction indicator is on in that situation. Warnings are displayed in the side mirrors or windscreen frame.

Amongst ADAS equipped on SAE Level 0 vehicles, there are several collision warning systems, each of which has a different field of vision and range. Forward Collision Warning (FCW) warns the driver of the presence of obstacles ahead of the vehicle, at relatively long distances, so that the driver can react with a wide margin to obstacles ahead when driving at relatively high speeds, such as on motorways. Cross Traffic Alert (CTA), on the other hand, detects vehicles closer and at a greater lateral distance than FCW. Because of this shorter longitudinal range, CTA works at low speeds, such as when exiting a car park or approaching an intersection with poor vision. The wider range allows it to detect traffic that is crossing with the vehicle. Park Assist sensors often have an even smaller range and are therefore only effective in avoiding collisions with stationary objects.

In addition to the collision avoidance related ADAS, there are also others related to speed regulation. Curve Speed Warning (CSW) systems, for example, warn the driver about unsafe speeds during curves. The more elaborate Intelligent Speed Adaptation (ISA) function compares current driving speed to one of three types of speed limit, [25], 1) fixed speed limits, i.e. posted speed limit at a location; 2) dynamic speed limits, which additionally take account of the actual road and traffic conditions (weather, traffic density); and 3) variable speed limits, which additionally take account of special locations such as road construction sites, pedestrian crossings and sharp curves. In case of speeding, the ISA system can warn the driver (e.g. with audio visual signals), assist the driver (e.g. with a haptic throttle, which provides resistance above the speed limit), or even restrict the driver from going faster (e.g. the dead throttle, which makes it impossible to go faster than the local speed limit), [26]. ISA can further be categorized by whether it can be switched off by the driver (overridable vs. non-overridable). The EU will make the overridable ISA with acoustic warnings or with assistance mandatory by 2022 for all new car models.

Finally, there are also ADAS related to lane departure which help the driver stay within lane boundaries. Lane Departure Warning (LDW) systems provide a warning when the vehicle is about to veer out of a lane. Lane Keeping Assist (LKA) also actively steers to keep the vehicle within lane boundaries.

The systems just described represent only a part of the multiplicity of SAE Level 0 systems.

SAE Level 1 can provide continuous steering or brake/acceleration support in specific circumstances. Systems equipped on this kind of vehicle are generally the Adaptive Cruise Control (ACC) for longitudinal control and the Lane Centring (LC) for lateral control, [27]. Adaptive Cruise Control (ACC) automatically regulates the vehicle's velocity to maintain a secure distance from the preceding vehicle and adhere to the predetermined velocity. If braking is required, the ACC can typically produce up to 30% of the automobile's maximum deceleration. If a more substantial reduction in speed is necessary, the driver will receive an audible signal. Regular ACC can generally be activated at speeds of 30 km/h or higher. Some ACCs have a stop-and-go feature, which enables the ACC to bring the vehicle to a complete halt, allowing it to be used in traffic congestion.

Adaptive cruise control made its debut in the mid-1990s thanks to Mitsubishi, which introduced a system designed to slow the car down by downshifting the gears of the automatic transmission, but it was Mercedes that brought it to the market a few years later: the S-Class luxury sedan brought adaptive cruise control very similar to today's systems. A more recent development is the computerized binocular vision system, first introduced to the market in 2012 by Subaru.

A novel ACC functionality is Predictive Speed Control, which integrates the ACC with the navigation system and other sensors, enabling it to adjust the vehicle's speed to the current speed limits and reduce velocity before curves, intersections, and roundabouts. ACCs that have this feature are also referred to as predictive ACCs.

The Lane Centering (LC) function automatically directs the vehicle to maintain its position in the centre of the lane. This varies from Lane Keeping Assist (LKA), which only delivers minor steering inputs when the automobile is already drifting and about to cross lane boundaries. At lower speeds, the LC feature often utilises the vehicle ahead to maintain the centre of the lane, while at higher speeds, lane boundaries are employed. These systems usually provide minor steering input and always require the driver to maintain their hands on the steering wheel.

An early example was provided by Toyota in 2002, while the actual system was installed by Audi in 2008.

In SAE Level 2 the driver must still keep his hands on the steering wheel, but in addition to the previous level, systems on board these vehicles can combine lateral and longitudinal control under specific circumstances, [27]. Thus, the system executes longitudinal (accelerating, braking) and lateral (steering) dynamic driving tasks when activated and can deactivate immediately upon request for immediate takeover by the human driver, [28].

Generally, this means a combination of Adaptive Cruise Control (ACC) and Lane Centring (LC). Car manufacturers often offer stop and go ACC with LC and Blind Spot Monitoring as one system package. An example of a feature that is generally only offered in combination with a Level 2 type system is Lane Change Assist, which can automatically perform a lane change maneuver after the driver has initiated or approved the lane change. Newer Level 2 systems also sometimes offer Route Navigation, where the vehicle can perform highway driving from the entrance ramp to the exit ramp by following the navigation route. While these systems appear to take over the driving task completely, the driver is still obliged to monitor the driving situation and, in the EU, [29], keep their hands on the steering wheel.

With the subsequent SAE levels, the driving functions are no longer attributable to ADAS alone, as from SAE Level 3 onwards the role of the human driver becomes increasingly marginal, as it is artificial intelligence that takes over, understands the environment, and makes the car move until it is eliminated with the last SAE Level. Specifically, while Level 2 systems require the driver to be attentive and to monitor the driving environment, Level 3 systems allow the driver to turn his attention away from the complete dynamic driving task (steering, accelerating/braking, OEDR) in certain domains that the system is designed to operate in, [28].

They deactivate only after requesting the driver to take over with sufficient lead time; may − under certain, limited circumstances − transition to minimal risk conditions if the human driver does not take over; and may momentarily delay deactivation when immediate human takeover could compromise safety.

Among the SAE Level 3 systems it is worth mentioning Tesla's Autopilot, which allows the vehicle to control its gait in complete autonomy, even if the driver does not keep his hands on the wheel or is distracted, keeping speed within limits, safety distances, avoiding obstacles, and even changing lanes when necessary.

In SAE Level 4, on the other hand, the "handover" between the guidance system and the driver occurs when the design conditions are no longer met and compatible. Therefore, the system must be able to transfer the vehicle to the human driver in a condition of minimum risk and within the operational design conditions.

Finally, while Level 4 systems accomplish vehicle guidance only in a specific operational design domain, e.g., during a traffic jam on a motorway, SAE Level 5 systems can accomplish the complete journey from origin to destination in a high automation modus and can do so anywhere on-road that a human can legally drive a vehicle, [28].

Apart from activating, deactivating, and setting waypoints and destinations, no human intervention is necessary for the operation of autonomous vehicles. Therefore, in an extreme scenario, traditional driver controls, such as a steering wheel, pedals, or instrument cluster, are not required.

It should be emphasized that it is not the vehicle that is classified with an SAE Level of automation but rather the driving function; in fact, during travel, there may be a combination of different levels of automation: for example, Level 3 for a highway section that then becomes Level 1 with Adaptive Cruise Control (ACC) in the final urban section.

On 14 July 2022, Europe changed the law and gave the green light for Level 3 autonomous driving cars to circulate on the road.

Although there are still some obstacles in the adoption of driverless vehicles of a technological, normative, ethical, and social nature, [30], [31], [32], [33], [34], [35], it is evident how much the automotive industry has worked over the last century to make a multitude of automated functionalities available in our vehicles, a number that is set to grow even further in the near future; for example, car manufacturers such as BMW Group and Daimler AG are planning next-generation technologies for driver assistance systems up to SAE level 4.

## 3 The Users' Propensity to Use Steering Wheel Controls: Result of a Mobility Survey

The application case study comprised is of the Naples metropolitan city and the Province of Caserta (south of Italy). The survey was carried out through a CAWI (Computer Assisted Web Interview) method randomly selecting car drivers through the main social media during the winter of 2023, through the use of an ad-hoc software developed for the scope.

The questionnaire designed consists of two sub-sections:

1. socio-economic background (e.g., age, gender, occupation) and mobility habits (trip frequency, average travel time);
2. on-board presence of steering wheel controls with the aim of:
    - investigate the level of usage of the driver assistance systems by type (i.e., steering wheel controls to listen to music vs. to answer calls);
    - investigate the users' opinion about the role of the steering wheel controls in improving road safety, also mitigating driving stress (improving the travel experience).

The questionnaire responses were analyzed through qualitative analysis.

Overall, 307 car drivers were interviewed, and Table **1** reports the main survey results: 63% of the sample was male; 66% were 18-40 years old; 68% were employed.

Table 1. Survey results: socio-economic characteristics

| | *number* | *%* |
|---|---|---|
| **Gender** | | |
| male | 192 | 62.54% |
| female | 115 | 37.46% |
| **Age** | | |
| 18-30 | 110 | 35.83% |
| 30-40 | 94 | 30.62% |
| 40-50 | 53 | 17.26% |
| Over 50 | 50 | 16.29% |
| **Profession** | | |
| Employed | 221 | 68.40% |
| Not employed | 14 | 6.19% |
| Student | 72 | 25.41% |
| **Total sample size** | **307** | **100.00%** |

Results in the presence of steering wheel controls onboard the cars are reported in Fig. **2**. 60% of the respondents currently have steering wheel controls onboard their car to listen to music and/or answer calls. In addition, among those who do not have them, 89% of the respondents believed they would like to have them in their next car.

Figure 3 reports the results in terms of both the level of usage of these driver assistance systems and users' perception of their impact on road safety and driving stress. In particular, the results were reported separately for the type (steering wheel controls to listen to music vs to answer calls). About 60% of the respondents frequently (high) use steering wheel controls to answer calls and more than 80% of the drivers stated that these devices significantly improve both road safety and driving stress. Instead, about the steering wheel controls to listen to music, more than 68% of the respondents use them frequently (high) and about 74% of the drivers stated that these devices significantly reduce driving stress and increase road safety. Interestingly is to observe that no differences in frequency of usage have been found between steering wheel controls to answer calls and to listen to music. In terms of users' opinion, a significant difference was observed between steering wheel controls to answer calls and steering wheel controls to listen to music; specifically, the former is considered safer and better at reducing stress than the latter (about 8 percentage points more).

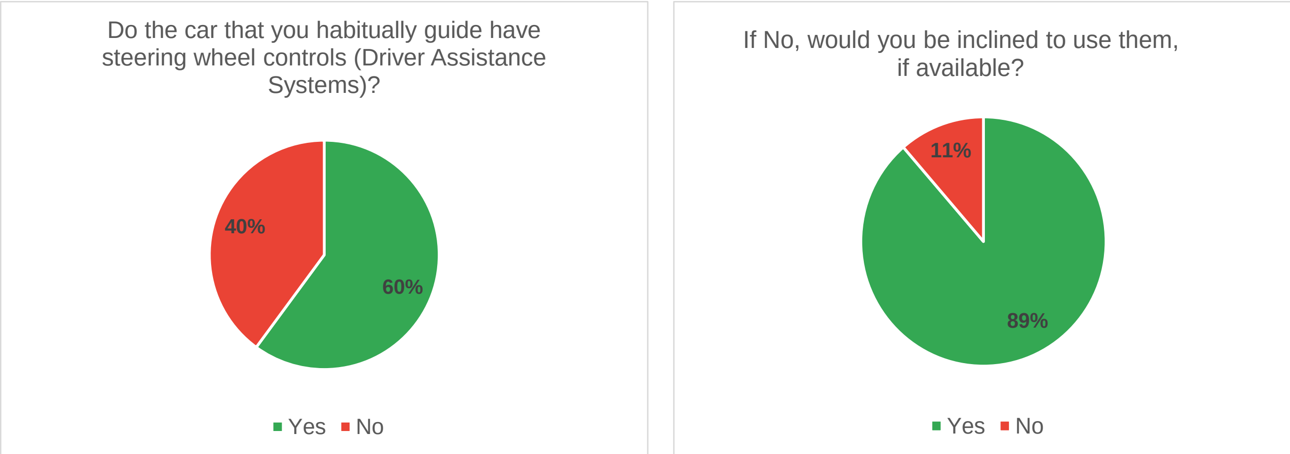


Fig. 2: Survey results: presence of steering wheel controls on board the vehicles

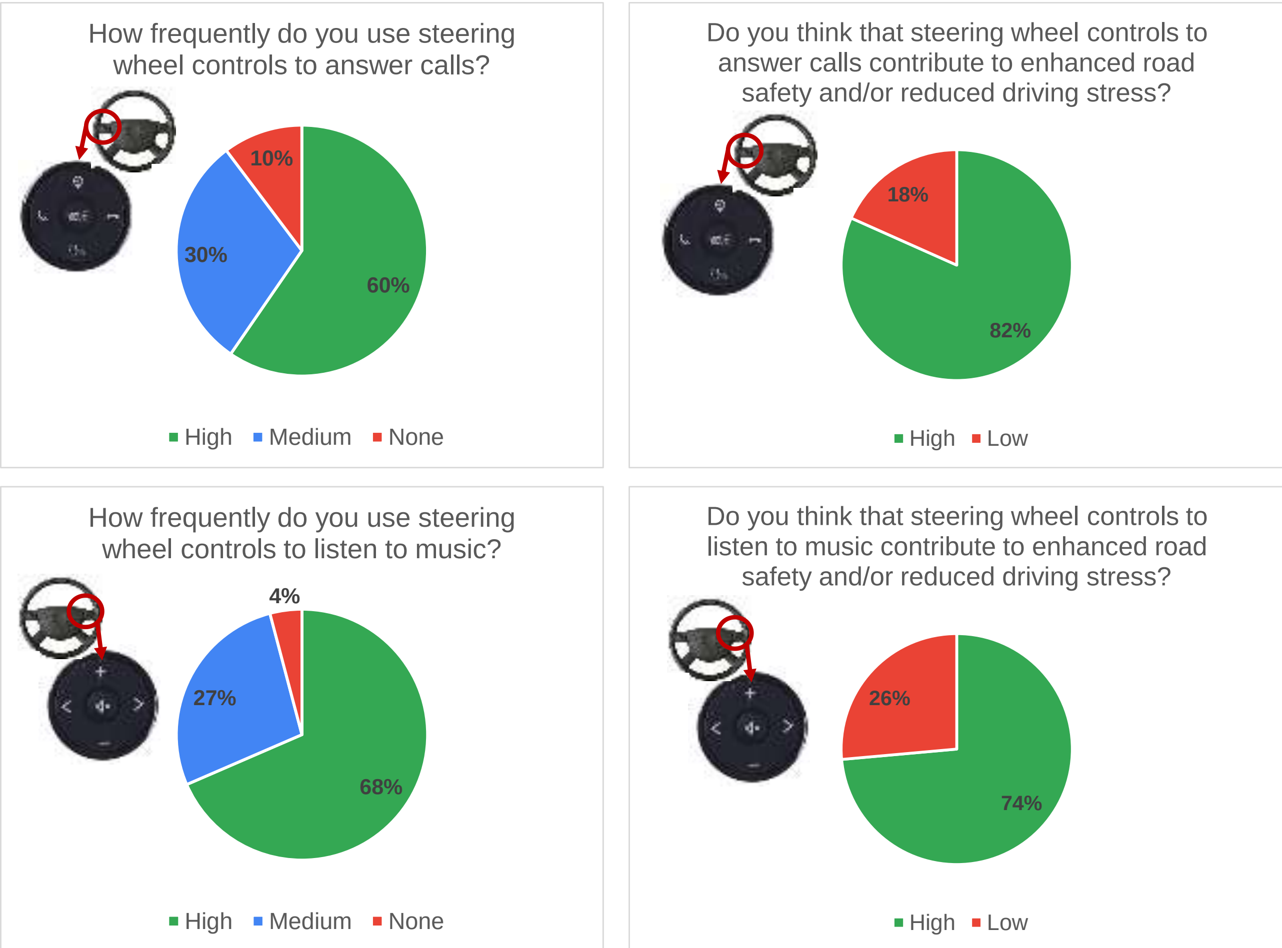


Fig. 3: Survey results: frequency of usage and users' opinion about the role of the steering wheel controls (Driver Assistance Systems) in improving road safety, also mitigating the driving stress (improve the travel experience).

# 4 Conclusion

The safety and comfort of passengers have been the major driving forces for developing advanced driver assistance systems (ADAS), [36], [37], [38]. Today, ADAS has become a salient feature for safety in modern vehicles and from 2024 some of them will become mandatory on new cars. In addition to improving the safety of current vehicles, these systems represent, together with artificial intelligence, the right direction toward self-driving vehicles, [39], [40]. Indeed, the way to autonomous driving is closely connected to the capability of verifying and validating Advanced Driver Assistance Systems (ADAS), as it is one of the main challenges to achieve secure, reliable, and thereby socially accepted self-driving cars, [41]. Pushing towards the autonomous is fundamental for future mobility. Indeed, autonomous vehicles have the potential to reduce road accidents, alleviate traffic congestion, abate pollutant emissions, reduce fuel consumption, [42], [43], [44], potentially decrease land use, and profoundly modify the scope and boundaries of mobility services, [45], [46]. Furthermore, autonomous mobility, together with e-mobility, [47], [48], [49], [50] and smart roads, [51], [52], [53], can significantly contribute to the sustainable mobility and the decarbonization of the transport sector. The field of ADAS has matured towards more and more complex assistance functions, applied with a wider scope and a strongly increasing number of possible users due to the wider market penetration.

Starting from these considerations, the paper investigated the evolution of these systems over time and the users' propensity to use steering wheel controls. Estimation results show that 60% of the respondents currently have the steering wheel controls on board their car to listen to music and/or answer calls.

Of those who have these devices, about 60% (68%) of the respondents frequently (high) use steering wheel controls to answer calls (to listen to music). 82% (74%) of the drivers stated that these devices to answer calls (to listen to music) significantly improve both road safety and driving stress, (improve the overall travel experience). Furthermore, it is interesting to observe that steering wheel controls to answer calls are perceived as more useful than those to listen to music (about 8 percentage points more). Finally, among those who do not have steering wheel controls, 89% of the respondents believed they would like to have them in their next car.

These results underline the relevant effort that the automotive industry has performed in the last decades to integrate advanced functionalities onboard the vehicles. Future research will follow the evolution of possible market penetration scenarios through, for example, cost-benefit or multi-criteria analysis, [54], [55], also within rational transportation planning decision-making processes, [56], [57].

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