TRUSTONOMY

Building Acceptance and Trust in Autonomous Mobility

Position Paper
Driver training challenges for automated vehicles
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Trustonomy project

Trustonomy (*trust+autonomy*) was a project connecting stakeholders from different automotive industry, research, and transport areas. The consortium was composed of sixteen organizations from nine countries of Northern, Central, and Southern Europe. The vision of the project was to raise the safety, trust, and acceptance of automated vehicles by helping to address the technical and non-technical challenges through a well-integrated and inter-disciplinary approach. *Trustonomy* compared different technologies and approaches in terms of performance, ethics, and acceptability in different scenarios for automatic driving and requests to take control (*RtI – Request to Intervene*). It covered various types of users (diverse in terms of age, gender, and experience), means of transport (cars, trucks, buses), automation levels (L2-L4), and driving conditions. The project investigated the domains of: Driver State Monitoring (DMS), Human–Machine Interfaces (HMI), driver training, risk assessment, early warning, trajectory planning, Driver Intervention Performance Assessment (DIPA), driver's trust and acceptance. The main objectives were:

- to develop a methodological framework for the operational assessment of different Driver State Monitoring systems (evaluating the driver's ability to intervene);
- to develop a methodological framework for the operational assessment of various HMI designs;
- to develop an ethical automated-decision-support framework, covering liability concerns and risk assessment;
- to develop novel driver training curricula for human drivers of Automated Driving Systems (ADS);
- to define a Driver Intervention Performance Assessment framework;
- to measure the performance, trust, and acceptance of human drivers of ADS (through simulations and field trials);
- to organise communication and exploitation actions, policy recommendations, and contributions to standards.

As autonomous vehicles will become a reality in a few years, *Trustonomy* investigates various technologies, risk, training, and trust in automation from a legal and ethical perspective. The project represents a human-centred approach, as the human factor will remain essential for safety and performance due to the necessity of driver-vehicle interaction when ADS reaches its boundaries and because of the co-existence of autonomous and non-autonomous vehicles.

The development of Trustonomy complies with the reference standards and methodologies for project coordination and management in order to ensure state-of-the-art results for technical deliverables (reports, prototypes) and communication activities (dissemination, cross-fertilisation, exploitation).

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1 Introduction

1.1 European Driving Schools Association (EFA)

Since 1982 EFA, the European Federation of Driving Schools (https://www.efa-eu.com/), has represented 24 national driving schools' associations, as well as 10 international nongovernmental organizations specializing in the field of road safety. It currently represents around 120,000 companies with around 220,000 driving instructors. Every year EFA offers training and consultancy services to tens of millions of European citizens.

EFA has, engaged in campaigns to reduce deaths on the roads launched by the European Commission and the United Nations. EFA offers quality training models for driving schools, aimed at both drivers (of any age) and driving instructors.

For decades, EFA has been implementing projects related to road safety as well as publications, videos including:

- Hermes project: The HERMES project began in March 2007 and was finish in February 2010. Its main aim was to create a 4 days training course for driving instructors to allow them to develop their 'coaching' skills. In addition, a number of coaching scenarios have been developed to enable instructors to coach in on-road training, track training and the classroom, and to meet a wide range of goals in the driver education process;
- The ECOWILL project was launched in May 2010 and ended in April 2013. Its aim was to reduce carbon emissions by up to 8 Mt until 2015 by boosting the application of eco-driving all over Europe. To reach this ambitious target the project rolled out short duration eco-driving training programs for licensed drivers in 13 EU countries and at the same time promoted the education of learner drivers in eco-driving.
  The main objectives of the project therefore were: Integration of eco-driving in driving school curricula and driving tests; Establishment of minimum standards for contents and set up of eco-driving trainings and train-the-trainer seminars; Establishment of an eco-driving infrastructure which will keep the approach alive after the end of the project; Roll-out of (short-term) eco-driving trainings for licensed drivers;
- Safe2Wheelers project: In the period 2000-2012, the riders killed per 10,000 Powered Two Wheelers (PTW) registered has more than halved, passing from 2.68 to 1.32. Nevertheless, PTW riders are still among the most vulnerable road users and other efforts are necessary toward a vision zero accident concept. On the other end, the use of PTW is currently increasing worldwide, especially in urban environments, since PTW offer many benefits for personal mobility: less congestion, time gain, energy savings, easier parking. As prior initiatives to improve PTW safety have concentrated on single aspects, a truly holistic and integrated approach towards PTW safety is still lacking. This COST Action addresses this gap, by bringing together PTW safety experts to i) acquire, unify and coordinate PTW safety research, and ii) ensure broad dissemination towards PTW users, industry and public authorities;
- Simusafe project: Road transport is known to be the most dangerous of all transport modes and poses a major societal challenge for the EU. According to the European Commission (ec.europa.eu), road crashes cause almost 30,000 fatalities and more than 100,000 serious injuries a year in the EU. In 2015, there were more than 26,000 road fatalities in the EU. It has been claimed that 90% of road-traffic crashes are caused by driver error with risky behaviour being a significant factor in traffic collisions. Improving road safety means understanding the individual and collective behaviour of all the actors involved (drivers, two-wheelers, pedestrians) and the interactions between themselves, the transport-related systems, and the infrastructure. In order to build more realistic driving simulators and simulation models, SIMUSAFE collected and integrated multiple sources of road user data in three research cycles;
- FitDrive project: FitDrive means improving the European mobility, by reinforcing safety, competitiveness and performance of European transport processes, through innovative ICT solutions for enhanced security and robustness of the transport operations. FitDrive rises with the goal of improving the current transport system, increasing its robustness and support safety, security and quality of life through the monitoring of driver's performance and the enhancement of roadside controls, while relying on behavioural research

and forward-looking activities for policy making and training. The FitDrive project will design, implement and test new toolkits and methodologies for monitoring and evaluating driving performance, cognitive load, physical or mental fatigue, reaction time, while providing information to drivers, intelligent road systems and police roadside controls.

1.2 Motor Transport Institute (ITS)

The Motor Transport Institute (ITS; Pol. *Instytut Transportu Samochodowego*) conducts, coordinates, and promotes scientific, research, and implementation activities in the field of transport. The Transport Telematics Centre (CTT) of the ITS conducts research on driving automation systems (including the verification of the effectiveness of perception systems) and research on road infrastructure in connection with the implementation of AVs on Polish roads (signage, V2I). CTT employees conduct promotional activities to raise the awareness and acceptance of autonomous mobility. CTT conducts research on driver behaviour and traffic psychology, training programs, and social campaigns on transport psychology. In 2021, the Autonomous and Connected Vehicles Competence Centre (CK:PAP, pol. *Centrum Kompetencji Pojazdów Autonomicznych i Połączonych*) was established in ITS as the Institute’s internal expert unit that supports the work of the Polish government, particularly the Ministry of Infrastructure, in the field of automated mobility. CK:PAP centralises the competences and implementation processes in the country, ensuring compliance with EU regulations, thus increasing the competitiveness of domestic economy, particularly in the automotive industry and innovation. For years, ITS has been implementing projects related to the safety of road users as well as scientific and research initiatives, including:

- TRUSTONOMY: Building Acceptance and Trust in Autonomous Mobility (EU; H2020; 2019-2022; EUR 9 million). The project aims to develop methods for the assessment of automated vehicle components and guidelines to increase the level of safety, trust, and acceptance of these vehicles. ITS conducts research on driver state monitoring, HMI, driver training (pillar leader), evaluation of driver interventions, user trust, and user acceptance. ITS is the leader of the research phase and acts as an Innovation Manager.
- AV-PL-ROAD: Polish road to transport automation (NCBR; GOSPOSTRATEG, 2018-2022; PLN 8.2 million). The project aimed to develop guidelines for legal regulations introducing autonomous vehicles on Polish roads. Based on analyses and the results of field research, together with other partners, ITS (task leader and financial leader) developed recommendations for authorities, institutions, and road managers. As part of the project, the CK:PAP was established within the structures of ITS.
- RID4D: The impact of using Intelligent Transport Systems services on the level of road safety (NCBR and GDDKiA; RID; 2016-2018; PLN 2.1 million). The project focused on assessing the impact of Intelligent Transport Systems on road safety, particularly in the context of the implementation of the National Traffic Management System. For this purpose, the Institute (the leader of the consortium) conducted simulation studies, which resulted in the development of multi-criteria methods for assessing the impact of Intelligent Transport Systems on traffic safety and efficiency.
- aDrive: Innovative simulation technologies for the evaluation of driving automation systems in terms of road safety (NCBR;2015-2017; PLN 2.6 million). The project aimed to develop a technology for evaluating automation and vehicle driving support systems in simulated conditions. As a result of the project, solutions were created for the automotive industry sector that contributed to the provision of new research services for driving assistance and autonomous systems. The project was carried out by a scientific and industrial consortium consisting of ITS, the Warsaw University of Technology, and the SEARCH S.C. – Safety Engineering Research company.

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1.3 Document overview and structure

The document has been developed by the Motor Transport Institute (ITS; driver training pillar leader in the Trustonomy project) with the support of the European Driving Schools Association (EFA). It consists of three chapters.

The first one introduces ITS and EFA, describing their expertise and goals.

The second chapter discusses new driver training challenges and needs related to advanced safety automation systems. The document gives an insight into the impact of ADAS/ADS on road safety, the current level of knowledge, and the expectations of vehicle users. For this purpose, the authors used the results of the work carried out at the Motor Transport Institute under the Trustonomy and AV-PL-ROAD projects.

The third section concludes the document.

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2 Emerging driver training needs

EU fatality data shows that, despite changes in traffic regulations and stricter safety requirements, vehicle users need an additional stimulus to accelerate mortality decrease. A wide range of EU road traffic regulations are strongly associated with Connected and Automated Vehicles (CAVs), which are seen as a solution for better safety in traffic. The vast technological changes have to be accompanied by proper educational support suited to different types of users and technological solutions. Current driving courses are still far behind the technological facilities that are already well known and widely available on the market. Newly developed automated driving systems (L2-L3 according to SAE J3016, in the current state of the market) are not properly presented to potential customers and to the general public, the capabilities promised being far beyond the objective limitations of these systems [1].

These circumstances are accompanied by the general lack of training courses regarding new on-board systems, and the relatively high cost of the ones that are available. Drivers' knowledge about the systems comes mainly from promotional and instructional videos, which do not provide a proper level of involvement and do not verify the acquired knowledge and skills.

The following subsection highlights the need for preparing tailor-made ADS training and describes the useful guidelines to be followed during the development of a driver training course.

2.1 Road safety: The implementation of CAVs in Europe

Autonomous vehicles are seen as a way to reduce motor vehicle crashes through the elimination of the human error factor. In 2010, the European Union set a target of reducing mortality by 50% in a decade. By 2018, EU members achieved a 20.7% reduction. Meeting the target required a similar percentage reduction between 2019 and 2020, which was not achieved. In May 2018 the European Commission adopted a new Strategic Action Plan for Road Safety, setting a new target for the 2020-2030 period [2]. The action plan proposes further policy changes, new vehicle safety standards, and a strategy for automated driving.

In 2019, the European Parliament announced that 46% of road fatalities were caused by passenger cars. More than three quarters (76%) of road deaths were men and 24% were women. Compulsory safety technologies could help save more than 25,000 lives and avoid at least 140,000 serious injuries by 2038, given that human error is involved in about 95% of all road traffic accidents [3].

To reduce the human error factor, the European Parliament adopted new measures to improve road safety. The technological changes provided for comprise a number of updated mandatory minimum safety requirements for new vehicles. With the new regulations that came into force in 2022, all new models have to be equipped with safety features such as Automated Emergency Braking (AEB) and overridable Intelligent Speed Assistance (ISA). This will be a standard for all existing models sold in the EU by 2024. Moreover, as of 2028, new heavy goods vehicles will have to comply with direct vision requirements [4].

The initiative that has an important influence on vehicle designs and the fitment of safety equipment is the New Car Assessment Programme (NCAP). The main goal of NCAP is to promote automated driving technologies and to raise the awareness of their safety benefits and, most importantly, of their limitations. The European New Car Assessment Programme (Euro NCAP) provides consumers with a safety performance assessment of some of the most popular cars sold in Europe. Based on Euro NCAP's existing active safety testing protocols, extended test scenarios were developed that cover the Operational Design Domain of the currently available SAE Level 2 systems. NCAP conducted consumer tests of driving assistance systems before General Safety Regulations were introduced. The tests it performs cover not only the mandatory systems but also those most commonly found in new vehicles.

The systems that are subject to evaluation include:

- Speed Assistance (ACC, speed limiter);
- Occupant Status Monitoring;
- Lane Support (LDW, LKA);

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- AEB Car-to-Car (Autonomous Emergency Braking, Front Assist).

For the purpose of evaluating these systems, since 2020, NCAP has developed dedicated test protocols and assessments broken down into three main areas, based on a balance between driver involvement on the one hand and vehicle assistance and safety support on the other.

Euro NCAP tests system functionality and/or performance during normal driving and in typical accident scenarios. In the course of assessment, the Safety Assist score is determined [5].

2.2 Automation vs. driver skills

It is estimated that, by 2025, L2/L2+ vehicles will account for over 30% and L3 vehicles for up to 15% of all vehicles on the market. However, the current training system does not include their proper usage.

Driver training aims to ensure that drivers are aware of road safety. However, due to the lack of guidelines for the provision of information and teaching on ADS, this subject remains unfamiliar to trainees. While developing novel curricula, Trustonomy focused on the currently most common autonomous safety features, such as Adaptive Cruise Control (ACC), Lane Keeping Assistant (LKA), Emergency Brake (AEB), and other L1-L3 systems that are currently popular in vehicles. The project focused on people who already poses a driving licence and require supplemental training regarding automation features in their vehicles. This type of training should familiarize drivers with vehicle safety features and make sure they do not excessively depend on the systems. It should also be mentioned that automakers name their features differently and that systems functionalities may differ across manufacturers. The outcomes of the project may be interesting for the EU (possible changes in current training requirements), automakers (standardization of driver assistance systems), insurers, consumers, and driving schools.

Driving is commonly considered as a multifactorial process and requires the engagement of significant cognitive resources. The task of driving a vehicle necessitates continuous road monitoring and surroundings analysis; it also requires making quick decisions to maintain safety [6]. Driving involves three levels of control [7]:

- operational – refers to driver's response to traffic conditions with limited decision information, such as reaction steering and braking due to sudden changes; control at this level makes use of sensorimotor abilities and occurs in short time intervals;
- tactic – requires manoeuvring the vehicle in response to normal road conditions, e.g. at junctions; this type of control occurs over several seconds;
- strategic – refers to route planning, including route and destination selection; strategic control occurs at intervals of minutes to hours.

It is assumed that during the periods of automated driving the driver will become no more than a passenger. The driver's role during autonomous mode will be out-of-the-loop, and he/she may not have enough information to maintain control on operational and tactic levels of driving or may be influenced by distraction and fatigue.

The development of technology and progress through successive levels of car autonomy are hoped to lead to the elimination of accidents resulting from human error. Before this happens, however, a difficult transitional period is ahead of us. During that time, drivers with different experience behind the wheel will be present on the roads, and – more importantly – vehicles with different car autonomy levels will also appear.

Over the recent years, many new systems have been developed. This situation will change the human role from that of a driver to that of a supervisor. Nowadays, the driver has less and less impact on driving; however, in situations extremely unrecognizable to the system the driver should react immediately. The third level of automation defines the use of the first ADS systems. At this level, the vehicle can perform manoeuvres independently of the driver in specified conditions. At further levels of autonomy, the capabilities of the ADS system are expanded and allow it to take more control over the vehicle.

At present, the theoretical and practical examinations, which are the basis for verifying drivers' skills, do not touch upon the subject of autonomous systems. The scope of the examination is defined by a decree that describes

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the minimum requirements for driving tests. In the theoretical part, the candidates should demonstrate their knowledge of the following subjects [8]:

- traffic regulations: signs, speed limits, etc.;
- the driver: the importance of taking special care, assessing the situation, and making decisions; awareness of response times and changes in driving behaviour due to alcohol, drugs, medicines, or fatigue;
- the road: key principles for safe distance between vehicles, risk factors associated with different road conditions;
- other road users: risk factors related to the presence of other road users;
- general rules and regulations: rules on administrative documents, behaviour in the event of accidents;
- mechanical aspects related to road safety: applicants must detect the most common defects, particularly in the steering, suspension, and braking systems, tyres, lights and indicators, headlights, rear-view mirrors, windscreen and windscreen wipers, the exhaust system, safety belts, and audible warning signals;
- safety equipment, particularly the use of safety belts, head rests, and child seats;
- environmental rules concerning the use of vehicles (appropriate use of audible warning signals, moderate fuel consumption, reduction of harmful emissions, etc.).

The elements required in the theoretical test do not include the subject of autonomous systems. The same goes for the practical test, where the subject matter covers the preparation and technical inspection of the vehicle for road safety purposes and where applicants must demonstrate their ability to prepare for safe driving.

The challenges for driver training stem from the fast changing technology and from the differences between vehicle brands. For example, electric and traditionally powered vehicles need different maintenance and driving skills. A training institution cannot possibly have all types of vehicles available for driver training. This means that a large part of training must be provided at workplaces and by manufactures. For providers to adjust driver training curricula to the changing technologies, the main challenges must be defined:

- supplementing training with issues related to new automation systems;
- supplementing training with issues related to the compulsory systems installed in vehicles;
- introducing changes in the scope of training;
- increasing the duration of theoretical training;
- introducing new materials containing all of the new topics;
- changing the entry requirements for students;
- higher requirements for instructors;
- higher requirements for examiners;
- introducing changes in the theoretical and practical exams;
- increasing the number of training hours in real traffic;
- introducing practice in test tracks or simulators.

The advanced AV technologies that will be implemented in the coming years will necessitate the driver to have a new set of skills, different than the one required in the past. Driving autonomous vehicles will no longer require manual driving and manoeuvring skills, but it will involve more driver oversight and selective intervention. It is possible to distinguish three types of skills that are necessary to act as an autonomous vehicle supervisor, especially for SAE L2 and L3 automation: information exchange, awareness, and supporting a vehicle in working on a joint task [9]. Modern drivers will have to adapt to different levels of automation and understand the division of tasks between automation and manual control at each level. Therefore, all drivers using automation levels from 1 to 3 should be required to be familiar with the electronic AV functions available in their vehicles.

Overall, when driving a highly automated vehicle, drivers will need to maintain a constant level of awareness of the functions and operation of the autonomous system and the environment while performing other, non-driving-related tasks of varying degrees of difficulty and equally cognitively absorbing. In addition, attention should be paid to the fact that drivers will also need to be aware of when they can safely perform secondary tasks. For example, in the case of Level 3 automated vehicles the driver is not required to monitor the road continuously but must be

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ready to take control of the vehicle when requested by the system. Therefore, drivers of AVs should be required to master the technique of transition from full automation to manual steering and to understand the differences between the respective levels of automation.

As reported by NHTSA, in 2020 in U.S. there were 2,880 fatal crashes that involved distraction (8% of 35,766 fatal crashes). These crashes involved 2,968 distracted drivers, since some crashes involved multiple distracted drivers [10]. Therefore, the driver's supervisory role, even if his job is only to monitor the automation and not to manually control the system, requires him or her to maintain an appropriate level of vigilance. In a critical situation, the driver should be able to identify the system failure and react to it as quickly as possible. The driver must occupy his or her position and should be able to take control of the vehicle at any time. As a result, the driver's key competencies are being quick off the mark and being highly perceptive. However, such competencies are required in both groups of drivers – those who drive vehicles equipped with ADS systems and those who drive vehicles that are not equipped with them.

In the event of an ADS breakdown, the driver should know what time is appropriate to take control of the vehicle and how much time he has to take action. This is important because the need to take over manual control usually occurs in the most dangerous situations and when drivers do not expect a transfer of control. In order to react properly in the event of a restriction or malfunction of the system, the driver must maintain a constant level of driving skills and be capable of performing all tasks that would normally be performed by an autonomous system (e.g. maintaining longitudinal control and side control) as well as emergency manoeuvres (e.g. Collision Avoidance). The use of automation systems may increase the probability of drivers losing these skills; this effect is called the automation paradox [11,12].

Research conducted as part of Trustonomy Pilot 1 showed that, on average, 35% of drivers overestimated their skills. In some cases, these differences were insignificant (1 point). However, in the case of 3 criteria the difference between the trainer's and the participant's assessment was up to 3 points on a 5-point scale. Participants tend to overestimate their self-esteem because they often do not have any benchmark to evaluate their skills against. The trainer, thanks to his or her experience, is able to objectively assess the level of drivers' skills. Incorrect skills assessment is dangerous because it results in drivers not perceiving or tending to ignore the possible risks.

Moreover, as part of the Trustonomy project, Motor Transport Institute conducted survey among regular car drivers (83 respondents), asking them about automation-focused knowledge sources. The results indicate that despite the awareness of the positive impact of ADAS on safety (80%), many people do not know how to use them properly. Only 6% of the respondents had received training in the use of driver assistance systems.

An alarming number of drivers (53%) admitted that they had learnt how to operate systems by trial and error.

This means that, <u>instead of focusing on the traffic situation, they were distracted by trying to activate the system</u>. Such cases pose an even greater risk on the road, which is in contradiction with the objectives of using ADS [13].

A large proportion of vehicle users report that they do not read manuals (according to the surveys only 27% does it). The section of the manual devoted to "driver assistance" has more than 100 in some cases, and the entire vehicle manual has 400-900 pages, which means that most users will never read the instructions, even though they should. Currently, the manual is the only source that allows the user to learn and understand the operation of the systems. It is worth verifying the quality of the information provided in the manual. Moreover, vehicle manuals are often written in an incomprehensible manner; they are too long and complex, which discourages a thorough reading of their contents. They also often contain translation errors and typos, which make it additionally difficult to assimilate the information. To what extent reading the instructions guarantees the correct use of the systems that the vehicle is equipped with is unknown. Too long instructions and the lack of reliable training materials result in a lack of reliable and up-to-date knowledge among users, which leads to very dangerous situations.

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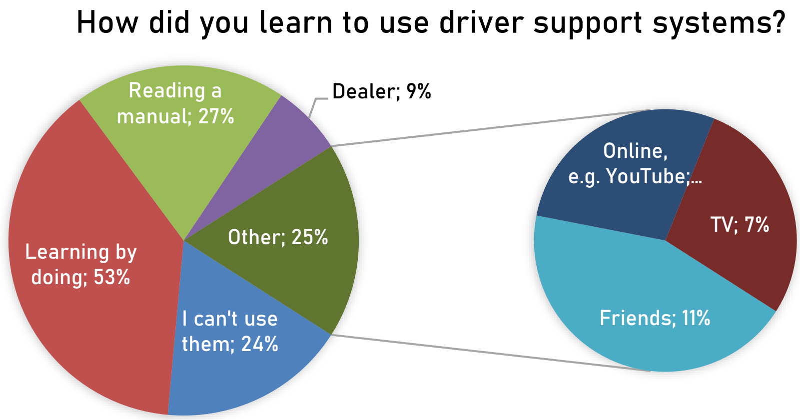

Figure 1. Ways of learning to use driver support systems [13].

Survey results show that, despite the changes in traffic regulations and stricter safety requirements for vehicles, users do not have knowledge on proper use of automation features. The current driver-training-related regulations do not result in new drivers being provided with necessary practical skills and knowledge of the recently introduced systems. Many people do not know how to use automation features properly. Even if drivers learn how to use one kind of feature, they are very often confused, as the system functions, limitations, and warnings vary depends on the manufacturer. Drivers using different vehicles expect to have the same settings and options in the features that have the same function. Lack of knowledge may lead to distrust or overuse of the systems, and incorrect use of automation systems be even more dangerous than driving without safety assistance. To achieve the main goal, which is to increase level of road safety and driving comfort, technological changes and education should run parallel.

2.3 Motivations for buying automated vehicles

In Poland, about 70% of new vehicles are purchased for business purposes. This makes the role of companies in the promotion of autonomous systems and the education of their users extremely important. Both fleet managers and dealers should be required to prepare and provide employees with key information about the vehicles and systems that these vehicles are equipped with. In order to develop training materials, as part of the Trustonomy project, Motor Transport Institute conducted a survey among vehicle users and car fleet managers. The research was carried out in cooperation with the Association of Car Fleet Managers.

Car fleet managers were asked how important driver support systems were when looking for new vehicles in the fleet.

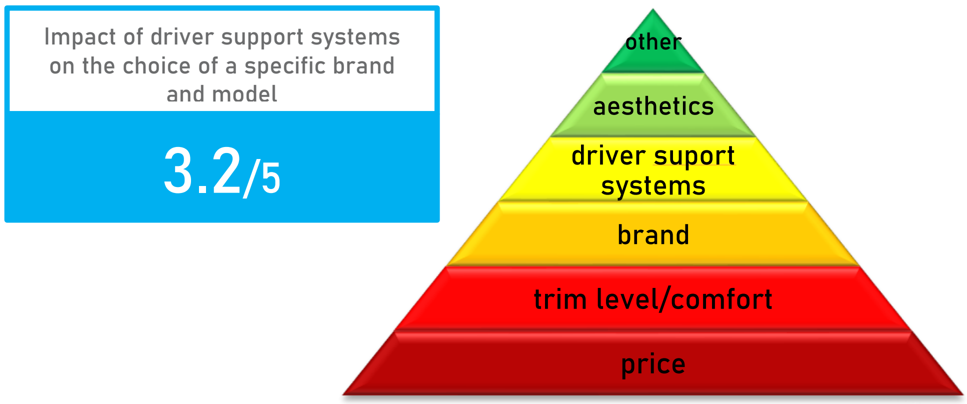

Figure 2. Impact of ADS on the choice a specific vehicle (Trustonomy project materials).

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Similar question was given also to the ordinary car drivers. They were asked about the reasons why they bought an automated vehicle or a vehicle equipped with ADAS. Thankfully, the respondents noticed the positive impact of such vehicles on driving comfort (19%), road safety (39%), and cost reduction (16%). Although, most of them admitted that they had never undertaken any training, they show big interest in taking part in a dedicated training course if one was possible [14].

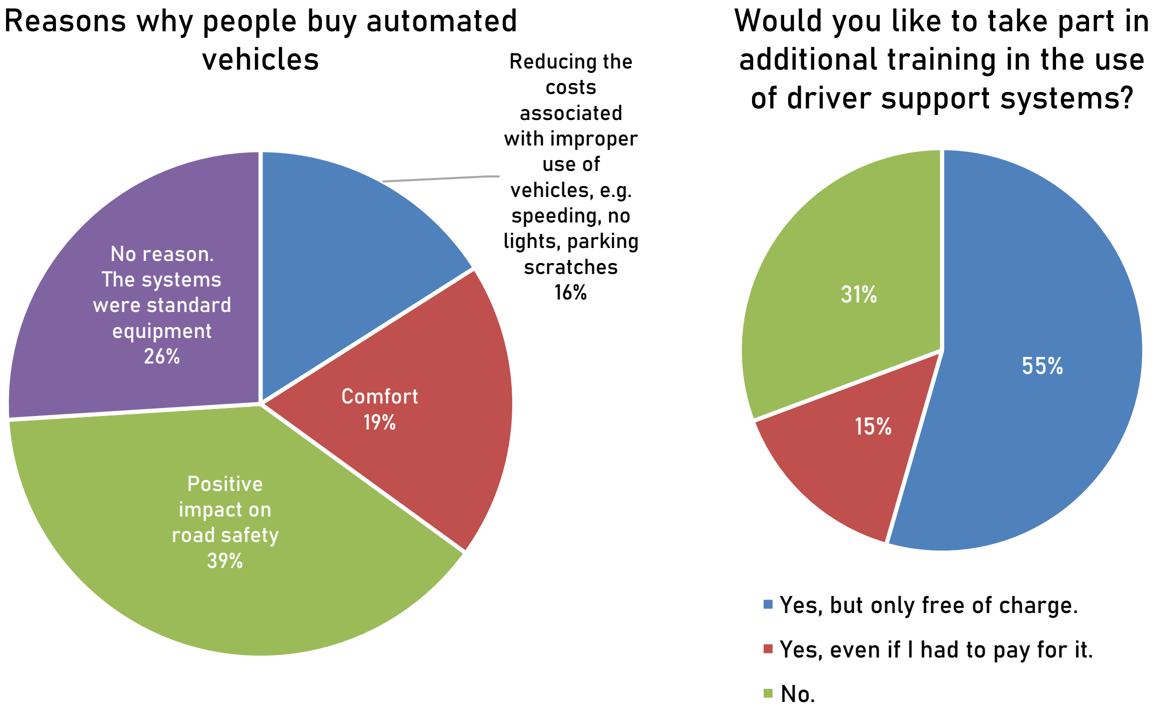

Figure 3. Reasons why people buy automated vehicles (left); Drivers' interests in ADS training (right); Trustonomy project materials.

2.4 Users' expectations regarding trainings

Users' expectations, based primarily on promotional materials, significantly diverge from the actual capabilities of the systems. Ensuring an accessible form of knowledge transfer is essential for the proper use of the systems. It will improve both road safety and the acceptance level of driving automation systems, thus supporting the implementation of these technologies in Poland. A good solution would be to introduce training for drivers and/or prospective drivers in the field of handling the solutions implemented in vehicles. Properly developed training materials, accessible knowledge, and training under the supervision of an instructor would positively influence drivers' knowledge and skills. This would allow the systems to be used consciously, thus eliminating the problem of over-trust or stress when using them for the first time.

96% of the car fleet managers admitted that driver assistance systems could increase safety. However, employees of only 20% of the companies participated in training on the use of such systems ("Yes" answer; Figure 4). Fleet managers were also asked what knowledge was passed on during the training. Most of the respondents said that drivers learnt the system operation principle and the proper understanding of system messages. Only about half of the respondents admitted that knowledge of system activation, deactivation, and limitations was provided to trainees.

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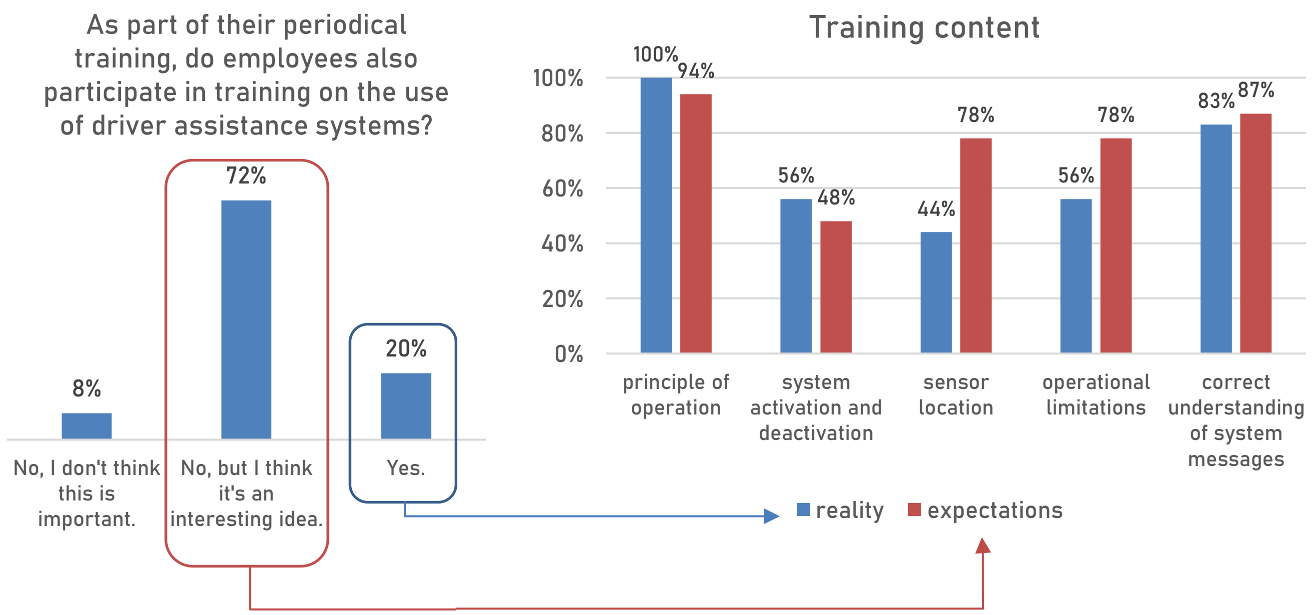

Figure 4. Car fleet managers' opinions on ADS driver training (Trustonomy project materials).

Those respondents who responded negatively to the periodical training on driver assistance system were asked what they thought about introducing this type of training and what issues should be raised during the course.

2.5 Trustonomy and AV-PL-Road findings

The lack of guidelines for the provision of information and education on ADAS systems and for the inclusion of this area in the examination makes this subject unfamiliar to trainees. This should be changed, and changing this is one of the EU recommendations in the Reducing Casualties Involving Young Drivers and Riders In Europe report [16].

Therefore, the ambition of the Driver Training pillar was to develop a course that will address automated features that are being implemented in new vehicles available on the market. Currently the European-level regulations do not specify how to familiarize drivers with automation. It is therefore not required for any country to provide drivers with information about the operation of driver assistance systems. Consequently, it is up to trainers whether or not they provide such information during the training. As a result, both novice and experienced drivers do not have the knowledge and skills necessary to maintain safe human-vehicle cooperation.

The Trustonomy project aimed at addressing different automation levels and vehicle types in designing novel curricula for different ADS usage types, including risk management at mixed traffic environments. The project focused on drivers already possessing license, that require supplemental automation-related training.

The survey results presented in the previous section were used to develop ADS-focused driver training reflecting users' actual needs and expectations. In this regard, the Consortium has developed several different courses, and tested their effectiveness:

- 1-page ADS manual was tested by the Motor Transport Institute (ITS; passenger car simulator),
- Remote semi-practical training (simulated) was tested by ITS, Solaris (buses) and ItalScania (trucks),
- Standalone practical training session was done in ITS premises and at University of Leeds (passenger car simulators),
- Mixed classroom and practical session was carried out by Skoda Auto Szkoła (SAS; real Skoda passenger vehicles),
- Mixed remote and practical training was done by Työtehoseura (TTSFI; trucks).

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Results from the questionnaire that measured participants' opinion on how training would help them understand vehicle automation and ancillary systems found in HDVs (carried out by TTSFI) showed that there was some difference between young drivers (aged 18-23) and older drivers. Older and more experienced drivers found the training materials more useful in understanding the difference in comparison to older systems used in vehicles, whereas the lack of general knowledge of vehicles in younger age groups contributed to their lower scores in this respect. All participants in this pilot believed the training to have positive impact on road safety [15].

Drivers share a need to learn more about automation in their vehicles, even at its lower levels [15].
Research showed that they are also looking for an interaction with a trainer and seeking clear guidelines:

98% of participants who underwent both theoretical and practical training (mixed classroom and practical drives, passenger vehicle) would recommend this type of training to others (88% would definitely recommend, 10% would likely do so);

83% of the respondents stated that the training they had undergone should be compulsory (yes, rather yes).

The comparison of these results with those obtained by ItalScania and Solaris, among a group of professional drivers, revealed once again that there is a lack of reliable information about automation and drivers shared a need to learn more on this topic.

Training should help drivers understand system limitations and prepare them to situations when the system reaches its boundaries. A good example of that was a bad weather situation during simulator tests in ITS, when driver was expected take control over the vehicle regardless of no request to intervene. In total 21 participants (of 81) reacted and took manual control. **Only two of those who reacted properly were asked to read a manual prior the assessment driving session**. Participants who took part in practical sessions and remote semi-practical training achieved better results (9 and 10 people, respectively).

Guiding trainees throughout the training is necessary to obtain good results. Otherwise trainees tend to become distracted and loose interest in the subject.

Trust in and reliance on an autonomous system are extremely important factors influencing the actual application and use of AVs, especially as it takes time to build them. It takes even more time to rebuild them after a failure or collision. The use of automation can lead to one of three incorrect trust levels. It can cause over-trust, when users consider the system to be fully reliable. It can result in a lack of trust, when users reject the possibility of automation and do not want to use it. It can also lead to improper trust, when users do not understand the system's operation and violate its critical assumptions. Research shows that both too much trust and lack of trust can have a negative impact on risk awareness and self-awareness when the vehicle switches from automatic to manual mode. Drivers tend to lose awareness faster when trusting the system. In addition, they accept and trust the system more when they feel that it shares their intentions. On the other hand, when drivers experience distrust in a vehicle driving in fully automatic mode, their stress increases and this may result in a higher workload for the driver. System feedback (information about what the automation is currently doing and why) helps increase trust in the system.

In Trustonomy Pilot 4 (ULEEDS), the training drivers received prior to encountering the RtI scenarios provided an ODD against which they evaluated the performance of the automation. For example, as shown in Figure 5 concerning subjective workload, those drivers who had been trained and then encountered a failure in the automation (Group 2), reported higher levels of workload as a result. On the other hand, Group 4 who had not received training did not

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report this increase in workload, and their workload was stable, presumably because their mental model of the automation was not as refined. Simple training on the capabilities and limitations of the automation is therefore an effective way of drawing attention to situations in which drivers may be required to input higher levels of cognitive or physical adaptations.

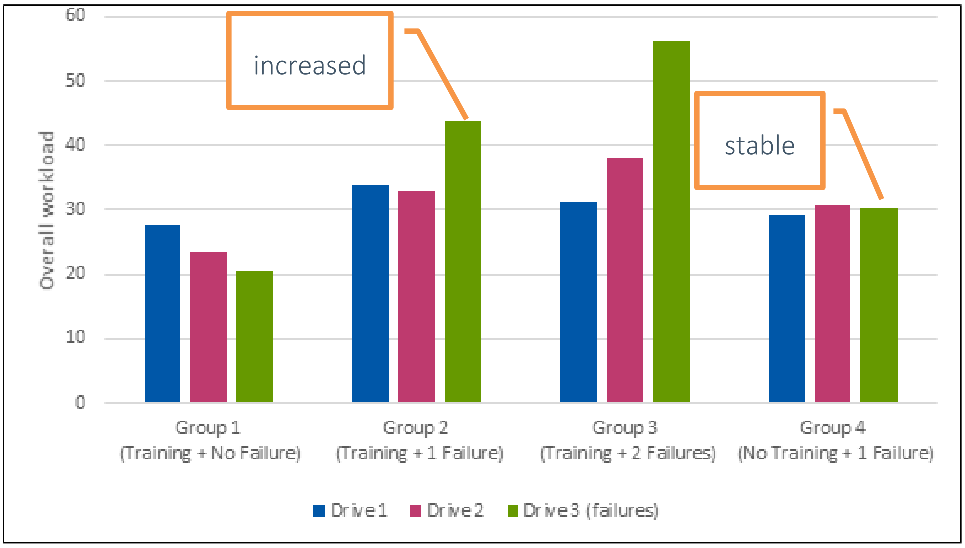

Figure 5. Overall workload by Group and Drive.

The AV-PL-Road research showed that most of the users positively perceived and understood the benefits of driver assistance systems after completing the briefing and the test drive. The level of trust was the lowest for the Blind Spot Detection system, which may have resulted from an incorrect understanding of its operation or from the fact that it was the only one among the examined systems that did not intervene but only warned the driver. Despite this, almost all participants believed that the tested systems had a positive impact on road safety. The respondents also declared their willingness to have such driver assistance systems in their own vehicles.

The tests of selected driver assistance systems revealed a certain technological immaturity and imperfections of the systems already introduced.

These solutions have a chance to improve road safety only if they are developed and properly used. Please note that these systems provide only driver assistance and, contrary to what advertisements say, do not completely replace his or her attention. This means that the human factor still remains the main factor behind road incidents. Changing this state of affairs and the safe implementation of highly automated vehicles requires building appropriate competencies, awareness, and acceptance in current and future users. For this purpose, it is necessary to conduct social campaigns, reliable advertising campaigns, and extensive driver training ensuring access to relevant knowledge [15].

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3 Conclusions

Increasing vehicle autonomy and the further development of technology are expected to reduce the number of accidents caused by human error. Before this happens, however, we must face the challenges of a difficult transition period. It will be a difficult time, as drivers with different levels of experience will be responsible for vehicles with varying levels of autonomy. At present, due to the dynamic development of autonomous systems, users do not have enough knowledge about them and do not use them, or use them by learning from their mistakes.

Due to the lack of information on systems, ongoing education of all car users is vital. It ought to be at least reflected in the driver training system – during the course participants should receive updated information about the systems that are mandatory in cars and the systems to be installed in the next 2-5 years. Today, participants in driving courses are obliged to obtain knowledge about the ABS system (anti-lock braking system), but this knowledge is still strictly theoretical. Implementing subsequent systems to achieve level 5 autonomy makes sense if vehicle users are aware of how to use them correctly and what their limitations are; then, their knowledge will be expanded gradually.

The gradually acquired knowledge on the systems and driver training will allow for a better understanding and general acceptance of the idea of autonomous cars. When starting to learn the systems from level 0, it is easier for drivers to move to subsequent systems at higher levels, which expand their scope of activity or aggregate several systems into one. It is already known that in the coming years driver assistance systems will be added to the mandatory equipment of vehicles. Under the new rules, all motor vehicles (including trucks, buses, vans, and sport utility vehicles) will have to be equipped with the following safety features:

- intelligent speed assistance,
- alcohol interlock installation facilitation,
- driver drowsiness and attention warning systems,
- advanced driver distraction warning systems,
- emergency stop signals,
- reversing detection systems,
- event data recorders,
- accurate tire pressure monitoring.

Supplementary advanced safety measures will be required for cars and vans. These include:

- advanced emergency braking systems,
- emergency lane keeping systems,
- enlarged head impact protection zones capable of mitigating injuries in collisions with vulnerable road users, such as pedestrians and cyclists.

One of the main challenges for driver training to address is distraction. Part of the research community suggests that drivers should be required to remain vigilant at all times while travelling, even if they do not have manual control of the vehicle. On the other hand, some AV manufacturers have taken the position that intervention or continuous monitoring of the road by the driver will not be required in fully autonomous vehicles at all. Human attention is a finite resource, and secondary tasks such as monitoring autonomous systems can lead to becoming distracted. More research is needed on this issue. The automotive industry and the relevant public authorities should work together to address this problem and minimize the risks arising from shared control of the vehicle.

The second challenge is to understand the possibilities and limitations of autonomous systems. As of today, there are few specific programmes or projects designed to provide drivers with knowledge and awareness of the possible effects of automation. To reduce the risk of misuse of these new technologies, it is necessary to train and inform drivers about the systems installed in their vehicles. An example of an activity that is one of the ways drivers can obtain information on CAV technology is the "My Car Does What" campaign, funded by the Toyota Safety Research and Education Settlement Programme and independently developed by the University of Iowa and the National Safety Council [17]. MyCarDoesWhat.org is an educational platform on safety features such as anti-lock braking system, blind spot monitoring, or health and load monitoring.

The development and evaluation of training programs for autonomous driving systems should be based on both practical and theoretical considerations. In practice, the criteria for selecting training programs may include compliance with training objectives, suitability, the available resources, the capabilities of training centres, and target recipients. The choice of training programs may also be related to driver factors. For example, Sable [18] ascertained that younger drivers preferred technology-based methods such as online videos or hands-on "on-the-game" training, whereas older drivers preferred the more traditional instructor-led classes. This is in line with the results obtained by Trustonomy in the P1 pilot (TTSFI). As demonstrated by the Safe-D National UTC Report [19] it is best to use different training protocols, considering the demographic differences among participants. However, it should be emphasized that **guiding trainees throughout the training is necessary to obtain good results. Otherwise trainees tend to become distracted and loose interest in the subject.**

Therefore, Trustonomy has developed an automation-oriented course accompanied by a training assessment module. The course covers different driving automation systems, different automation levels, different brands of vehicles, and different vehicle types. As intended, Trustonomy makes use of ICT-based tools, but the materials were also implemented in the form of traditional courses delivered by professional trainers. The trainings developed were warmly welcomed. The participants praised the quality and scope of the materials. Many of them pointed out the lack of similar training courses on the market, and at the same time a large number of people were interested in deepening their knowledge about automation features.

Depending on the course type, approximately 73% of the respondents believe that automation training should be mandatory for every driver (based on the results obtained in ITS at the end of the study).

Moreover, NTHSA emphasizes that training where drivers learn about an action (task) through exploration, testing generated hypotheses, and trial and error can effectively reduce overconfidence and help drivers develop strategies to deal with scenarios not covered by the training. For this reason, a well-prepared and well-composed online tool, which in fact is an interactive application involving the driver in the learning process, may be a solution for supplementary automation-related training. It may combine the advantages of training under the supervision of a trainer (thanks to the use of active tips and commands) with ease of access. It is therefore recommended that training programmes be designed and implemented using a fusion of different techniques, including the required material, and be widely available from a wide variety of stakeholders for use by drivers.

The new AV technologies will surely be a challenge for the current training systems. Regardless of who will be responsible for the training systems, be it driving schools, manufacturers, or dealers, they should ensure that drivers acquire the skills necessary to operate a particular type of automated vehicle and that they are fully aware of the capabilities and limitations of the vehicle, such as the division of roles between the human operator and automation. The training is expected to mitigate the deterioration of driving skills that the long-term impact of automation may lead to.

In the current system, training takes place mainly before obtaining a driving license, while education on autonomous solutions should also cover drivers who already have a driving license. It may be necessary to change to a system where training is seen as an ongoing or at least periodic commitment by the driver. An example of good practice would be aviation, where pilot skills are continuously monitored and periodic custom training is provided to maintain or improve the skills. In summary, the training system should include compulsory training leading to the trainee obtaining a driving license, compulsory training for professional drivers, and optional training for people who already hold a driving license. Driving techniques improvement centres, which should prepare training programs introducing the technology of autonomous cars and discussing legal issues, will play an important role here. In addition, practical classes would allow trainees to practice using driver assistance systems. During such training, attention should be paid to the knowledge of the construction of a vehicle, the operation of sensors and radars, which might not work or have limited functionality under certain conditions. After training, the driver should be aware of the system's limitations and know what to do in such situations.

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Glossary

ACC	Adaptive Cruise Control
ADS	Automated Driving System
AEB	Autonomous Emergency Braking
AV	Automated Vehicle
CAV	Connected and Automated Vehicle
DIPA	Driver Intervention Performance Assessment
DSM	Driver State Monitoring
DSMAF	Driver State Monitoring Assessment Framework
DT	Driver Training
HMI	Human–Machine Interface
LKA	Lane Keeping Assist
ODD	Operational Design Domain
RtI	Request to Intervene
SAE	Society of Automotive Engineers
ToC	Transition of Control

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