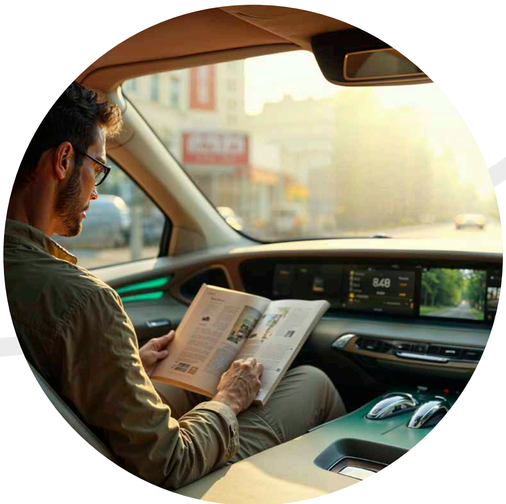
Final Report

Assessment of Advanced Driver Assistance and Dynamic Control Assistance Systems (ADAS/DCAS)



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Executive Summary

Study results in a nutshell

The potential to increase **traffic safety** can be better achieved when ADAS are developed and introduced from a human-centered perspective. User engagement, satisfaction, acceptance and trust are key factors for the usage of ADAS.

For ACC: user acceptance, trust and usage levels are on high levels and therefore impacting road safety positively.

For LKA: the research results are less satisfying, trust and usage are below a certain level. Safety potential is therefore not being exploited. LKA performance is especially unsatisfying on country roads and e.g. in bad weather situations. Unfortunately, those areas of application where the greatest safety gains are expected.

Countries with better ADAS acceptance and trust show more engaged and informed users, advanced road infrastructure and car park specificities.

The performance, user acceptance and safety impacts by driver assistance systems build the focus of research in this study. Users are more likely to adopt and use technology when they believe it provides clear benefits or added value. In this context e.g., safety and comfort benefits are key user expectations regarding assistance systems. This perception not only shapes attitudes toward technology but also strengthens technology-related trust, which further facilitates acceptance. Road safety impacts by ADAS or DCAS are therefore linked to acceptance (and related expectations) as well as to trust levels of users.

Data collection and analysis are built on the following **empirical foundations**:

I. a comprehensive secondary data collection and analysis,
II. statistical analysis of country and car park data, and,
III. an extensive European consumer survey.

The **European consumer survey** is an important foundation of the study. The survey sample covers almost 13,500 responses from a wide set of countries (with a certain influence by Germany, Austria, Denmark and Switzerland). The survey illustrates key influencing factors and their interrelations, showing how e.g., performance in system precision, perceived security and stress reduction impacts satisfaction, trust, and ultimately system use. By mapping these connections, the survey highlights the central fields of action that need to be addressed in order to improve acceptance und usage of ACC and LKA.

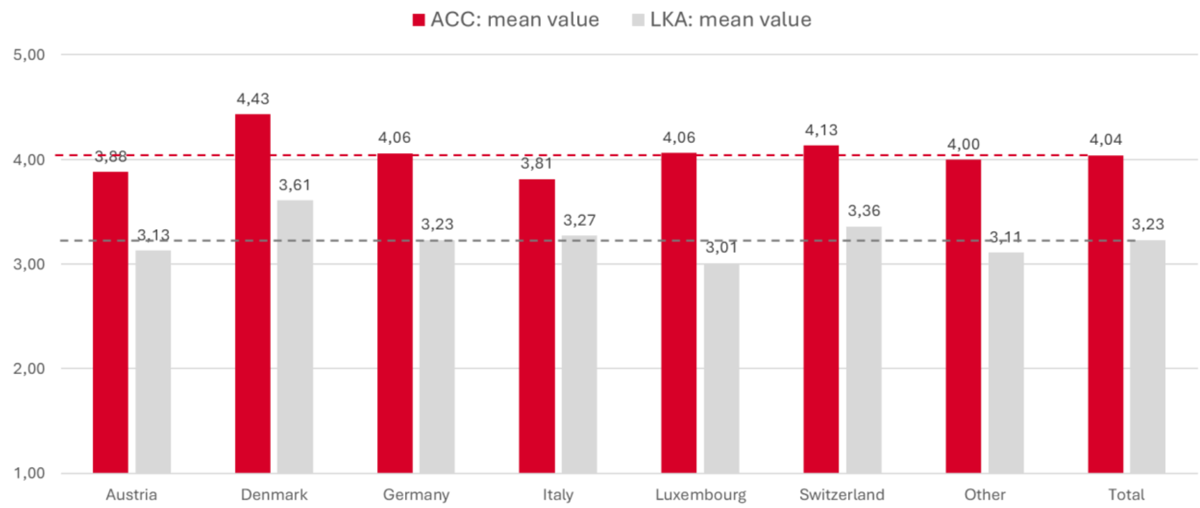

Figure 1: overview of user satisfaction scores for ACC and LKA across countries

Key survey results for ACC: this system is positively evaluated by users, with key strengths identified in reliability, perceived safety benefits, and comfort. These factors lead to a high overall satisfaction level (mean score: 4.04), which in turn translates into a high level of trust (mean score: 3.76). This positive evaluation for ACC is reflected in actual usage behaviour: 69% of drivers report using ACC frequently or all times, while only 12.8% actively switch the system off. Moderate complaints about system intervention are observed, yet they do not substantially undermine the positive assessment. Overall, the results indicate that ACC achieves both high satisfaction and trust, which are closely linked to widespread and consistent system use.

Key survey results for LKA: deficits for LKA in precision, perceived security, stress reduction, and system intervention directly undermine user satisfaction, as expectations for safety and comfort remain unmet. This dissatisfaction translates into even lower trust levels (mean = 2.80), with nearly one third of drivers not using the system (29.7%) and 30.7% actively switching LKA off.

Overall, the survey shows clear differences in user perception, satisfaction, trust, and acceptance for ACC and LKA. Across countries, these patterns remain relatively consistent: ACC performs strongly overall, while LKA's weaknesses limit trust, acceptance and finally usage. One country is different compared to the others: Denmark. Danish drivers are more satisfied, show higher trust and finally use ADAS more intensively. A deep dive into the Danish data shows specificities, such as:

- stronger technology openness and engagement with ADAS.
- better familiarity with ACC and LKA.
- less complaints, e.g. about system interventions.
- lower switch-off rates, i.e. for LKA.
- car park specificities and good road infrastructure.
- pro-active communication concept (e.g. by FDM) about ADAS and safety impacts.

On the other end of the spectrum Austria and Italy are more skeptical, while Switzerland and Germany perform slightly above the average EU scores.

Literature review concludes that UNECE regulations - especially UN R171- form the core framework for safe ADAS deployment by enforcing continuous driver monitoring and clarifying responsibilities in Level 2 systems, complementing system-specific standards like UN R157 and UN R79. Across numerous studies, ADAS technologies - most notably AEB, LKA/LDW, ACC, and ISA - show substantial crash-reduction potential, though their real-world effectiveness depends heavily on system design, environmental conditions, and user behavior. Remaining challenges for advancing toward DCAS phase 3 include ensuring reliable driver readiness, robust fallback mechanisms, clear operational domains, and improved user understanding to prevent misuse and over-reliance.

Statistical road and car park data: The analysis on fleet penetration performed on German and Italian used car market data reveals new-vehicle penetration quota for systems LKA, ACC, and Parking Assistance, exceeding quotas of 80% in Germany for LKA. EU traffic safety-relevant statistics reveal however that there is still potential to increase safety impact of these systems.

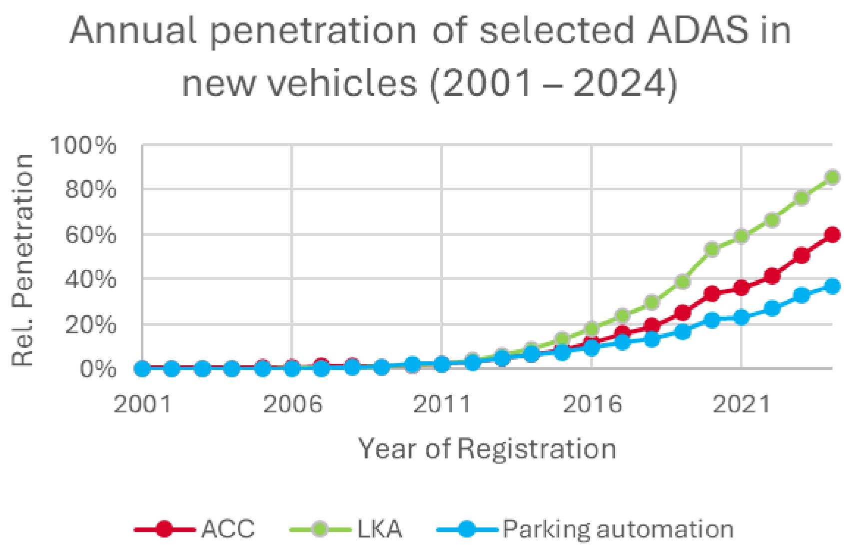

Figure 2: New-vehicle ADAS penetration quotas in Germany

Policy recommendations: We propose to further bridge the gap between ADAS safety potential and safety effect by tackling three identified areas of concern. First, we propose a set of measures to help ensure that drivers better understand use, limitations, and safety benefits of ADAS. Furthermore, we promote introducing a set of measures targeted at improving data transparency to help better understand safety impact and identify areas of improvement for ADAS systems, infrastructure compatibility, as well as existing policies. Lastly, we propose that with the increasing number of ADAS present in the fleet comes an increasing need to improve both across-system reliability and ODD standards and more standards for ADAS – related user interfaces.

Outlook and future implications: Moderate/poor survey results for LKA systems and the limited acceptance of a future of autonomous vehicles indicate that consumer acceptance in DCAS phase 3 will not improve unless issues identified in the study are better addressed.

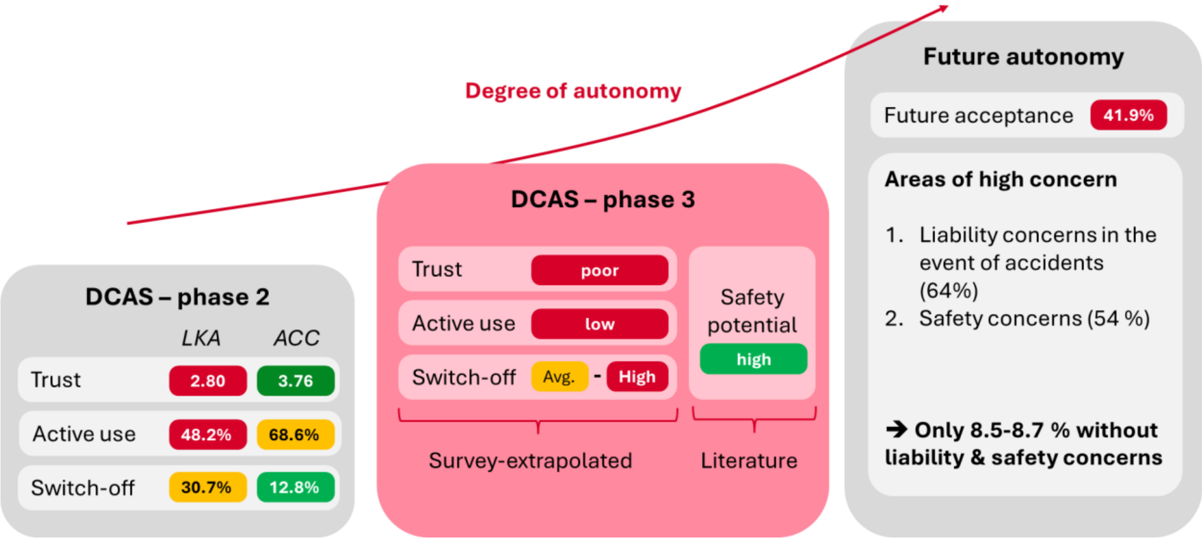

Figure 3: Expected development of ADAS acceptance metrics (trust, use, and switch-off rates)

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Overall project lead. Focus on human centric driving studies and data analysis.	User satisfaction, acceptance and trust studies, here ADAS customer barometer.	Functional safety, safety of the intended functionality and cybersecurity.

1 Introduction

Driver assistance systems (ADAS) and automated driving (AD) are becoming increasingly important and will shape the future of mobility. They are key components of technological innovations in the automotive industry. People are seeking more individuality and safety, while also wanting to make the most of their travel time. Whether for relaxation, work, communication, or simply enjoying the driving experience, these technologies offer new possibilities.

NCAP has played a pivotal role in advancing and promoting vehicle safety standards worldwide. By providing transparent and easily understandable safety ratings, NCAP has driven both manufacturers and consumers to prioritize safety in vehicle design and purchasing decisions. On other hand the European Union has introduced increasingly stricter regulations for the integration of ADAS in new vehicles. The General Safety Regulation (EU) 2019/2144 was adopted, which mandates that all new vehicles must be equipped with certain ADAS, such as **Intelligent Speed Assistance (ISA)**, alcohol interlock installation facilitation, driver drowsiness and attention warning, advanced driver distraction warning, emergency stop signal, reversing detection and event data recorder. This regulation is mandatory for implementation in all EU member states starting from July 6, 2022. Since July 2024, every newly sold car in the EU must be equipped with a **Lane-Keeping Assistant (LKA)** that can detect solid road markings. This requirement is regulated under UNECE R79. Overall, Euro NCAP and EU regulations are leading to safety features like ADAS becoming increasingly standard in vehicles, aiming to raise the overall safety level on the roads and reduce the number of traffic accidents and injuries. In contrast, **Adaptive Cruise Control (ACC)** is not mandatory, but it has become widely adopted due to the significant comfort benefits it offers.
Despite early announcements in 2018 about highly automated driving systems (HAD) at Norm SAE J3016 Level 3, the market launch was delayed due to significant technical challenges in development, testing, validation, approval, and homologation. In 2022, Mercedes introduced Level 3 systems in Europe, followed by BMW in 2023, while Audi plans to launch them earliest in 2027. Level 2/2+ systems are already referred to as **Driver Control Assistance Systems (DCAS)** and are regulated under UNECE R171.

The transition from level 2 ADAS systems, where the driver remains responsible, to level 3 systems (HAD) is also very significant. For this reason, there is an increasing trend in the Automotive industry toward introducing so-called Level 2+ systems, aiming to bridge this gap both technically and in terms of user acceptance. With Level 2+/2++ systems, the driver is allowed to take their hands off the steering wheel, but they must keep their attention on the traffic and remain ready to act at any time. In contrast, with Level 3 systems, the driver can look away from the traffic and is only required to be "perception ready." This can act as a bridging technology to facilitate the introduction of Level 3 systems, as all stakeholders can gain experience and knowledge. However, it could also hinder the path to further automation, as cheaper system components and fewer sensors may prevent the leap to Level 3. Additionally, there are further questions and complexities, as the Level 2+ system may offer a hands-off feature, but the vehicle may not be within its ODD (Operational Design Domain). How this case with limited system setup can be secured is, for example, difficult to answer.

The potential of this technology is immense, yet the complexity in its development and usage creates barriers. Numerous driving studies and market research by MdynamiX and the IFM – Institute for Driver Assistance and Connected Mobility at Kempten University, involving various assistance functions in over 40 studies with more than 1,000 participants, have shown relatively low customer acceptance. While customers desire more automated functions, they often feel overstrained [44], stressed [45][46], and do not trust the system enough. The maturity level of some current systems is estimated to be around 50% by subjects [7]. Although market penetration is increasing, driven by NCAP and the EU-wide commitment, the adoption rate of freely selectable ADAS/AD functions remains moderate today, when compared against the overall vehicle fleet. [4]. The studies also reveal significant differences between gender, age, experience, occupation, and premium versus volume brands [9]. As people increasingly hand over control to the vehicle and disengage from the driving process, user experience, sense of safety, resulting trust, and associated technology acceptance play a central role [7] and are key to success. If, in the future, passengers turn away from the driving experience, the comfort experience will also change significantly. Ultimately, the success of automated driving will be determined more by customer acceptance, purchase decisions, the fulfillment of user promises, trust, and recommendations than by technology availability – technology for people [4]. Only when people understand and trust the system, buy, use, and enjoy it while understanding its limitations will the potential benefits for society, safety, and economic regions ultimately emerge.

The partners MdynamiX and the Institute for Driver Assistance and Connected Mobility at Kempten University (IFM) have built extensive expertise for the study offered here through numerous industrial research projects and publicly funded initiatives. Unique insights have been gained from over 40 consecutive driving studies with interviews involving more than 1,000 participants. Driving studies were also conducted in other countries, such as with Volkswagen do Brasil [10], to examine the cultural influence and relevant market requirements. Additionally, a customer satisfaction barometer has been developed at the IFM, with regular surveys conducted. The database contains additionally over 1,000 interviews. The close collaboration with the automotive industry also provides crucial technological insights and roadmap initiatives. This expertise can be applied in the offered study. Extensive publications on this can be found in the appendix. A In addition, regular communication and proximity to FiA and the experts from the clubs help to optimally address the needs of this study.
The following study will primarily focus on the following three cases: Intelligent Speed Assistance (ISA), Lane-Keeping Assistant (LKA), and Adaptive Cruise Control (ACC). Additionally, efforts will be made to gain insights into Driver Control Assistance Systems (DCAS) as a Level 2 system.

2 Objectives

The primary aim of this study is to evaluate the implementation, effectiveness, and potential risks associated with ADAS/DCAS in real-world driving conditions. This aligns with the focus of Institute for Driver Assistance and Connected Mobility (IFM) on developing methods and specifications for new driver assistance systems, as well as validating their safety and reliability. Additionally, MdynamiX commitment to optimizing the driving experience through human-centered research and advanced testing & evaluation methods supports these objectives.

Additionally, the study analyzes the performance and reliability of ADAS/DCAS technologies and assess their integration with existing road infrastructure. This objective is closely tied to IFM's research into connected mobility and their holistic simulation and testing methods to ensure system performance and safety. MdynamiX expertise in driving dynamics, automated driving, and the use of simulation environments and Hardware-in-the-Loop (HiL) solutions further supports this objective by focusing on system performance and safety.

The study also aims to provide insights into the opportunities and challenges associated with ADAS/DCAS technologies. This is in line with IFM's research into connected mobility, which is crucial for understanding the broader implications and integration of these technologies. MdynamiX's human-centered research, which focuses on user needs and human-machine interaction, helps in identifying and addressing these opportunities and challenges.

To support policymakers and stakeholders, the study develops recommendations aimed at enhancing system performance, ensuring regulatory compliance, and building public trust in ADAS/DCAS technologies. This aligns with IFM's commitment to advancing driver assistance and automated driving functions, as well as their collaboration with industrial partners to meet regulatory and safety standards. MdynamiX's focus on optimizing the driving experience and user acceptance through human-centered research contributes to building public trust and ensuring regulatory compliance.

The study primarily focuses on the following three cases: Intelligent Speed Assistance (ISA), Lane-Keeping Assistant (LKA), and Adaptive Cruise Control (ACC). Additionally, efforts are made to gain insights into Driver Control Assistance Systems (DCAS) as a Level 2 system as well as on DCAS phase 3.

Emphasis Areas:

- System Reliability and Safety Risks: Focus on identifying and mitigating safety risks, supported by IFM's validation of safety and reliability and MdynamiX simulation and testing methods.
- User Acceptance, User Experience, and Barriers to Adoption: Study user acceptance and experience, and identify barriers to adoption, leveraging MdynamiX human-centered research.
- Road Safety Impact: Evaluate the impact of ADAS/DCAS technologies on road safety, aligning with IFM's research into functional safety and connected mobility.

This structured approach ensures a comprehensive evaluation of ADAS/DCAS technologies, addressing both technical and human factors to support their successful implementation and adoption.

3 Project Team and References

3.1 Consortium Structure

The consortium is composed of MdynamiX AG (Referred to as MX) and the Institute for Driving Assistance Systems and Connected Driving (Referred to as IFM), part of the Kempten University of Applied Sciences of Kempten. MdynamiX is responsible for coordinating the project (WP 1), ensuring deadlines are met and the outcome quality is high.

Figure 4: Benningen research area

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3.2 Partner Profile

MdynamiX AG

MdynamiX is exceptionally well-suited to meet the requirements of the FIA study on Advanced Driver Assistance Systems (ADAS) and Dynamic Control Assistance Systems (DCAS). The organization holds an ISO 9001 certification for quality management and a TISAX certification for information security, emphasizing our commitment to high standards in research practices and data security. With a dedicated team of 60 employees, experts in different fields, MdynamiX possesses the capacity and expertise to conduct thorough and innovative analyses.

The company's holistic approach to vehicle development ensures comprehensive evaluations of ADAS/DCAS systems, considering all aspects of vehicle performance and safety. Our collaboration with various vehicle original equipment manufacturers (OEMs) provides practical insights and real-world data, which are crucial for assessing system performance and integration. By bridging the gap between academic research and industry application, MdynamiX ensures that its findings are both theoretically sound and practically relevant.

Headquartered near the Benningen research area (Figure 3), MdynamiX can facilitate easier collaboration and data collection. The organization boasts an interdisciplinary collective of experts in driving dynamics and acoustics, ensuring a well-rounded analysis of ADAS/DCAS systems. With extensive experience in research projects and publishing, MdynamiX has a proven track record in conducting and disseminating research.

These strengths collectively enhance MdynamiX's credibility and capability to effectively contribute to the FIA study, aligning well with the study's objectives of assessing the implementation, effectiveness, and potential risks of ADAS and DCAS in real-world driving conditions.

Institute for Driver Assistance and Connected Mobility (IFM) at Kempten University of Applied Sciences:

The IFM focuses on research and development in the areas of driver assistance systems (ADAS) and connected mobility. The institute is directly located on the Fakt Motion testing grounds with direct access, in a technology campus right next to Continental, ABD, rfpro, MdynamiX, Expleo, and many others. The institute works on various cutting-edge technologies in automotive engineering, particularly those that enhance vehicle safety, automation, and the integration of new mobility solutions. IFM is known for conducting comprehensive studies and projects, often in collaboration with industry partners, to advance knowledge in areas like autonomous driving, vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, as well as user experience and acceptance of new technologies. It also engages in both industrial and publicly funded research projects, contributing valuable insights into the development and implementation of innovative automotive systems. The institute supports not only academic studies but also provides practical, real-world insights for the automotive industry. Its work is often focused on improving safety, optimizing mobility systems, and exploring the technological and societal impacts of emerging automotive technologies. With its close ties to the automotive sector, the institute is positioned as a key player in advancing the future of mobility and driving technologies. The philosophy of the IFM is based on the idea of bringing people and future technologies together, conducting user-centered research in the context of automated driving and vehicle dynamics. A team of more than 50 employees works closely with the automotive industry and has access to state-of-the-art laboratory, testing, and simulation facilities. Notably, the new driving simulator is worth mentioning, as it features a unique 6D motion system with exceptionally high dynamics and agility.

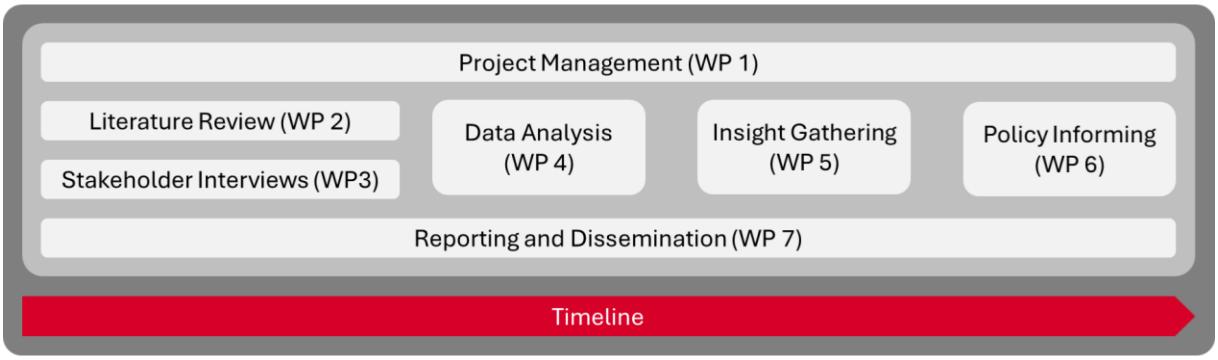
3.3 Work Package Distribution

Table 1: Overview of consortium members and tasks assigned (MX: MdynamiX, IFM: Institute for Driving Assistance and Connected Mobility

Member (Affiliation)	Role and Expertise
Prof. Bernhard Schick (MX, IFM)	Expert for ADAS/AD technologies, evaluation, human centric driving studies and data analysis
Prof. Dr. Uwe Stratmann (IFM)	Expert for market and consumer research in the field of the international automotive industry. Responsible for the European customer barometer in this study (see i.e. chapter 6.1)
Prof. Dr. Rolf Jung (IFM)	Expert for functional safety, safety of the intended functionality and cybersecurity
Florence Wagner (IFM)	Functional safety, safety of the intended functionality and cybersecurity research and studies
Seda Aydogdu (MX)	UX- User experience and human centric driving studies and survey
Gioele Micheli (MX)	Human factor and User Experience, human centric driving studies and data analysis

4 Methods

The project follows a work package approach. Each work package is a compact collection of tasks associated with a distinct methodical approach. Each work package has a work package lead that is responsible for ensuring the work packages results are of expected quality and delivered in time. There are two supportive work packages (Project Management and Reporting and Dissemination), three information-gathering work packages (Literature review, Consumer Survey, and Data analysis), and two information-summarizing work packages (Insight gathering and Policy Informing).



Index	Title
WP1	Project Management
WP2	Literature Review
WP3	Stakeholder Interviews
WP4	Meta Study and Data Analysis
WP5	Insight Gathering
WP6	Policy Informing
WP7	Reporting and Dissemination

Figure 5: Work package structure

Figure 6: Focus countries participating and their respective clubs

The analysis is centered on so-called Focus countries in Europe. These countries are selected to serve as account for socio-economic, cultural, or regional differences. The project is centered on a limited number of countries to gather more in-depth information on these regions. Country selection is based on factors such as affiliation with European sub-region, availability of FiA partners for survey-distribution, and availability of public ADAS-related data.

This work follows a KPI-based approach to data collection. This means that from objectives established, a set of comprehensive KPIs are formulated that are the basis for all research conducted. In this way, all results are streamlined to answer the question of how well the KPI's targets are met. To establish well-defined target values, extensive research projects would have to be conducted that would go beyond this project's scope. Instead, fulfillment of criteria is drawn on the basis of facts and data (drawn from the information-gathering work packages) upon which the respective work package lead form a verdict in the manner of an expert-rating.

The resulting verdict is then categorized into three labels:

- Below average / not fulfilled (Dashboard color red): KPIs is significantly below average values of other systems or countries or does not fulfill policy-driven goals.
- Average performance / fulfillment (Dashboard color yellow): KPIs are performing averagely good and fulfill or are on track of fulfilling policy-driven goals.
- Good performance / exceeding fulfillment (Dashboard color green): KPIs are fulfilled beyond average or exceed policy-driven goals.

4.1 Project Management and Structure (WP 1)

Project management is a supportive work package that ensures success in all other work packages. For this, a project lead is selected among the consortium to lead all efforts. The project manager is responsible for ensuring deadlines are met while work package output quality is high, aligning project efforts with objectives. The project manager will lead consortium-internal dialogue and resolve difficulties to guarantee objectives are met. The project manager is the primary contact point for FiA and organizes regular meetings. The work package's outcome is the successful completion of all other work packages.

Subordinate tasks:

- Ensure deadlines are met in time
- Ensure high-quality output for all work packages
- Track alignment with objectives
- Lead intra-project communication
- Lead contractor's side in meetings with FiA
- **Result:** High quality, timely results in all work packages

4.2 Literature Review (WP 2)

Research is conducted to create an overview of ADAS/DCAS technological SotA and outlook, research on the SotA of the regulatory landscape in the EU and finally research on safety and reliability of this system with the focus on the cases Intelligent Speed Assistance (ISA), Lane-Keeping Assistant (LKA), and Adaptive Cruise Control (ACC).

The method of a systematic literature review (SLR) is applied to this work package. The structured, transparent and replicable process to identify, evaluate and synthesize existing research on this topic is the standard approach. The method begins by defining clear research questions and inclusion/exclusion criteria. A comprehensive research strategy is developed to locate relevant studies across multiple databases. Retrieved articles are screened for relevance and data is extracted. The quality of the studies included is assessed using established appraisal tools. Finally, the findings are synthesized for the meta-analysis and summarized to provide a comprehensive overview of current knowledge, SotA and gaps.

This systematic approach focuses on

Research Questions:

ADAS/DCAS reliability, safety, and risks
User acceptance and user experience of ADAS/DCAS
Barriers to adoption of the systems
ADAS/DCAS safety impact

Exclusion and inclusion Criteria:

Where are the topic boundaries
What is the focus
Which systems are of interest (ISA/LKA/ACC)
What literature must be included (Regulations)

Selection of Literature:

Screening process and literature gathering
Data extraction
Documentation of results

4.3 European Customer Satisfaction Barometer (WP 3)

4.3.1 Analysis Model

Theoretical foundation

Customer satisfaction and inherent trust play a pivotal role in the development of automated driver assistance systems (ADAS), not only for ensuring market success but also for advancing road safety. Systems such as adaptive cruise control (ACC) and lane keeping assistance (LKA) - already widely deployed - significantly impact the perception of safety among drivers. This perception influences trust and acceptance, both crucial for the broader adoption of these technologies and, eventually, fully autonomous driving.

By understanding the interplay between customer expectations, satisfaction, and behavior, important stakeholders such as the group of vehicle manufacturers can refine systems to address not just convenience but also critical safety concerns. The insights from customer satisfaction studies are instrumental in designing systems that drivers perceive as both reliable and lifesaving, thus fostering safer roads and supporting the evolution toward autonomous mobility.

Customer satisfaction, trust, and acceptance of new technologies are closely linked in a reinforcing cycle. High customer satisfaction builds trust, which increases the likelihood of users accepting and adopting new technology. In turn, when technology meets user expectations and is easy to use, it boosts satisfaction and deepens trust. Together, these factors drive continued usage and loyalty. Different studies provide empirical evidence for the strong relationship between trust, acceptance and usage of new technologies (e.g. Lee and See, 2004; Endsley, 2017; Kraus et al., 2020).

Usage rates of ADAS systems are therefore linked to customer expectations, their fulfillment and the resulting trust. This is the linking pin between analyzing customer satisfaction and advancing road safety. Even if the penetration of ADAS systems shows an impressive development the final trust and usage is deciding about the impact on safety development.

Beyond that, future success of ADAS innovations and autonomous driving system largely depends on technology acceptance: how willing and able users are to adopt and integrate new technologies into their routines. If users perceive the innovation as useful and easy to use, they are more likely to adopt it (e.g. Davis, 1985). High acceptance leads to widespread use, which is critical for an innovation to gain traction, deliver value, and succeed in the market. Without user acceptance, even the most advanced innovation can fail. That is the fundamental hypothesis of the Technology-Acceptance Model by Davis (1985). And various empirical evidence underlines the importance of that theory.

Applied analysis model for the European satisfaction barometer

Customer satisfaction is the result of a subjective comparison of expectations and experiences with a particular product or service. According to the confirmation/disconfirmation paradigm (which goes back to Anderson, 1973), the identification and characterization of customer expectations is a key factor for effective customer satisfaction management. In the case of new-to-the-world innovations, these expectations are usually not known or only known to a limited extent, which in turn makes it difficult to develop new products that meet the needs of the target customer group.

Customer satisfaction is substantial in terms of acceptance of and trust in an innovation. According to Technology-Acceptance Model (Davis, 1985) these are important prerequisites for the subsequent market success of new products. ADAS such as lane keeping assistance or adaptive cruise control have been installed for several years and now have high market penetration.

Anderson's confirmation/disconfirmation theory (Anderson, 1973) provides the fundamental theoretical concept for analyzing customer satisfaction. For the present research the theory is supplemented by behavioral aspects. This comparison process is subjective and individual to the customer, since cognitive and affective factors influence the resulting satisfaction.

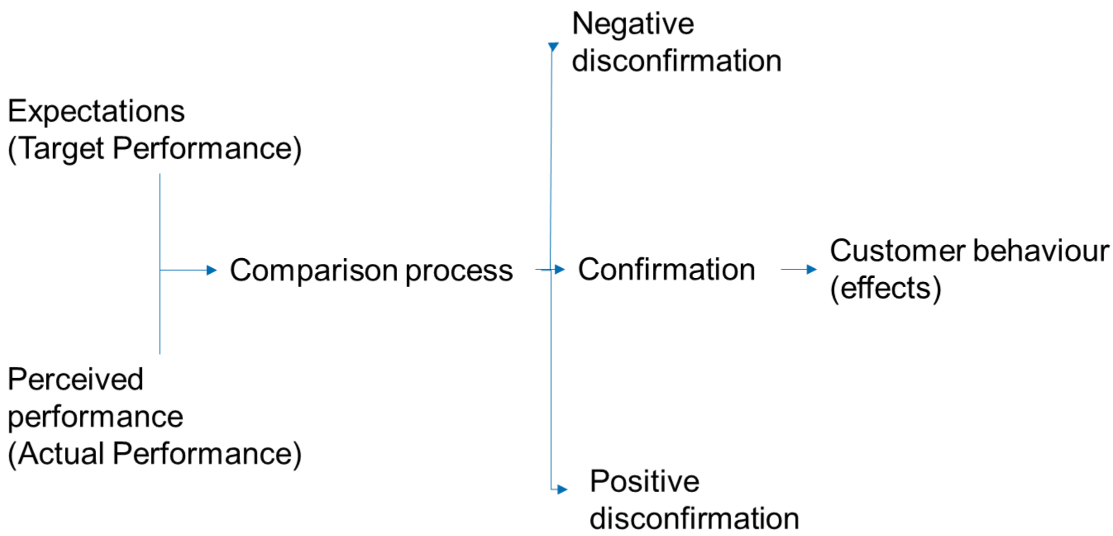


Figure 7: Analysis concept of the customer satisfaction study

4.3.2 Methodology of the customer survey and sample profile

A quantitative customer survey is selected as the main data collection technique. In addition, qualitative expert interviews were conducted to discuss and justify certain hypotheses and survey findings.

Survey methodology

The research is in particular analyzing following ADAS systems: adaptive cruise control (ACC) and lane keeping assistance (LKA). Latest systems like the lane change assistant were not covered in this survey due to low penetration of these systems in the car parc.

Car drivers were asked about following core aspects:

- General relevance of ADAS out of customer perspectives
- Core expectations towards ADAS in general and specificly for ACC and LKA
- Fulfillment of customer expectations and the resulting
- Customer satisfaction levels, which lead to a certain level of
- Trust against ACC and LKA
- Usage profiles and rates
- Drivers of satisfaction and dissatisfaction
- Future outlook: acceptance of autonomous driving

An online questionnaire was designed according to these ADAS aspects. The questionnaire was translated into the local country language and distributed via online channels for the different countries in question. The distribution was done by the local clubs (like ADAC etc.).

Sample selection and profile

The dataset comprises 13,374 respondents, with Germany (6,362), Austria (4,813) and Denmark (1,164) forming the largest subgroups and together accounting for 92.3% of the total sample. Switzerland (484), Luxembourg (119), Italy (114), and other markets (318) are represented by smaller case numbers. However, given the relatively low variance of results across countries, even these smaller samples provide meaningful insights for cross-country comparisons.

Table 2: Sample profile description

	Total	Male Share in Sample	Dominant Vehicle Registration Year	Dominant Driving Style in Sample	Dominant Roads + Experiences	Dominant technical affinity + ADAS familiarity
TOTAL	13,374	87.2%	Year 2021 for new car registration (median). Impact of vehicle age on e.g. satisfaction is statistically not significant.	Typical driver in sample is moderately sporty. Style is neither defensive nor offensive.	Mix out of city, country and highway. Rather frequent drivers, often with >15,000km p.a.	Given technical affinity and given familiarity with ADAS.
Germany	6,362	90.9%				
Austria	4,813	81.0%				
Denmark	1,164	94.6%				
Switzerland	484	87.2%				
Luxembourg	119	78.2%				
Italy	114	85.7%				
Other	318	82,9%				

Across all groups, the median vehicle registration year is 2021, reflecting a modern fleet. It is striking that e.g., the vehicle age has no significant impact on driver satisfaction (will be discussed later). Driving styles are predominantly moderately sporty, without a distinct defensive or offensive tendency. Reported usage covers a balanced mix of city, country, and highway driving, with many respondents covering more than 15,000 km annually.

Overall, the sample represents frequent drivers with strong technical affinity and familiarity with advanced driver assistance systems (ADAS). In summary, the dominant user profile in samples is improving the quality of the survey outcome. An overview of the sample profile is provided by table 2 (see below).

4.4 Meta Study and Data Analysis (WP 4)

4.4.1 ADAS penetration study

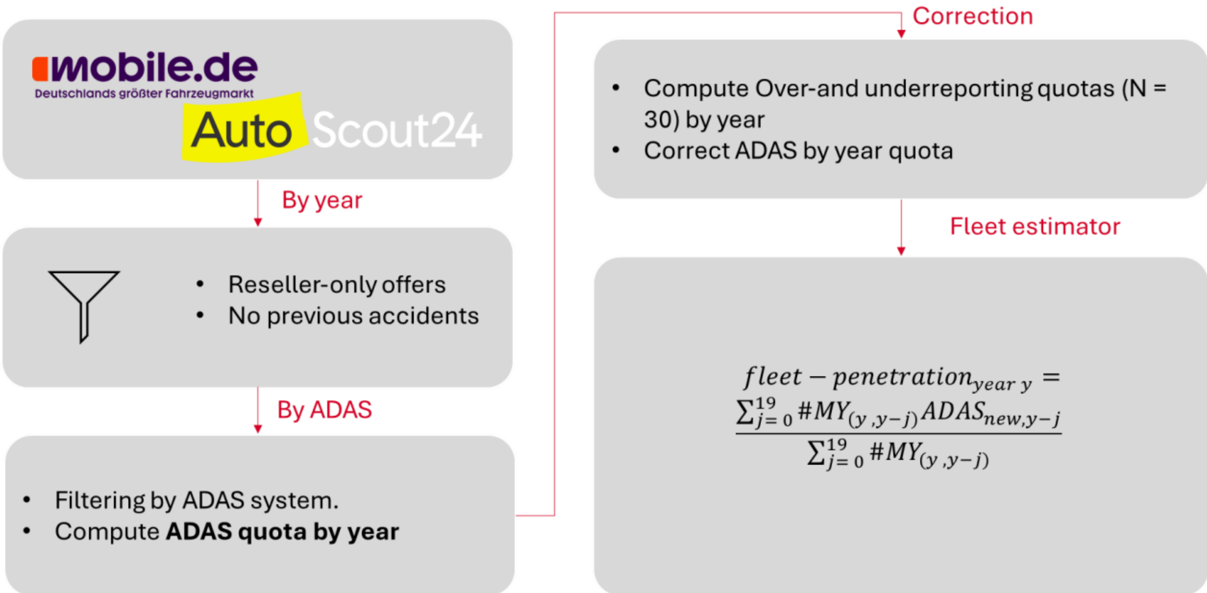


Figure 8: method of ADAS penetration study

To improve transparency in available ADAS penetration numbers, an empirical approach to forming an understanding of past and current development is chosen. For this, platforms of used car markets in chosen focus countries are chosen. The method's goal is to determine the ratio of vehicles equipped with a certain ADAS in comparison with all new vehicles, both by year and by country.

To find this value, for each reseller market, a set of quality criteria is then used to reduce false reports in results. Quality criteria can include requirements like professional merchant-only resale offers. The frequency and thereby the ADAS rates for each system are computed. Methodically, numbers computed in this fashion are susceptible to false positive reporting and false negative reporting. By computing false positive and false negative rates for each year, a statistical model can be used to adjust the computed rates.

Based on the new vehicle penetration rate, the fleet penetration by year can then be computed to allow for insights into the relation between system safety and outcomes.

4.5 Insight Gathering (WP 5)

Drawing on the results of WP 2-5, a thorough analysis is made to further answer the overarching research questions in a complete approach. For this, we summarize all individual work package results and integrate them in a dashboard analysis. The summary will be structured hierarchically from the central objective: Creating an evidence-based foundation on the basis of which recommendations for policy makers and other stakeholders can be given. The hierarchical approach subordinates the key objectives, and KPI are subordinate to the specified objectives. At the base level, all results cater to KPI-based dashboards showcasing values for current state, potential for improvement, and challenges found, combining both quantitative and qualitative findings.

Subordinate tasks:

- Work package coordination
- Summarize all insights
- Create full, evidence-based picture of current ADAS landscape
- Expert workshops
- Evaluate fulfillment of all objectives and answer related questions
- Create solid basis for policy informing
- **Result:** KPI – based analysis and dashboards

4.6 Policy Informing (WP 6)

The work package involves coordinating efforts to deduce recommendations from evidencebased research, tailored to various stakeholders. In order to help the stakeholders to enhance system performance, ensure regulatory compliance and build public trust in ADAS/DCAS, policy informing is conducted. Methodically, the evidence-based research and data analysis is used as a foundation. Based on results the policy recommendations are developed and derived during a structured discussion workshop. To represent stakeholders' interests and views the participation of experts from academia and research with experience in automotive industries and development as well as regulation and decision making is important to the discussion. Stakeholder-dependent, actionable recommendations are elaborated as a result of this work package.

4.7 Reporting and Dissemination (WP7)

The aim of this work package is documenting continuously all results, preparing presentations for regular exchange with FiA, writing reports and being responsible for the content of public presentations.

Coordinating regular meetings with colleagues, experts and initiators of this project to maintain a constant exchange of the status of results, new ideas and findings is the procedure to track the progress and timeline of the project. Dashboards for presentations and content for reports are created subsequent to regular meetings. All findings and results from research, reviews, analysis, studies and discussions are documented and visualized in a final report and presentation.

5 Literature

5.1 Regulation

Regulatory Requirements for ADAS Systems Based on UNECE Standards: A Focus on UN R157, R171, and Related Regulations.

UN Regulation No. 171 (DCAS) plays a critical role in regulating driver assistance systems, particularly those operating at SAE Level 2, where both the system and the driver are involved in control tasks. It complements other UNECE regulations, such as UN R79 (Steering Functions) and UN R157 (ALKS), by focusing on driver engagement, system validation, and clear user communication. While other regulations address the technical aspects of individual systems (lane keeping, lane change), UN R171 ensures driver monitoring and safety in combined systems (e.g., ACC + LKA). It mandates continuous driver availability and interaction with the system, offering a framework for safe integration of increasingly automated vehicles into real-world environments. This regulation fills a crucial gap in current automotive standards, enhancing safety and functionality in Level 2 systems.

The regulatory framework under UNECE standards aims to harmonize the safety and functionality of Advanced Driver Assistance Systems (ADAS), ensuring their safe operation. UN R157 focuses on Automated Lane Keeping Systems (ALKS), UN R171 addresses Driver Control Assistance Systems (DCAS), and UN R79 covers Steering Assistance for systems like Lane Keeping Assist (LKA). These regulations work in tandem to support the development of Level 2 and Level 3 automated driving functions. However, UN R171 is particularly significant in bridging the gap between lower-level ADAS and full automation by enforcing strict driver monitoring and system engagement requirements, ensuring that vehicles operating with ACC, ISA, and LKA features maintain a high standard of safety while the driver remains actively responsible.

Table 3: Key UNECE Regulations for ADAS Systems

Regulation	Scope / Function	Key Requirements	Driver Responsibility / Monitoring
UN R157 "Automated Lane Keeping Systems (ALKS)"	Lane-keeping, longitudinal control on specific roadways (e.g., motorways)	− System only activated on roads with physical separation. − Minimum sensing range of 46m, full lane width coverage. − Minimum risk maneuver for fallback in case of driver non-intervention.	Driver must be ready to take over if needed; remains responsible.
UN R171 "Driver Control Assistance Systems (DCAS)"	Level 2 systems with sustained longitudinal and lateral support (e.g., ACC + LKA)	− Continuous driver monitoring (hands on wheel, gaze/head) and disengagement warnings. − Clear user communication on system limitations. − Validation of system's functional safety and operational domain.	Driver remains in control; must remain engaged with the system at all times.
UN R79 "Steering Equipment / Lane Keeping Assist"	Assesses systems providing steering assistance (LKA)	− Tests for lane-keeping and lane-changing functionality. − Steering system safety: forces, failure behavior.	Driver remains responsible; system supports, but does not take over control.

The introduction of UN R171 is essential to the overall UNECE framework as it specifically addresses the growing complexity of ADAS operating at Level 2, which combines multiple systems such as ACC and LKA to provide sustained control assistance while maintaining the driver's responsibility. Unlike UN R79 and UN R157, which primarily focus on individual systems, UN R171 emphasizes driver monitoring and continuous engagement, ensuring that the driver is both aware of the system's limitations and able to intervene when necessary. This regulation is crucial for bridging the gap between semi-automated systems and fully autonomous vehicles. Moreover, it helps manufacturers comply with functional safety and system validation standards, ensuring that ADAS technologies are both effective and safe for real-world use. [38-42]

5.2 Systems and Safety Impact

State-of-the-art ADAS systems now feature advanced multi-sensor fusion, safety-critical functions like ACC, LDW/LKA, BSD, ISA, and continue evolving toward personalized, cooperative, and AR-enhanced capabilities. Human factors remain key—driver trust, training, and understanding are ongoing challenges. Regulation, through DCAS, is formalizing safety benchmarks and paving the way for higher-level ADS deployment. As these systems advance, achieving the balance between automation, driver engagement, and robust certification remains essential.

Modern ADAS deploy a range of sensor technologies—radars, cameras, LiDAR, ultrasonics—to deliver functions like Adaptive Cruise Control (ACC), Blind-Spot Detection (BSD), Lane Departure Warning (LDW)/Lane Keeping Assist (LKA), Intelligent Speed Assistance (ISA), and Emergency Brake Assist (AEB).
Adaptive Cruise Control (ACC) uses mainly radar, lidar, camera and sensors to maintain safe spacing from preceding vehicles and can include “Stop & Go” and predictive (GPS-informed) features. Lane assistance systems warn of unintended lane departure (LDW), gently steer to keep the vehicle within its lane (LKA or Lane Centering Assist), or take over in emergencies (Automated Lane Keeping Systems – ALKS). Blind-spot detection helps drivers avoid lane-change collisions through visual, audible, or haptic alerts. ISA systems prevent speeding by warning or actively reducing speed based on road-limit data, offering active or passive behavior.
Evaluations show that ADAS enhances safety and comfort, though challenges like false alarms, insufficient precision, and inconsistent user interfaces remain.

Through the literature considered the safety aspect of ADAS systems is summarized as positive. Studies, reports and conclusions represent the experiences from middle European countries and the USA. A range of safety impact and accident reduction numbers are given based on different data pool, analysis methods and inclusion/exclusion criteria. For future ADAS applications the given statements are considered as safety potential which cannot be proven by now.

Masello et al. [28] states that a full ADAS deployment could lead to a 29% decrease in accident frequency, resulting in an estimation of 18,925 fewer crashes in the UK. According to this study, the AEB has the most significant impact on road safety since it is effectively reducing accidents in most frequent accident types. LDW and ACC also contribute to the effective accident reduction, but their impact is generally less compared to AEB. 23% accident reduction potential is mentioned for LDW. For ACC the effectiveness varies based on driving context and primarily aids in reducing rear-end and collision-related accidents.

Results from an exploratory analysis of ADAS features and their safety outcomes in the USA indicate that improved safety outcomes are associated with the presence of three ADAS features: lane departure warning, forward collision warning, and blind spot detection [37].

Vehicles with ADAS features were less likely to be involved in fatal and severe crashes like head-on and rear-end crashes. Another statement published in this paper declares that more robust data is urgently needed for disentangling the safety effects of ADAS.

Swedish analysis of the LDW/LKA system in [26] shows a positive effect in reducing lane departure crashes. LDW/LKA systems were estimated to lower the driver injury risk in crash types that the systems are designed to prevent (head-on and single-vehicle crashes).

The meta-analysis study from Wang et al. [31] considers 73 studies across six different countries and technologies. Most interesting findings conducted that AEB has the greatest safety impact among the evaluated technologies and is significantly contributing to crash reduction. It is estimated to reduce around 1369099 crashes per year across the six countries studied. Accounting for an approximate 19.34% avoidance to total crashes. Both ACC and LKA contribute to improving safety, particularly in scenarios involving lane maintenance and longitudinal control, but their individual impact is less than that of technologies like AEB. ACC is estimated to reduce approximately 102,447 crashes per year, accounting for about 1.45% of total crashes. LKA results in a reduction of about 128,290 crashes annually, representing approximately 1.81% of total crashes.

Safety advantages and improvements from ADAS influencing other road participants is discussed in “Effect of Advanced Driver Assistance Systems (ADAS) on Pedestrian Safety” [30] and mentions ACC Effect of Advanced Driver Assistance Systems (ADAS) on Pedestrian Safety. LKA is covered under LDW systems, which help prevent unintentional lane drifts that could endanger pedestrians by ensuring the vehicle stays within its lane. The study indicates that ADAS features, such as Automatic Emergency Braking (AEB) and Pedestrian Detection, significantly improve pedestrian safety by reducing both the frequency and severity of accidents. Real-world data analyses demonstrate that vehicles equipped with ADAS experience fewer pedestrian accidents, primarily because these systems can quickly recognize potential collisions and initiate braking faster than human drivers are capable of.
Moreover, simulation studies and effectiveness assessments reveal that ADAS technologies effectively prevent or mitigate pedestrian collisions under various conditions, including low visibility and complex urban environments. However, some challenges remain, such as false positives/negatives and environmental sensitivity, which can affect overall effectiveness.
Within the study to evaluate the safety impact of ACC in [29] the following results are summarized: The study evaluates the impact of ACC parameter settings on rear-end collisions on freeways, particularly in traffic oscillations. Results indicate that safety impacts are largely affected by ACC parameters, with smaller time delays and larger time gaps improving safety, and the combination of ACC and variable speed limits (VSL) achieving better safety improvements in congested freeways, especially with ACC penetration rates less than 30%. ACC systems can reduce collision risks in congested traffic if properly designed with appropriate parameter settings, such as larger time gaps, smaller time delays, and greater maximum deceleration rates.

Accident reduction and reduction of collision severity is subject to the “Towards Zero Accidents Analysis of Advanced Technologies Enabling Safe Roads” paper. [27] Content shows that ADAS technologies such as AEB, Forward Collision Warning, and Lane Departure Warning Systems actively prevent crashes: AEB systems can detect imminent collisions and apply brakes automatically, significantly reducing rear-end accidents. Lane assistance systems help prevent accidents caused by drowsiness, distraction, or poor visibility. The impact is leading to fewer crashes, especially those involving inattentive or fatigued drivers and reduced severity when accidents occur. Also, this article indicates that ADAS has the potential to encourage safer diving habits over time, influencing long-term behavioral change and safer driving culture. Concluding, the ADAS technologies do not eliminate risk, but they mitigate it significantly by reducing reliance on human reflexes, enhancing situational awareness, and automatically intervening when needed.

Safety potential of ADAS is measured by the Austrians [11] and resulting in the following: This study analyzes the road safety impact of nine ADAS using Austrian crash data and considering factors like infrastructure, weather, market penetration, and user acceptance. Results indicate that warning/braking ADAS have the greatest future reduction potential with Intelligent Speed Assistance also contributing significantly. Crash reduction potentials were calculated for Adaptive Cruise Control (ACC), Adaptive Lighting, Alcohol-Interlock system, warning/breaking ADAS (AEB, FCW), Intelligent Speed Assistance (ISA), Curve-ABS, Lane Keeping/Departure Assistance (LKA/LDA), Turning Assistant, and ADAS regarding drowsiness. All ADAS support a reduction in crashes, fatalities, and injuries, even when considering risks like inattentive driving and limited functionality. The greatest potential is for warning/braking ADAS (AEB, FCW), potentially reducing approximately 8,700 crashes and 70 fatalities in Austria by 2040, a 24% reduction compared to the 2016-2020 average. Intelligent Speed Assistant (ISA) is the second most promising, potentially reducing overall crashes by 8% in 2040. The results for ACC indicate that it has a limited but meaningful impact on crash reduction. According to the study, ACC, along with other ADAS such as lane assistance and adaptive lighting, shows potential to reduce crashes by around 8% in 2040 compared to current figures. Specifically, ACC is expected to contribute to the overall crash and casualty reduction, although its impact is smaller relative to warning/braking systems like AEB/FCW, which exhibit the highest potential. Additionally, ACC plays a role in preventing crashes related to driver drowsiness and concentration lapses, especially when combined with other ADAS measures. LKA has significant potential for crashes and fatality reduction. The study estimates that LKA could reduce the number of fatalities by up to 90–100 persons in 2030 and 2040. It is identified as one of the ADAS with the highest potential in terms of fatalities prevented, especially when considering severe injuries and fatalities associated with lane departure crashes. In order to exhaust the full potential of ADAS safety advantages the user behavior is significant.

Tan et al. [12] present a summary of evidence for the crash avoidance effectiveness of ADAS in their paper. In this study, three common methods for safety benefit evaluation were identified: Field operation test (FOT), safety impact methodology (SIM), and statistical analysis methodology (SAM).

Table 4: Overview on ADAS-safety related studies

ADAS Technology	Crash avoidance effectiveness	Crash Type considered	Method for safety factor evaluation	Literature source
ACC	13%	Rear-end crash	Field operation test	19
ACC	12%	Rear-end crash	Field operation test	23
ACC	14%	Rear-end crash	Safety impact methodology	20
ACC + FCW	16%	Rear-end crash	Field operation test	22
ACC + AEB	45%	Rear-end crash	Statistical analysis methodology	24
LKA	35%	Lane departure crash	Safety impact methodology	25
LKA	20%	Lane departure crash	Statistical analysis methodology	21
LKA	30%	Lane departure crash	Statistical analysis methodology	24
LKA	32%	Head-on, single crash	Statistical analysis methodology	26

Results from this study are pictured in the table and highlight that the ACC technology is aligned with the rear-end crash type and has an avoidance effectiveness of 13% [19]. Another study indicates an avoidance effectiveness of 12% [23] and a third with 14% [20]. A combination of ACC and FCW is set for a rear-end crash type and giving an effectiveness of 16% [22]. ACC and AEB in combination result in a high score with 45% crash avoidance effectiveness. [24] LKA is considering the lane-departure crash type and presenting different results with 35% [25], 20% [21] and 30% [24]. For the LKA head-on, single crashes type the avoidance effectiveness is 32%. [26]

In a retrospective cohort study in the USA [14] analysis estimates the effectiveness of ADAS systems helping to prevent system-relevant crashes. Numbers resulting from the analysis indicate that AEB-equipped vehicles were 43% less likely (Hazard Ratio = 0.57) to be the striking vehicle in a front-to-rear crash compared to non-equipped vehicles. The analysis was also stratified to look at the effect in intersection versus non-intersection crashes. BSM-equipped vehicles were 4% less likely (Hazard Ratio = 0.96) to be involved in a same-direction sideswipe, though the differences were not significant. LKA-equipped vehicles were 9% less likely (Hazard Ratio = 0.91) to run off the road. LDW and LKA did not have a significant effect on risk of same-direction sideswipe or head-on crash.

German studies for accident prevention and ADAS systems performed by the Bundesanstalt für Straßen- und Verkehrswesen (BASt) [18] presents that ACC can significantly reduce rear-end collisions, especially in situations such as sudden braking maneuvers or other vehicles suddenly rear-ending them. Particularly in heavy traffic on highways, ACC significantly reduces the vehicle's reaction time and brakes early, which reduces the likelihood of a collision. The study confirms that ACC systems reduce the overall number of accidents, primarily through early and situation-dependent braking in critical distance situations, which significantly reduces both the frequency and severity of rear-end collisions. The most important factors influencing effectiveness are correct parameterization, system reliability, and the situations in which ACC is activated. Regarding LKA the studies and simulation results show that LKA reduces the likelihood of unintentional lane departure, which can reduce accidents caused by side or head-on collisions. LKA can be particularly effective in supporting drivers who are tired or distracted. A reduction potential of 50% considering runway accidents is mentioned while these results and the effectiveness of the system are dependent on sensor data, detection limits, and response times. Along with the benefits from ADAS technologies on road safety the challenges are highlighted in this report: At the same time, emphasis is placed on requirements for technology, infrastructure, and acceptance in order to achieve maximum social benefit. Efficiency and safety must be supported by system development, standardization, and legal frameworks.

Recent articles have started a discussion about ACC not contributing to road safety but in fact increasing the crash rates. [15] Otherwise, this article supports safety improvements by means of AEB and LKA. It is important to note that the ACC’s negative effect is based on only one study published by Netherlands insurance and mostly indicates and reveals that the data an analysis on real-world impact of ADAS is scarce.

Reliability of ADAS and their performance is often dependent on factors like road types, weather, lighting, road infrastructure, traffic density for example. According to users of ACC systems the vehicle can behave unpredictably with sudden accelerations or decelerations when a car in front changes lanes or cuts in. [34] Resulting from the given study the respondents concluded that ACC being "blind" in curves, disengaging too quickly, reacting to irrelevant obstacles, and conservative headway settings leading to sluggish overtaking behavior. Additionally, beeping sounds when the lead vehicle disappears from radar view and dependence on the driving skill of the car ahead were noted as displeasing aspects. Some drivers also expressed concerns about the ACC's limitations in specific conditions like heavy rain or when it's not functioning properly at low or very high speeds.

[16], [17] and [13] conclude that while ADAS technologies significantly contribute to road safety, their reliability and consistency are contingent upon proper system design, regular maintenance, and user awareness. Ensuring optimal performance requires addressing environmental challenges, maintaining sensor calibration, and educating drivers about the limitations of these systems.

The “Driver perceptions of advanced driver assistance systems and safety“ [36] explores how drivers perceive and interact with ADAS. Systems considered and of interest are ACC and LKA. Results are that 70% of drivers use ADAS while 40% feel that ADAS compromises their

safety when active (mostly referring to LKA) indicating a high usage but low confidence in ADAS. 30% of drivers report little or no knowledge of the ADAS in their vehicles. Most drivers learn by trial and error, not through formal training. Only 7.7% took a driving course, and only a third received any dealership training, usually under 10 minutes.
A big part of participants has no awareness of their feature since 89% know they have cruise control, but awareness drops significantly for ACC (28.5%), LKA (25%), and parking assist (20.3%). Additionally, there is confusion with feature names which affects the users' understanding. Based on the study's results the following actions are proposed:

- Improved training and education
- Transparent communication from manufacturers
- More research on real-world ADAS impacts
- Re-examination of the assumption that ADAS inherently improves safety.

According to [33] user knowledge and trust in the system are critical factors influencing ADAS acceptance. It is highlighted that the acceptance of ADAS depends on the sources and quality of knowledge available to users. Also, user acceptance and trust significantly influence their willingness to purchase ADAS technologies. Looking at the ADAS acceptance across different user groups, the acceptance is mainly influenced by prior knowledge, trust, perceived usefulness, and demographic factors in general drivers.

DeGuzman and Donmez [32] provide a survey study with the primary objective of assessing knowledge of and trust in ACC and LKA among owners and non-owners and investigating the relationship between knowledge and trust. The results and conclusions drawn from this study are as follows:

- Owning a vehicle with ACC or LKA does not appear to result in a better understanding of system limitations.
- For both owners and non-owners, participants tended to overestimate ADAS more than underestimate it.
- Prior to system use (i.e., for non-owners, who had no experience with ACC or LKA), knowledge of specific capabilities and response bias affects trust, which in turn, affects reliance intention.
- Once drivers have experience with the system (i.e., owners in our sample), knowledge of specific system capabilities and response bias do not have a significant influence on trust.
- For ACC owners, using the system more frequently is related to lower trust, which in turn was associated with a lower reported likelihood to engage in secondary tasks.
- Using LKA more frequently was not associated with lower trust, potentially due to the fact that participants were more aware of some of the common limitations, which reduced the negative impact of system failures on trust.

According to [11] user behavior significantly influences the effectiveness of ADAS. The study identifies several ways in which driver's actions and attitudes can impact system performance:

- Incorrect use and understanding: For ADAS to be beneficial, users must operate them correctly and be aware of their limitations. Lack of knowledge can lead to improper handling, reducing safety gains.
- Over-reliance and complacency: Drivers may develop a false sense of security, leading to decreased attention and increased distraction, which can undermine system benefits and potentially cause unsafe situations.
- Distraction and workload: The presence of ADAS can reduce driver workload, but this might also increase inattentiveness or cause drivers to neglect actively monitoring the driving environment, especially if they trust the systems too much.
- Behavioral adaptation (Risk Homeostasis): With ADAS, drivers may subconsciously adopt riskier behaviors, compensating for perceived safety improvements, thus possibly diminishing the systems' overall impact.
- Need for driver education: To mitigate these issues, improved driver training and clear information about ADAS capabilities and limitations are necessary, aiming to ensure systems are used properly and effectively.

Overall, user behavior plays a crucial role in realizing the safety potential of ADAS, emphasizing the importance of education, proper system design, and awareness of system limitations.

Testing and evaluating the safety of ADAS is in scope of Euro NCAP Assessments and gives a specific protocol on how to proceed. The Euro NCAP Assisted Driving Protocol v2.2 (2024) evaluates the performance of modern driver assistance systems across three core testing domains: speed assistance, distance assistance, and lane keeping assistance. These tests aim to assess the functionality, reliability, and driver interaction of such systems under realistic driving conditions. In the speed assistance domain, systems that combine camera-based speed limit recognition with map data achieve the highest accuracy in identifying and adapting to speed limits, while purely vision-based systems remain prone to errors under poor visibility or changing lighting. The distance assistance tests, typically assessing adaptive cruise control (ACC), focus on time gaps, response to cut-ins, and reaction to sudden deceleration. Systems using sensor fusion—integrating radar, camera, and sometimes LiDAR—demonstrate more stable and predictable behavior, particularly in complex traffic scenarios. Lane keeping assistance evaluates a vehicle's ability to maintain its lane through curves and under degraded road markings; early and smooth steering interventions score best, whereas abrupt or delayed corrections are penalized. Overall, Euro NCAP's findings highlight that the effectiveness of assisted driving depends not only on the individual system components but also on their seamless integration. A balanced and coordinated interaction among speed, distance, and lane-keeping functions is essential for achieving safe, comfortable, and trustworthy vehicle automation. [43]

Risks are maintained while a human driver is responsible and overseeing the ADAS operation. Discussions suggest that comfort systems like ACC are more delicate for trust, over-reliance and driving task distraction. Also, it is assumed and necessary that a responsive and responsible driver is present to operate a DCAS step 2 vehicle.

ACC and LKA are example ADAS implemented in vehicles. While there are no real-word studies on road safety effects with DCAS step 3 implementation, only assumptions based on experiences can be drawn. Meanwhile the literature [1-10] summarizes the most significant challenges present for a DCAS step 3 implementation:

- Driver Monitoring & Readiness: Studies focusing on how Level 3 systems monitor driver engagement and how the driver can safely transition control back to the system.
- Legal & Liability Challenges: Addressing legal responsibility for accidents or malfunctions, and the transition of responsibility from the vehicle to the driver.
- System Reliability & Fallback Mechanisms: Technical concerns regarding how well Level 3 systems handle unexpected road scenarios and potential failures, and the need for fail-safe mechanisms.
- Ethics & Public Trust: Ethical concerns related to driver disengagement, particularly in critical scenarios, and how these are handled in systems with partial automation.
- Operational Domains: Challenges around defining the geofencing and operational boundaries where Level 3 systems can operate safely without requiring full driver control.

6 Results

6.1 European Consumer Survey: ADAS Satisfaction Barometer

Chapter 6.1 presents the key findings of the customer satisfaction analysis. The results are based on 13,374 responses from six core European countries. The research validity and quality of results are therefore extremely high, especially for the countries Austria, Germany and Denmark. Switzerland, Italy and Luxembourg are considered as well even if the sample size is lower. However, consistency checks for these countries show high validity as well – the variance factor is low.

Total	Austria	Denmark	Germany	Italy	Luxembourg	Switzer-land	Other
13,374	**4,813**	**1,164**	**6,362**	**114**	**119**	**484**	**318**

Further European countries with a limited sample size (n<100) are analyzed in the group of "other countries". The core country pattern is consistent: national differences mainly concern the intensity of certain outcomes, not the overall direction of results. The evaluation follows the approach of the selected analysis model, i.e., the results are presented from customer expectations to satisfaction results down to the assessments of future autonomous mobility.

6.1.1 Relevance of and engagement with ADAS systems from customers' perspectives

Across all markets, engagement with the topic of driver assistance systems prior to vehicle purchase is moderate to low, with a total mean score of 3.15 (see figure 9). Therefore, ADAS does not play a very important role for users if they plan to buy a new car. ADAS systems are not vital for brand and vehicle choice as well – less than 40% stated that ADAS is decisive for brand and vehicle choice. The results are consistent across all countries, even if some differences can be observed.

While Germany and Switzerland show slightly higher involvement, Austria, Hungary, and Italy remain below the overall average, just one third of users postulates intense interest in that topic. Despite these variations, the overall differences between countries are relatively small, indicating a broadly consistent level of pre-purchase consideration across markets.

Core research message: overall engagement with driver assistance systems prior to purchase is moderate-low. Although Germany and Switzerland reported slightly higher values, the relatively small cross-country differences indicate a broadly consistent pattern across markets.

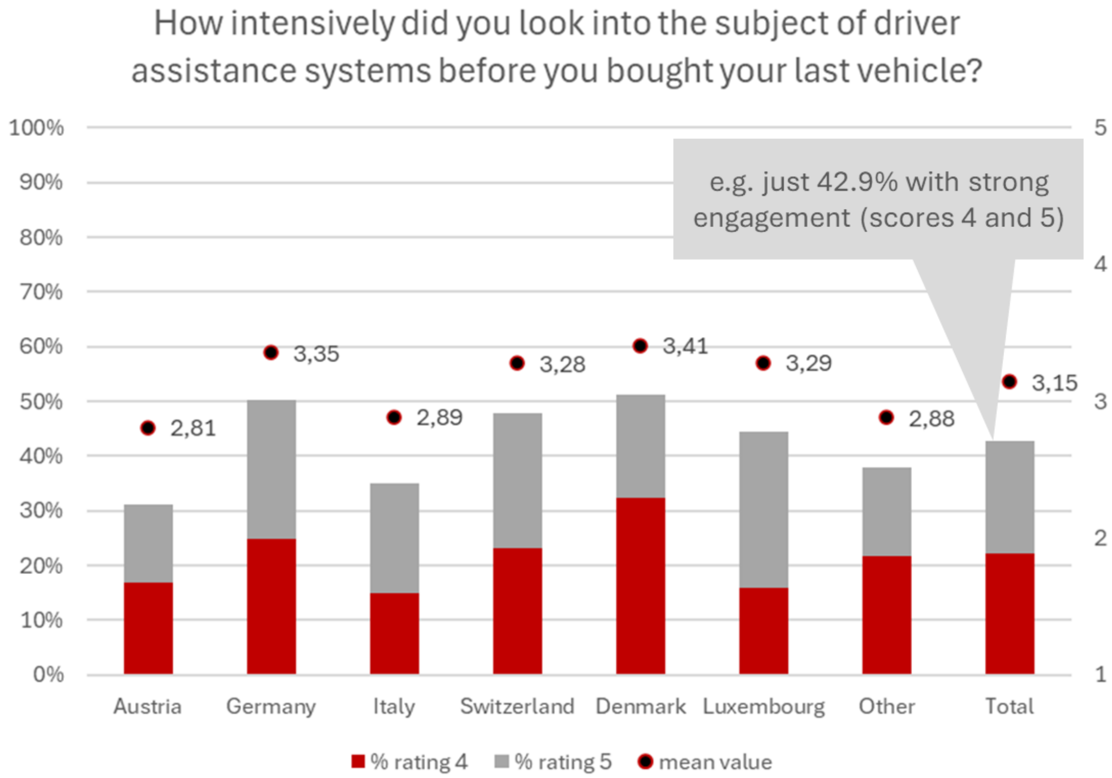


Figure 9: New car customer engagement with ADAS in the new car purchasing process (score 4: intense engagement / score 5: very intense engagement)

The next question is about familiarization with ADAS technologies by users. The results show that self-familiarization without instructions is the most frequently reported approach across all markets, with particularly high shares in Germany (59.3%), and especially Denmark (67.2%). It is striking that “No conscious familiarization” is especially high in Austria (30.6%) – this could be one reason for user acceptance problems. Dealer-based instruction reaches its highest level in Switzerland (49.4%), Austria (47.8%) and Denmark (40.5%). But is notably low in e.g. Germany (31.3%), Italy (31.9%) and Luxembourg (27.4%). See table 5 for a summary.

Table 5: How users get familiarized with ADAS systems

FAMILIARIZATION WITH ADAS BY…	…THE DELIVERING CAR DEALER (E.G. INSTRUCTION BY THE SALESPERSON)	…THE CAR MANUFACTURER'S INFORMATION CHANNELS (E.G. VIDEO/OPERATING INSTRUCTIONS, …)	…FREE INFORMATION CHANNELS (E.G. VIDEO, ONLINE FORUMS, ETC.)	I FAMILIARIZED MYSELF WITH THE SYSTEM WITHOUT INSTRUCTIONS	NO CONSCIOUS FAMILIARIZATION
Austria	47,8%	42,5%	27,6%	55,5%	30,6%
Denmark	40,5%	37,6%	20,3%	67,2%	7,5%
Germany	31,3%	46,6%	34,0%	59,3%	23,4%
Italy	31,9%	34,0%	30,9%	58,5%	19,1%
Luxembourg	27,4%	38,9%	31,0%	54,9%	9,7%
Switzerland	49,4%	45,2%	31,6%	58,9%	21,1%
Other	26,2%	43,8%	33,9%	61,3%	19,2%
Total	38,1%	44,8%	31,5%	57,9%	25,9%

Core research message: Self-familiarization dominates across markets (total value 57.9%), with Switzerland showing the highest focus on dealer instruction (49%), while Austria reports the highest shares of “no conscious familiarization” (30.6%). Greater engagement with ADAS technologies in Denmark (in Denmark “no conscious familiarization” shows the lowest share at all) may also lead to better customer satisfaction and acceptance.

Although the introduction to the systems reveals weaknesses, most customers feel relatively comfortable with the systems. This is somehow a contradiction and could result in a lack of system understanding due to the misjudgment of one's own abilities.

6.1.2 Customer expectations and fulfilment rates for ACC and LKA

Expectations are a decisive factor in the evaluation of user satisfaction with driver assistance systems (ADAS). Satisfaction is shaped less by the absolute technical performance of a function than by the extent to which it meets or exceeds what drivers anticipate. High expectations that remain unfulfilled often lead to disproportionately critical assessments, whereas moderate expectations that are met can generate comparatively positive satisfaction ratings.

Consequently, a systematic consideration of user expectations is indispensable for interpreting satisfaction scores and for identifying potential mismatches between technological performance and driver needs.

For both -ACC and LKA- the **core expectations** are very clear and in this order:

1. **Safety** plays the most important role, followed by
2. **Comfort** expectations, next is about
3. **Stress** reduction (interdependent with safety and comfort, but not mentioned as a primary factor)
4. Increased **driving pleasure** (which is not so relevant for users).

For **Adaptive Cruise Control (ACC)**, expectations are consistently high and largely met across all dimensions, with a slight over-fulfilment in driving pleasure (see figure 10). In contrast, **Lane Keeping Assist (LKA)** shows markedly lower expectations and even lower fulfilment values, particularly for comfort and stress reduction.

Overall, ACC is perceived as a reliable and beneficial system, whereas LKA remains associated with limited user confidence and comparatively low satisfaction. Both systems reveal a clear expectation–fulfilment gap, yet the magnitude differs between ACC and LKA.

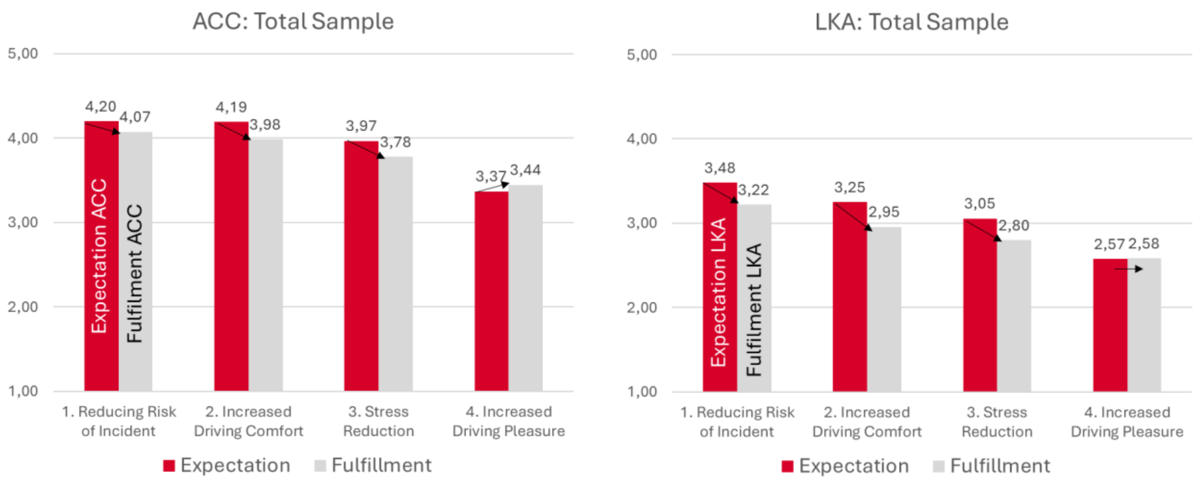


Figure 10: Driver expectations and fulfillment levels for ACC

Core research message: ACC shows high expectations largely met, while LKA reveals lower expectations and consistently weaker fulfilment. Safety and comfort benefits are in the expectation focus of users. These expectations need to be met to get satisfied users. Driving pleasure is obviously not so important to customers, so a certain degree of indifference can be assumed here.

6.1.3 Customer satisfaction and trust for ACC and LKA

Satisfaction and trust are key drivers of user acceptance of advanced driver assistance systems (ADAS). Without both, technologies will neither be fully accepted nor consistently used in everyday driving. Figure 11 shows the user satisfaction scores for the given countries. The research results are very clear: across all markets, satisfaction with ACC consistently exceeds LKA, indicating systematically higher user acceptance of ACC.

Across all markets, **satisfaction** with Adaptive Cruise Control (ACC) clearly exceeds that of Lane Keeping Assist (LKA). Particularly in Austria and Luxembourg, LKA satisfaction reaches the lowest levels (3.13 and 3.01), while Switzerland and Germany show comparatively higher evaluations for both systems. Denmark stands out relatively clearly with good satisfaction ratings – scores are much above the average and above all countries. This is a remarkable result for Denmark

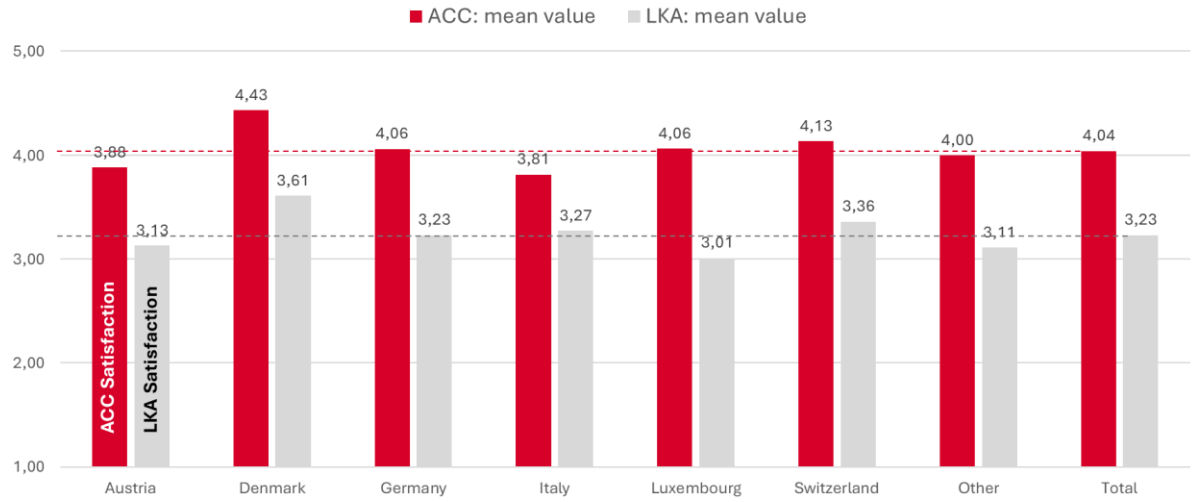


Figure 11: User satisfaction scores for ACC and LKA across countries

Core research message: the consistently observed gap between ACC and LKA across countries indicates a systematic difference in user acceptance, with ACC being more positively perceived. Denmark shows significantly better results. Austria shows low levels for ACC and LKA.

Net satisfaction score (NSS) - the conducted customer satisfaction measurement uses the concept of the net promoter score (NPS) (Reichheld et al., 2021). For this research a net satisfaction score (NSS) is applied. The NSS identifies the share of satisfied customers versus the dissatisfied one. For this purpose, scale ranges 1 and 2 are defined as detractors (range of dissatisfaction). Scale ranges 3 and 4 do not indicate complete satisfaction, i.e., no enthusiasm is triggered in the customer (see also Kano, 1984). Only the scale value 5, "completely satisfied", is considered as promoter, since only this leads to a clear positive confirmation. Subtracting the detractors from the promoters results in the net satisfaction score (NSS). This procedure clearly represents which state of satisfaction predominates. Theoretically, a result spectrum between +100% (all users are completely satisfied, scale 5) and -100% (all users are completely or partially dissatisfied, scales 1 and 2) is possible. A reading example for Austria: according to the survey results, the difference between very satisfied and not and not very satisfied drivers is 14.1 percent points for LKA (see figure 12).

NSS results reveal a consistent divergence between Adaptive Cruise Control (ACC) and Lane Keeping Assist (LKA). ACC achieves clearly positive net satisfaction across all countries, with the highest values clearly observed in Denmark (57.6%) – again a strong difference to the other countries. Denmark is the only country with a positive NSS for LKA.

In contrast, LKA records uniformly negative NSS results, with the lowest levels in Austria, Germany and Luxembourg. This systematic gap highlights ACC as a technology that is broadly accepted and valued by users, whereas LKA faces persistent skepticism and lower satisfaction.

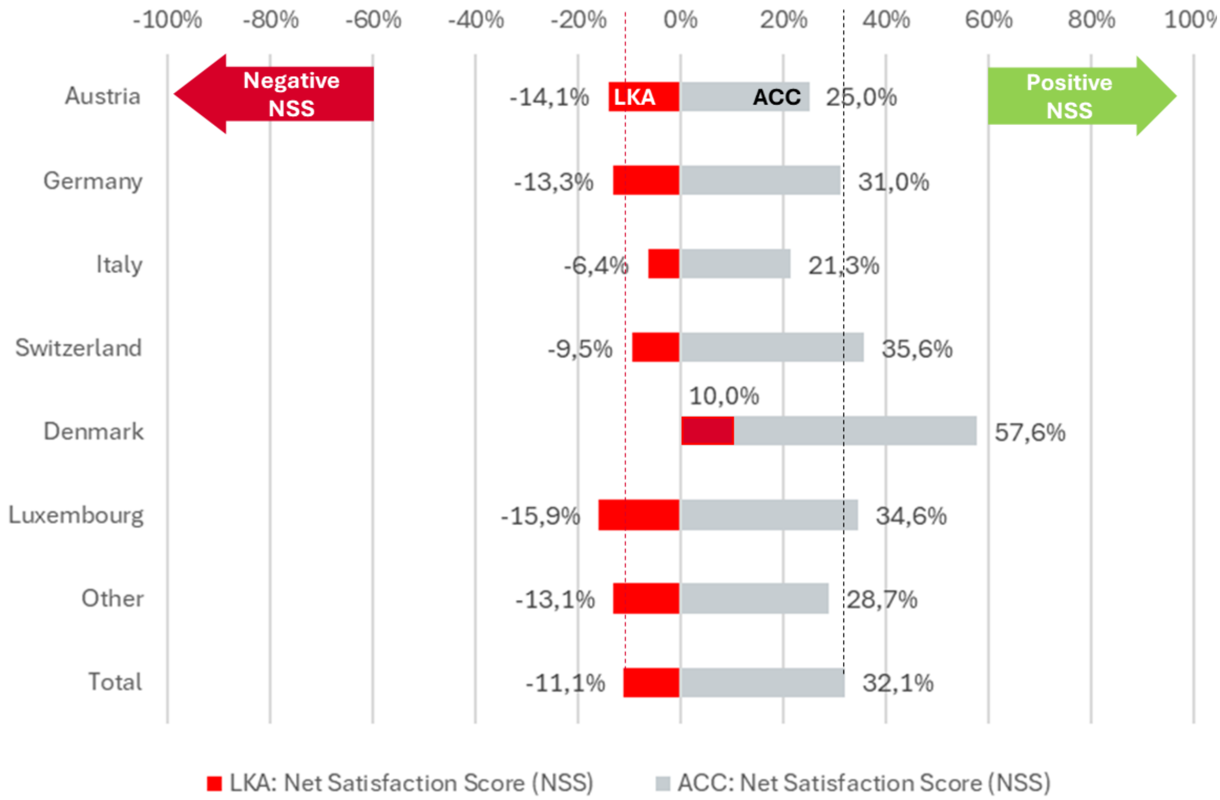


Figure 12: Net satisfaction scores (NSS) for ACC and LKA across countries

Furthermore, no statistical correlation is observed between vehicle age and satisfaction with either system. A reason for the missing correlation could be rising expectations of new car customers – new technologies need to perform better according to rising expectations.

Trust correlates very strongly with satisfaction: low satisfaction leads to an even greater loss of trust (see figure 13). Across all markets, satisfaction with Lane Keeping Assist (LKA) is consistently higher than trust, with an overall mean score of 3.23 for satisfaction compared to a mean score of 2.80 for trust.

This reflects a systematic gap of 0.43 points between satisfaction and trust, which corresponds to a relative reduction of approximately 13% from satisfaction to trust. While the magnitude varies slightly between countries, the decline is evident in every case, highlighting that positive satisfaction ratings do not directly translate into equivalent trust in the system. In the LKA context – low satisfaction level reinforces low trust. Again, satisfaction and trust scores are highest in Denmark. In comparison, Austrian drivers trust LKA the least.

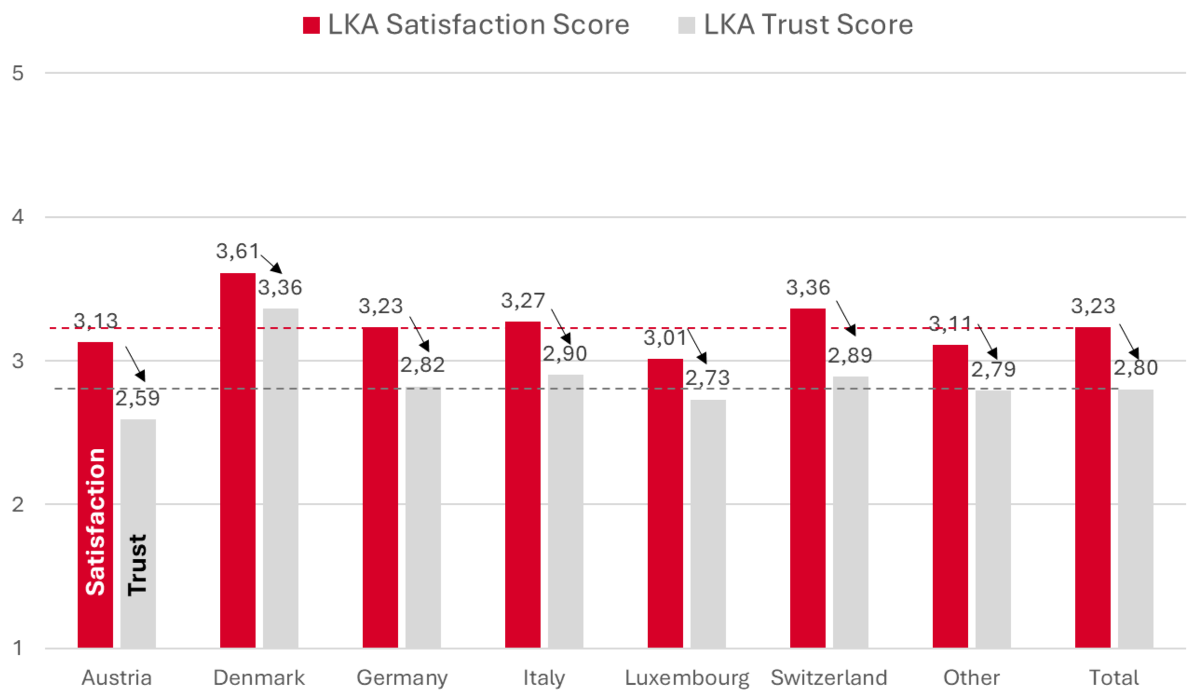
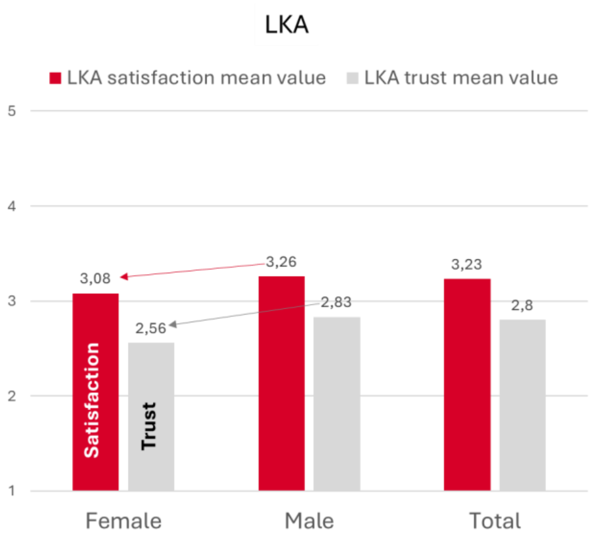


Figure 13: Mean scores for user satisfaction and user trust for LKA

According to recommendation rates, ACC is showing much better results compared to LKA. ACC with rates consistently above 80% across countries, for total sample 86%. LKA with rates of +/- 60% (this appears to be a poor result).

What is the **gender impact** on satisfaction levels for ACC and LKA? Males report higher LKA satisfaction (3.26 vs. 3.08) and trust (2.83 vs. 2.56) than females. However, the "total" values confirm the same pattern: moderate satisfaction, distinctly lower trust for LKA. ACC satisfaction exceeds 4.0 for males and 3.82 for females. ACC trust values remain high for both genders, but again on different levels (3.30 vs. 3.81).



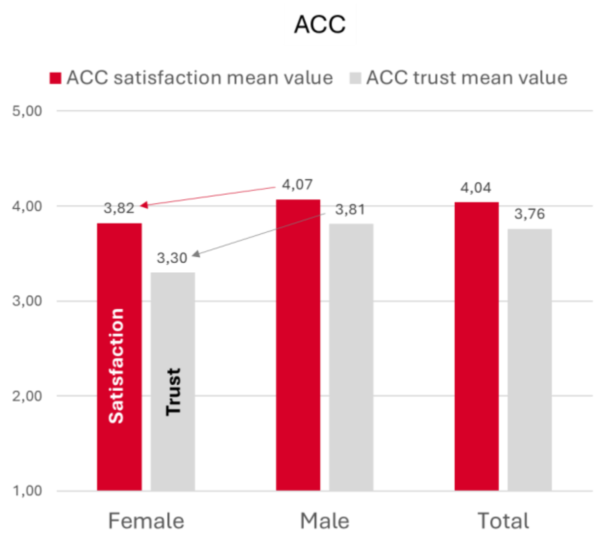


Figure 14: LKA and ACC satisfaction and trust results by gender

Gender impacts in the country comparison: Denmark shows the highest share of male respondents, and this demographic structure aligns with the pattern of elevated satisfaction scores. The strong male representation coincides with the already high national satisfaction levels, suggesting that the Danish sample combines a user group with generally positive system evaluations and a gender distribution that - based on the broader dataset - tends to report slightly higher satisfaction. The survey results therefore indicate a certain gender impact on ADAS acceptance.

Core research message: for LKA a mismatch between expectations and experiences is resulting in moderate/poor satisfaction scores. This satisfaction perception is influencing trust badly what could logically impact usage behavior. For all countries trust scores are always below 3.0 – except for Denmark. Male drivers tend to be slightly more satisfied and trust more.

Besides the correlation between gender and satisfaction, the study observes the impact by **user familiarity**. The correlation seems to be very strong (see figure 15). Users who feel very familiar with the system are e.g. satisfied with LKA (score 3.49), while that score is 1.80 for users who say they are not familiar with LKA. The satisfaction level is twice as high – a remarkable survey result and important for later conclusions on industry implications.

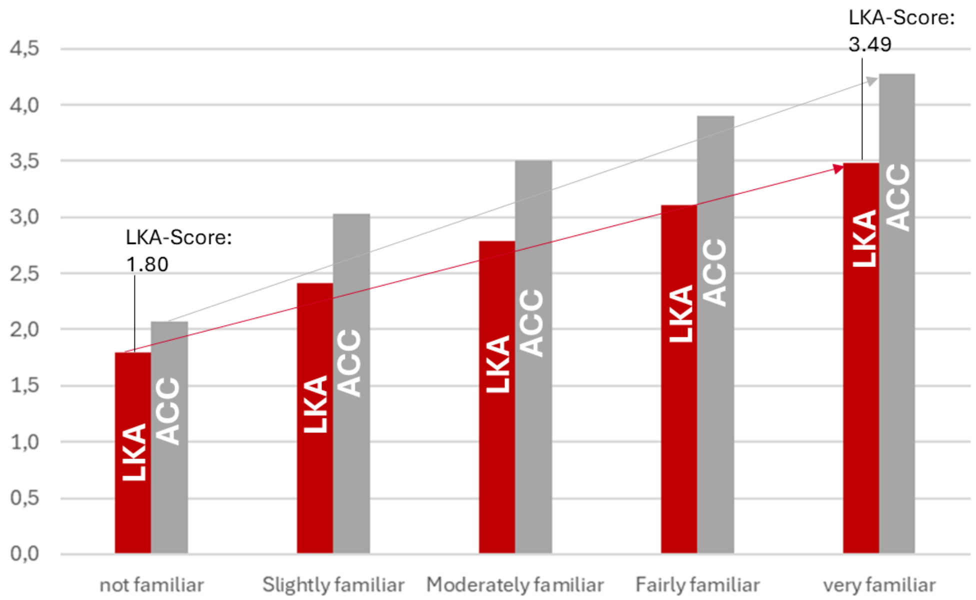


Figure 15: User familiarity with technology correlates strongly with satisfaction scores

Another question is whether the **road situation influences satisfaction levels** – the answer is yes. While LKA especially works well on motorways, performance on country roads seems to be much lower. Empirical evidence is shown by figure 16: average NSS for LKA is -24% for country roads. The corresponding score for highways is -7.5%, which is significantly better. Improvements in traffic safety through ADAS would primarily affect rural roads, but the systems appear to perform less well here than on highways. That seems to be a core weakness of e.g. LKA.

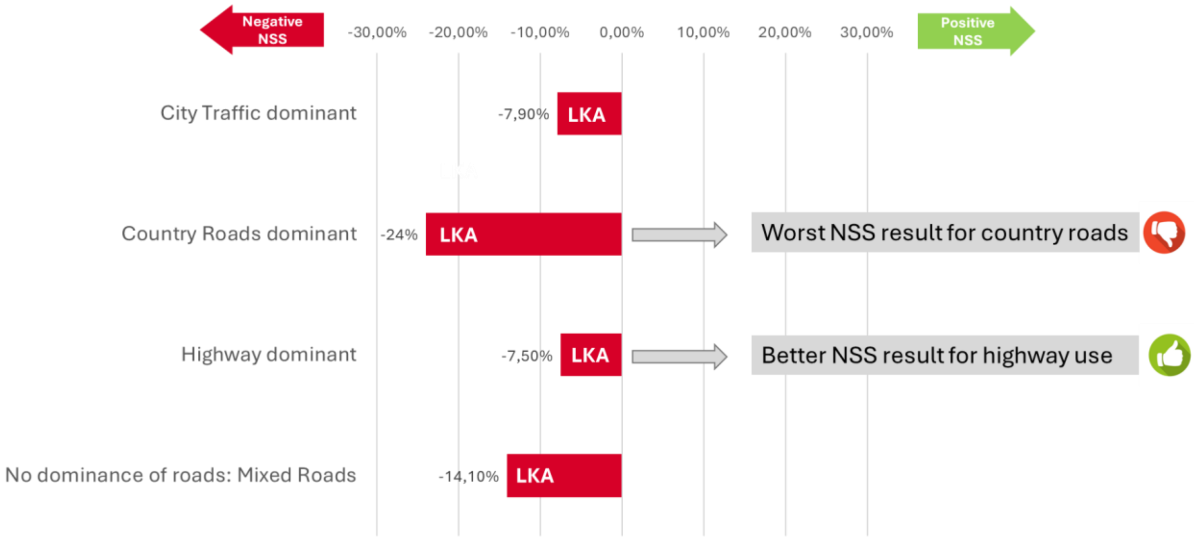


Figure 16: Impact on satisfaction by road situation* **DK and LU not in sample*

Figure 17 summarizes the first survey results: the consumer survey indicates correlation between gender, driver profiles, familiarization and road situation on one side, and satisfaction with ADAS on the other.

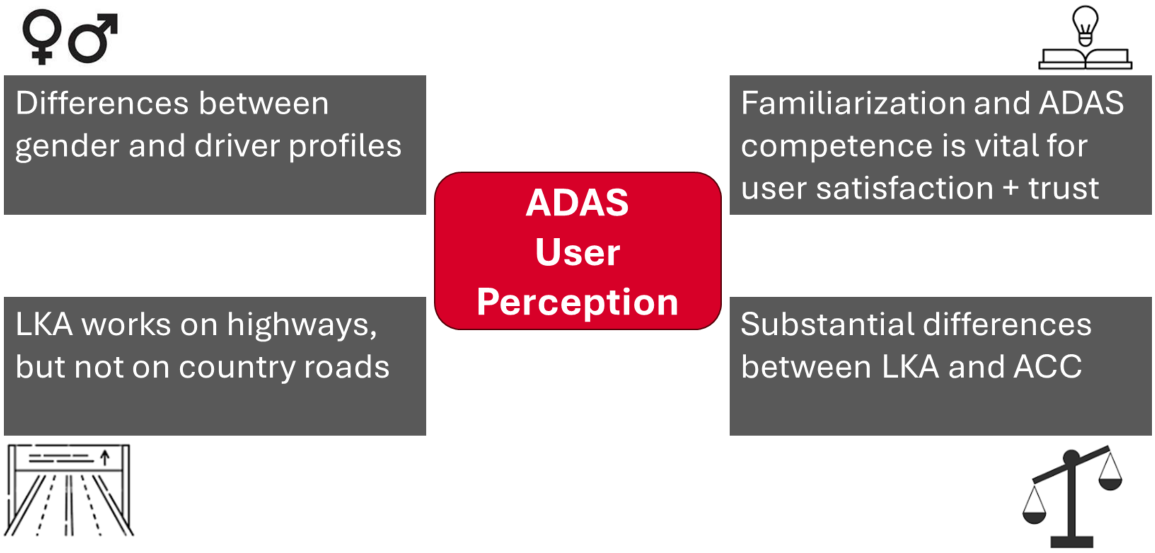


Figure 17: Summary of satisfaction results

6.1.4 Satisfaction and Dissatisfaction drivers for ACC and LKA

Overall satisfaction with advanced driver assistance systems (ADAS) results from the interplay of multiple subfactors, such as usability, reliability, and perceived safety. To fully understand user acceptance of systems like ACC and LKA, these dimensions need to be evaluated individually as well as in their combined effect on overall satisfaction. Following the core results for ACC and LKA are listed.

ACC satisfaction and dissatisfaction drivers

Major ACC factors are rated very positive (table 5). The overall ACC result is therefore satisfying. ACC is rated highly for usability, safety benefits, and reliability. These core features consistently dominate user satisfaction, with particularly high values in Denmark, Switzerland and Germany, underlining the perceived ease of use, safety benefits, and dependable performance of the system. By contrast, features such as customizability and functioning in all road or weather situations receive slightly lower ratings, though this pattern is consistent across most markets.

Table 6: Drivers of user satisfaction for ACC

Rank	ACC feature ranked by Satisfaction Score	TOTAL Ranking	Austria	Germany	Italy	Switzerland	Denmark	Luxembourg
1	Operation and usability	4,02	3,87	4,04	3,87	4,16	4,34	3,96
2	Sense of security	3,91	3,77	3,92	3,84	3,99	4,25	3,82
3	Reliability	3,90	3,79	3,90	3,79	3,97	4,25	3,98
4	System precision	3,87	3,74	3,86	3,59	3,98	4,29	4,06
5	Reaction speed	3,80	3,72	3,77	3,65	3,88	4,13	3,92
6	Traceability of system actions	3,63	3,55	3,67	3,43	3,68	3,69	3,47
7	Function in all road situations	3,54	3,48	3,50	3,52	3,50	3,92	3,61
8	Function in all weather situations	3,51	3,45	3,48	3,53	3,44	3,83	3,55
9	Customizability	3,46	3,30	3,43	3,32	3,59	4,00	3,70

Some highlights of ACC evaluation by country:

- Denmark shows consistently outstanding satisfaction across all ACC dimensions, with top scores in operation/usability (4.34), sense of security (4.25), reliability (4.25) and system precision (4.29). This pattern indicates a substantially higher perceived performance and trust level compared to the overall average.
- Switzerland combines high ratings in usability (4.16), precision (3.98) and reliability (3.97). Its profile reflects a uniformly strong system evaluation without extreme variance across features.
- Germany records above-average scores in key performance-related attributes such as usability (4.04) and reliability (3.90), pointing to robust perceived system stability and operational clarity.

- Luxembourg stands out selectively through strong evaluations in system precision (4.06) and reliability (3.98), suggesting specific strengths in system accuracy, despite more moderate values in other dimensions.
- Austria and Italy show comparatively lower satisfaction across multiple attributes, marking them as consistently below-average countries relative to others.

LKA satisfaction and dissatisfaction drivers

LKA shows a different picture (table 6). Many factors indicate problems out of users' perspectives. For Lane Keeping Assist (LKA), operation/usability is the only very positively rated factor, with strongest results in Denmark, Switzerland and Germany. All other dimensions receive just moderate or even negative evaluations, particularly customizability and functions in all road and weather situations, which represent the weakest aspects across markets. Putting this analysis in the context of figure 16 (see chapter 6.1.3), it confirms the very weak results for LKA in terms of "function in all road situations". As underlined before, influence of the road situation on the system's performance seems to be very strong. Drivers who mostly use highways show significant higher satisfaction compared to those who mostly use country roads.

Overall, the results highlight that while LKA is perceived as easy to use, it lacks acceptance in terms such as reliability, adaptability, and safety: critical factors for trust and broader adoption.

Table 7: Drivers of user satisfaction for LKA

Rank	LKA feature ranked by NSS result	TOTAL Ranking	Austria	Germany	Italy	Switzerland	Denmark	Luxembourg
1	Operation and usability	3,63	3,47	3,68	3,36	3,79	3,92	3,43
2	Reaction speed	3,38	3,30	3,39	3,33	3,41	3,65	3,29
3	Reliability	3,16	3,10	3,13	3,27	3,13	3,52	3,09
4	Sense of security	3,10	3,02	3,09	3,17	3,19	3,43	2,95
5	System precision	3,10	3,03	3,07	3,14	3,16	3,48	3,07
6	Traceability of system actions	3,01	2,95	3,02	2,96	3,11	3,15	2,95
7	Function in all weather situations	2,98	2,97	2,94	3,13	2,96	3,15	2,99
8	Function in all road situations	2,98	2,97	2,94	3,13	2,96	3,15	2,99
9	Customizability	2,75	2,71	2,68	2,67	2,78	3,18	2,85

Some highlights of LKA evaluation by country:

- Again, it is Denmark which exhibits the strongest overall evaluation of LKA, with leading scores in usability (3.92), reaction speed (3.65), reliability (3.52) and precision (3.48). The pattern indicates comparatively higher confidence in system responsiveness and stability.
- Switzerland shows consistently above-average ratings across central dimensions such as usability (3.79), reaction speed (3.41) and action traceability (3.11). Its profile reflects a stable mid-to-high satisfaction cluster without pronounced weaknesses.

- Germany performs solidly in usability (3.68) and shows moderate but balanced evaluations in other core attributes (e.g., reliability 3.13; precision 3.07), suggesting a relatively homogeneous perception without extreme deviations.
- Austria and Italy stand out through slightly lower ratings across multiple dimensions, marking it as comparatively critical markets in the LKA context.

Core research message: compared to Lane Keeping Assist (LKA), Adaptive Cruise Control (ACC) shows consistently higher evaluations across all subfactors, with usability, reliability, and perceived security as clear strengths. LKA, by contrast, is rated positively only for usability, while all other dimensions remain negative, highlighting fundamental limitations in user trust and acceptance.

6.1.5 Usage profiles for ACC and LKA

After analyzing the satisfaction and trust levels, the next question is about usage rates. The results show clear differences in the use and deactivation of ACC and LKA.

ACC achieves the highest positive values for active use, indicating that a majority of drivers employ the system frequently and only rarely switch it off. In contrast, LKA exhibits lower active use scores and substantially higher switch-off rates, reflecting limited user acceptance and more frequent disengagement.

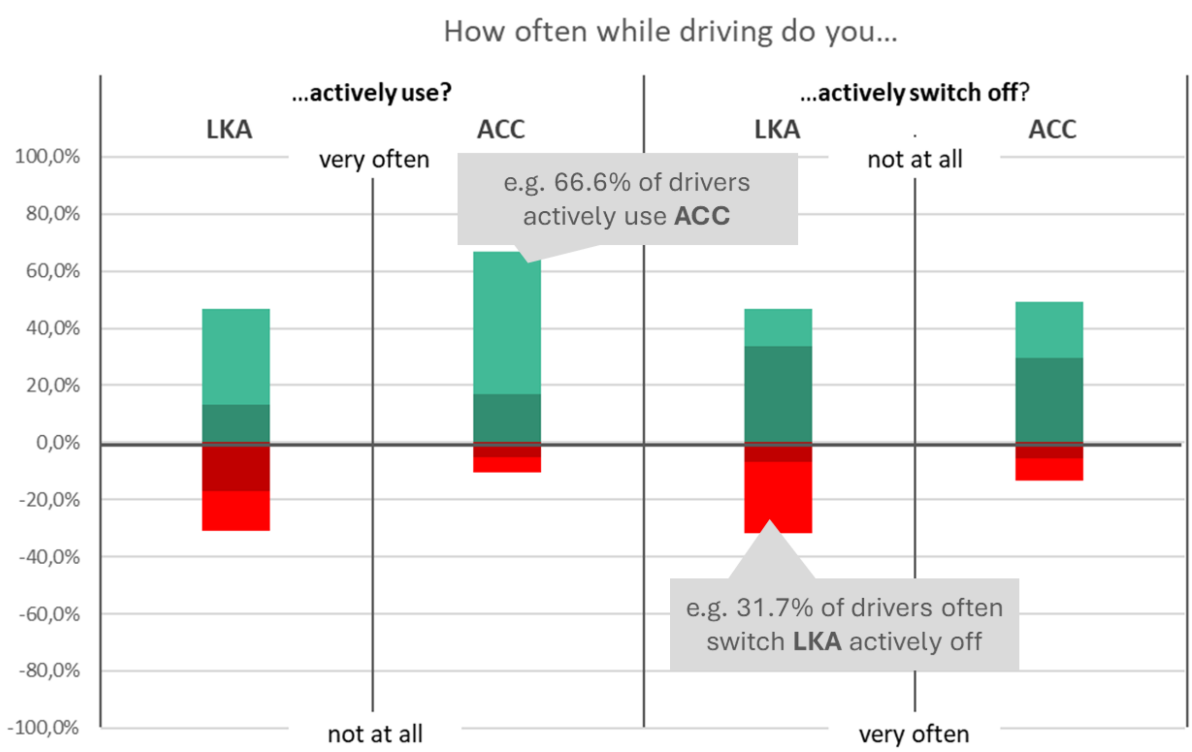


Figure 18: Usage and switch off rates for ACC and LKA (total sample)

The red segments of the chart highlight negative extremes, i.e., respondents who either do not use the system at all or who very often switch it off. For LKA, the red share is clearly larger in both dimensions, indicating a substantial proportion of drivers who actively avoid or disable the system.

By contrast, ACC shows much smaller red segments, reflecting that only a minority refrains from use or frequently deactivates it. This pattern underscores a markedly higher application intensity and everyday integration of ACC compared to LKA.

However, it is remarkable that Danish drivers use ACC and LKA significantly more often. The correlation seems to be clear: drivers in Denmark are more satisfied, have higher trust and use ACC and LKA much more often. This is a remarkable study outcome and underlines how vital satisfaction and trust for technology acceptance and trust is.

Core research message: the data highlight ACC as a system integrated into everyday driving, while LKA is more often actively deactivated and thus less trusted in practice. The relationship between satisfaction, trust and usage seems to be very strong.

Top 3 reasons for deactivation of LKA (total sample)**:**

The survey concept incorporated main reasons why users de-active LKA. Core reasons are:

1. Unpleasant intervention of the system: 54.4%
2. Lack of reliability: 32.8%
3. Unpleasant system warnings: 27.9%

Unpleasant intervention of the system is especially an issue for German users (62.5%) while again users from Denmark complain less (30.9%) But even for Denmark it is the most important reason to switch LKA off.

Top 3 reasons for deactivation of ACC (total sample)**:**

Even if the share of people who actively de-actives ACC is very low, what are the reasons for deactivation? The core results are:

1. Unpleasant intervention of the system: 41.3%
2. Loss of control: 22.5%
3. Lack of reliability: 18.4%

Again, deactivation is driven by unpleasant intervention of the system. Again, German users are complaining the most about that issue (50.9%). Danish drivers complain less (just 16.7%) – their main reason for deactivation of ACC is loss of control (29.4% - which is above the average).

6.1.6 Consequences for system improvements

Satisfaction and trust results require a deeper dive into those determinants which could improve performance of ACC and LKA. Following, core aspects for ADAS improvement are described. Therefore, users were asked to name the core aspects to improve ACC and LKA.

Top 5 aspects to improve performance of LKA

Across all markets, the strongest improvement needs for Lane Keeping Assist (LKA) concern:

1. system precision (45.2%),
2. reliability (35.3%),
3. function across different road situations (34.3%),
4. traceability of system actions (29.7%), and
5. personalization (26.8%).

Aspects such as function in all-weather situations (25.1%), operation (14.4%), reaction speed (11.9%), and sense of security (13.3%) are mentioned less frequently, indicating comparatively lower priority compared to the points mentioned before. Overall, the results highlight that user expectations focus primarily on core performance and transparency rather than on minor usability aspects. Different to other areas, Danish drivers do not differ too much from the other ones – they state similar areas for improvement.

Top 5 aspects to improve performance of ACC

Adaptive Cruise Control (ACC) is seen less crucial, and satisfaction rates are much above LKA. However, even ACC can be optimized. Strongest ACC improvement areas concern:

1. system precision (33.0%),
2. followed by function in all-weather situations (30.3%),
3. function in all road situations (27.3%),
4. traceability of system actions (25.6%), and
5. personalization (23.8%).

Other factors such as reliability (23.1%), and reaction speed (19.4%) are of medium importance, while operation (16.0%) and sense of security (10.6%) are least frequently mentioned. This indicates that users primarily demand accuracy, transparency, and robustness across conditions, whereas usability and perceived security are seen as comparatively less critical issues. As mentioned before, Denmark often shows different results but not here – the requirements are similar to the other countries. However, different to the other countries “traceability of system actions” is not an issue for them – just 9.3% see immediate potential to improve.

Across markets, the most pressing improvement areas for ACC are linked to precision, adaptability under varying conditions, and system transparency, while usability-related aspects such as operation and perceived security are of lower priority.

6.1.7 Future innovation: customer attitudes towards autonomous mobility

Actual trust in ACC and LKA is linked to the believe in future technologies. Across all markets, belief in autonomous mobility remains moderate-low, with 41.9% of respondents expressing confidence in this technology (see figure 19).

The highest level of approval is observed in Germany (50.8%), which stands out clearly above the total average. In contrast, Austria (32.3%), Italy (32.5%), and Denmark (33.9%) report considerably lower values, indicating pronounced skepticism. Switzerland (41.3%) and respondents from other countries (43.2%) are closer to the overall mean, reflecting more balanced attitudes. It is remarkable that Danish drivers are more critical about autonomous mobility while their satisfaction with ADAS is significantly higher.

Taken together, the findings suggest that while there is a certain openness towards autonomous mobility, acceptance remains limited across all markets, and even in the most optimistic context, a substantial proportion of respondents continue to express reservations.

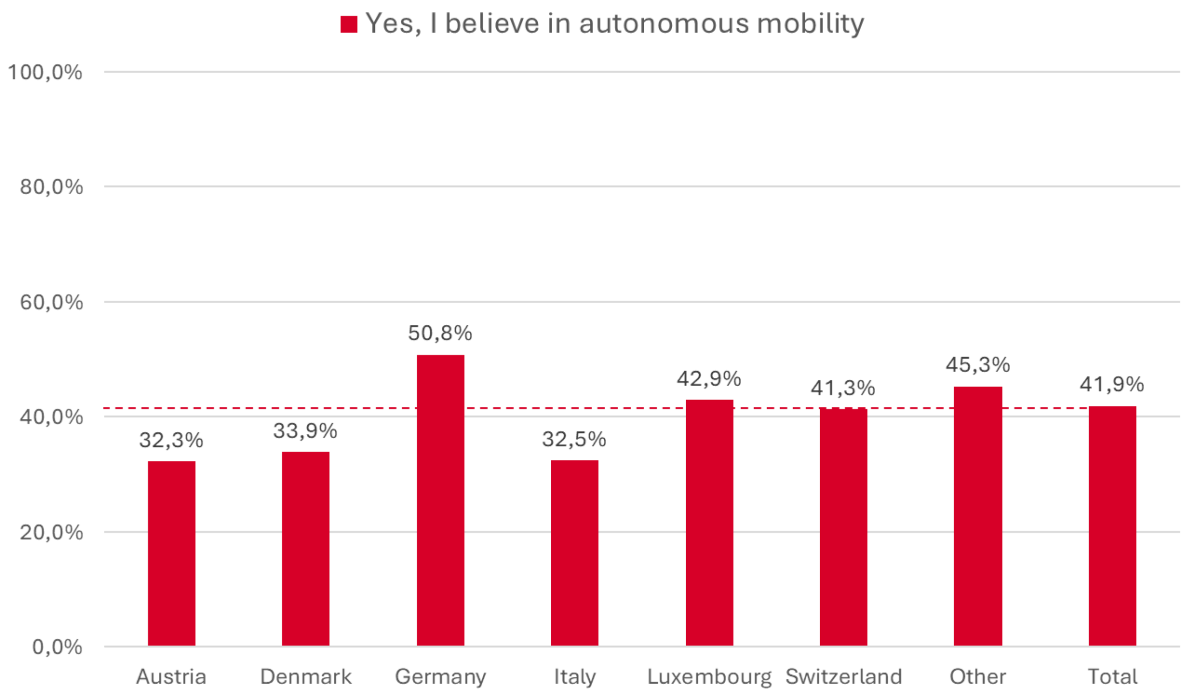


Figure 19: Believe in autonomous mobility across countries

Concerns about autonomous driving are especially about:

1. Liability issues (63.6% of total sample), and
2. Safety issues (54.7% of total sample).

Data protection problems are not so important (mentioned by 43.3%) compared to the first two major aspects.

If autonomous mobility were to become available, user preferences would primarily concentrate:

1. on highway trips (69.5%),
2. for shuttle services (63.6%),
3. for commuting to work (47.3%), and
4. for city traffic (44.6%).

These results suggest that respondents associate autonomous driving above all with longer-distance travel on highways. It is linked to the survey result that road situation is influencing ADAS performance.

6.1.8 Summary of results for consumer survey

The immense set of survey data can be summarized in our model below. The model illustrates the key influencing factors and their interrelations, showing how performance in precision, perceived security, stress reduction, and system intervention impacts satisfaction, trust, and ultimately system use. By mapping these connections, the model also highlights the central fields of action that need to be addressed in order to improve acceptance und usage of ACC and LKA.

ACC survey summary

The model demonstrates that Adaptive Cruise Control (ACC) is positively evaluated by users, with key strengths identified in reliability, perceived safety benefits, and comfort. These factors lead to a high overall satisfaction level (mean score: 4.04), which in turn translates into a high level of trust (mean score: 3.76).

This positive evaluation for ACC is reflected in actual usage behavior: 69% of drivers report using ACC frequently or all times, while only 12.8% actively switch the system off. Moderate complaints about system intervention are observed, yet they do not substantially undermine the positive assessment. Overall, the results indicate that ACC achieves both high satisfaction and trust, which are closely linked to widespread and consistent system use.

Figure 20: Summary of core survey results for ACC

LKA survey summary

Deficits for LKA in precision, perceived security, stress reduction, and system intervention directly undermine user satisfaction (total score 3.2), as expectations for safety and comfort remain unmet. More than 50% complain about unpleasant intervention of LKA – which increases the stress level and decreases trust. To conclude - moderate satisfaction translates into even lower trust levels (trust mean score = 2.80), with nearly one third of drivers not using the system (30.8%) and 30.7% actively switching LKA off and 29.7% ignore the assistance.

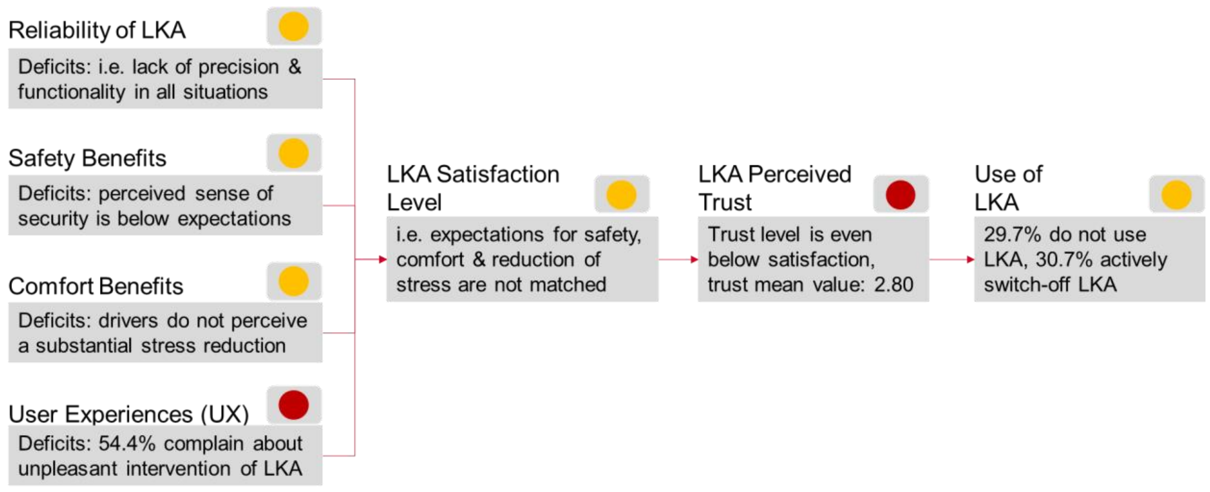


Figure 21: Summary of core survey results for LKA

Overall reflection: driver perceptions and attitudes on ACC and LKA

The comparative analysis of Lane Keeping Assist (LKA) and Adaptive Cruise Control (ACC) reveals substantial differences in user perception, satisfaction, trust and acceptance. While ACC is characterized by high satisfaction (4.04), strong trust (3.76), and frequent use (69% regularly, only 12.8% switch-off), LKA shows clearly lower satisfaction (3.2), even lower trust (2.8), and a high share of non-use (29.7%) or active switch-off (30.7%).

The underlying reasons diverge as well: for ACC, strengths lie in reliability, safety benefits, and comfort, with only moderate complaints about unpleasant intervention by the system. For LKA, persistent deficits in precision, reliability in different driving situations, stress reduction, and transparency lead to unmet expectations regarding safety and comfort, thereby undermining trust and reducing actual usage.

LKA's functionality outside of highways is often criticized. However, it is precisely on country roads that the greatest safety potential could be realized. Unfortunately, it is on country roads that its functionality is criticized. In summary, LKA often does not work in all driving situations in a proper way.

When considering the influence of drivers' behavior and attitude on satisfaction with the systems, hypotheses can also be derived here. The data indicates that tech-savvy users who engage intensively with the systems are more satisfied. This may be because certain system interventions are easier to understand. Ergo – users must be informed, trained, and also made aware of the limitations of the systems. This adjusts their expectations and understanding, which in turn has a positive influence on satisfaction.

Overall reflection: country results and highlights

Across the given countries, ACC achieves high satisfaction, trust, and frequent use, while LKA is marked by deficits that limit trust and lead to frequent non-use or deactivation. The core country pattern is consistent: national differences mainly concern the intensity of criticism, not the overall direction of results.

- Denmark: results of the survey in Denmark differ greatly from those in other countries (these, in turn, show relatively high levels of homogeneity). Users in Denmark are better informed, more satisfied, and also have greater trust in the systems. As a result, usage is also much more intense in Denmark – for both, ACC and LKA.
- Germany and Switzerland: show relatively slightly higher satisfaction and trust with both systems (above the average scores), though the gap between ACC (positive) and LKA (critical) remains pronounced.
- Austria and Italy: consistently more skeptical, Austria especially regarding LKA, with below-average trust and higher non-use.

Why are Danish people so much more satisfied? The study tries to explore this question with following assumptions:

- Danish users engage more intensively with ADAS (pre and after car purchase) and learn the systems more proactively. The proportion of people who do not engage with the systems is significantly smaller compared to other countries. At the same time, people are generally more interested and open to ADAS. This point might have a very strong impact on ADAS acceptance and satisfaction. What can the industry lean from that? Users need to be informed, to be trained and convinced about the benefits of ADAS. However, the principal issues often stay the same, but on a more positive level.
- With almost 95%, the share of male participants is very high – at the same time we identified a gender impact on satisfaction (for all countries). This is slightly influencing the results as well.
- A better road infrastructure might impact the results as well – especially due to the fact, that country roads with insufficient road markings impacting satisfaction scores badly.
- FDM promotes safety very strongly, e.g. in each car test ADAS is rated separately and the importance of ADAS for safety is underlined very strongly. In Denmark there is a very pro-active communication for ADAS.
- The car fleet is relatively young and cars are often high-end equipped. Due to the tax system combined with a newer car-fleet Denmark now has a strong market share of EVs.

These results are vital for industry and stakeholder implications and need for actions. It will be considered in the following chapters.

6.2 ADAS penetration study

6.2.1 German ADAS penetration

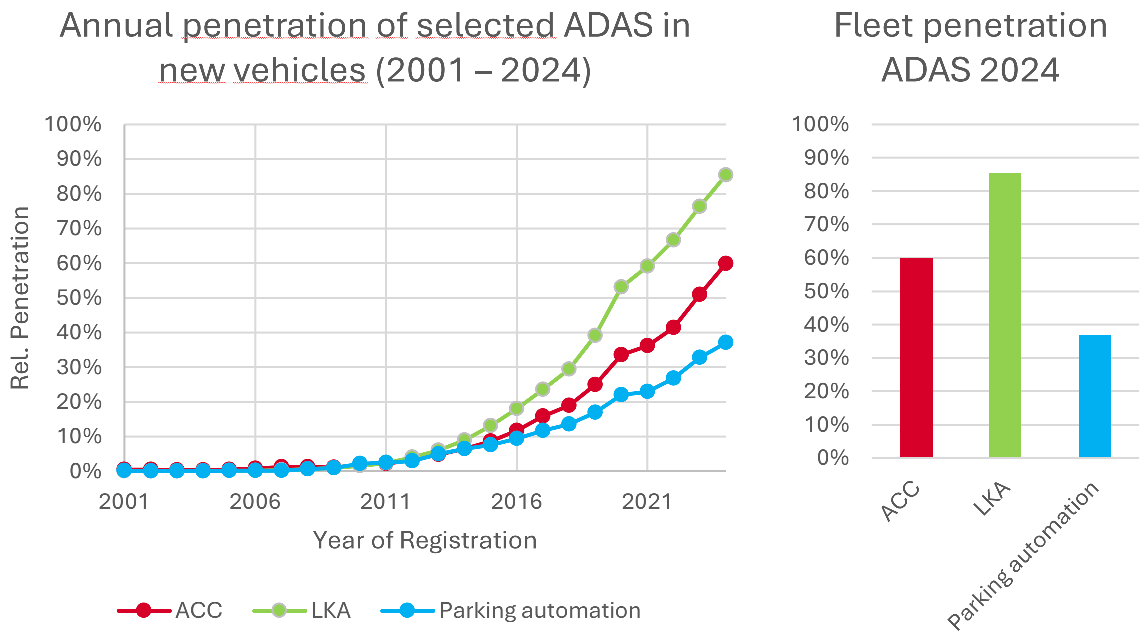


Figure 22: Development of new-vehicle ADAS penetration in Germany

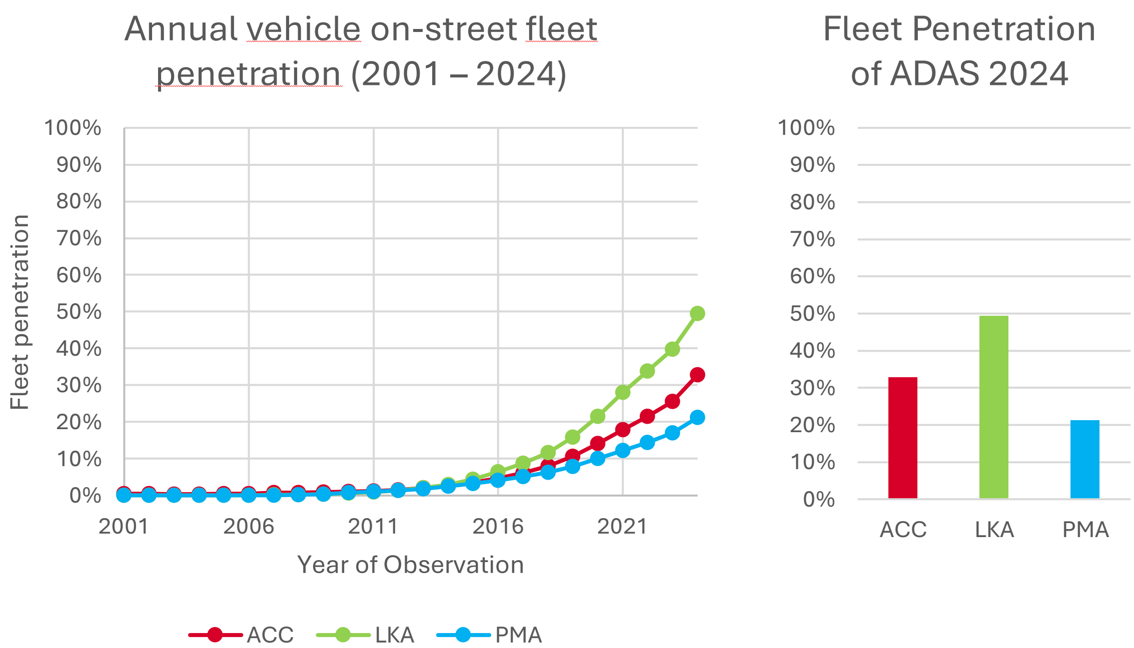


Figure 23: Development of on-street fleet penetration in Germany

6.2.2 Italian ADAS penetration

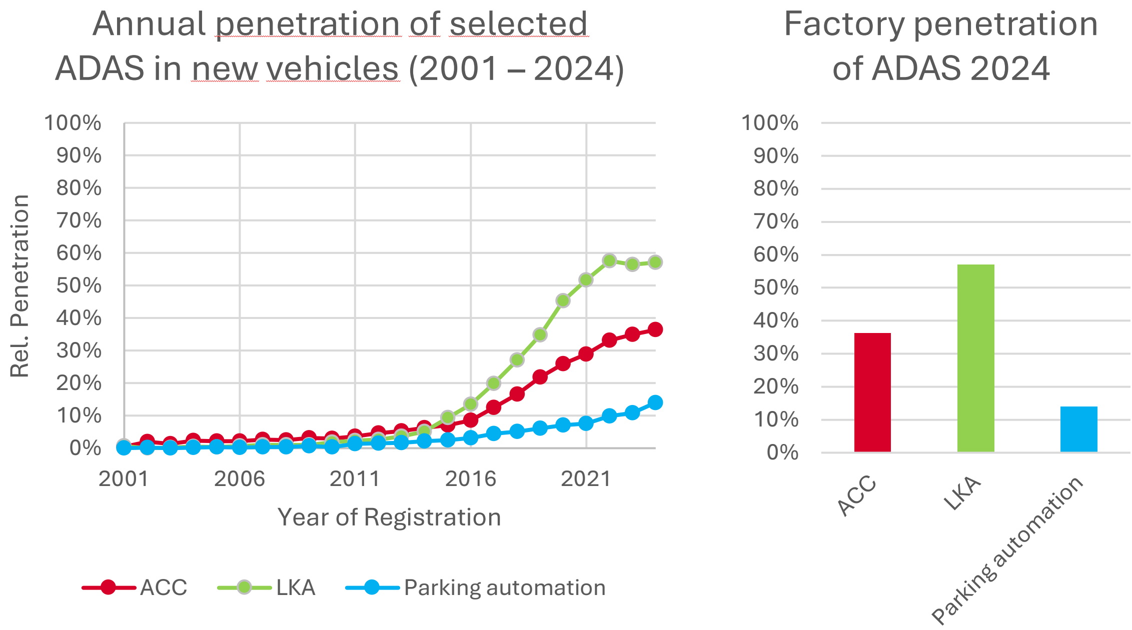


Figure 24: Development of new-vehicle ADAS penetration in Italy

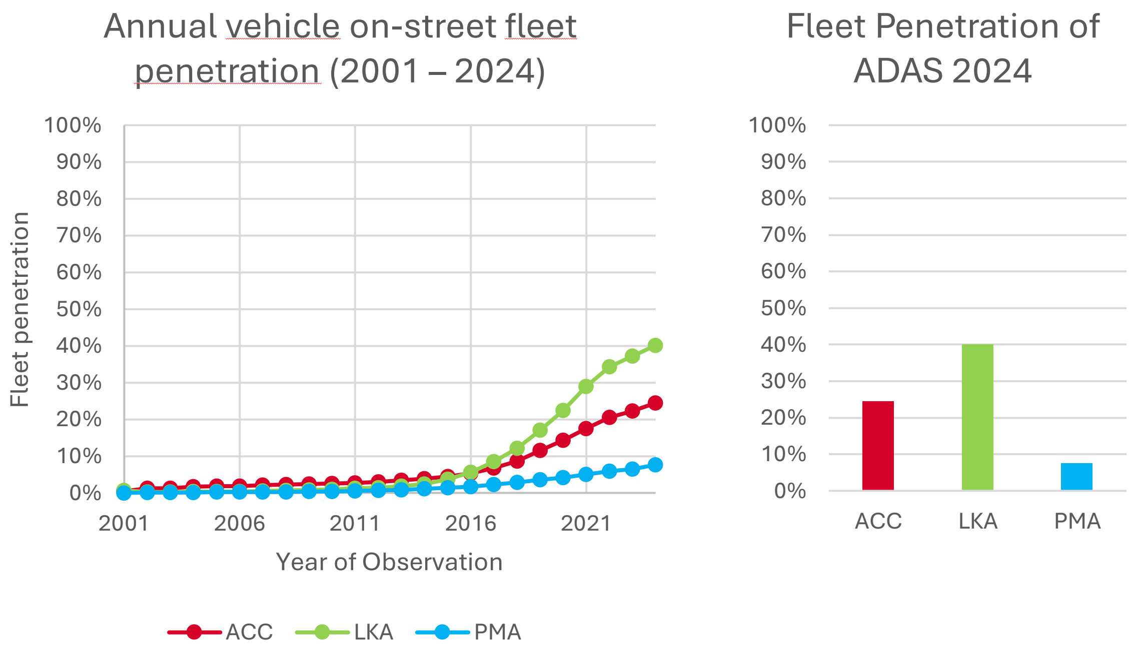


Figure 25: Development of on-street fleet ADAS penetration in Italy

6.3 European traffic safety statistics

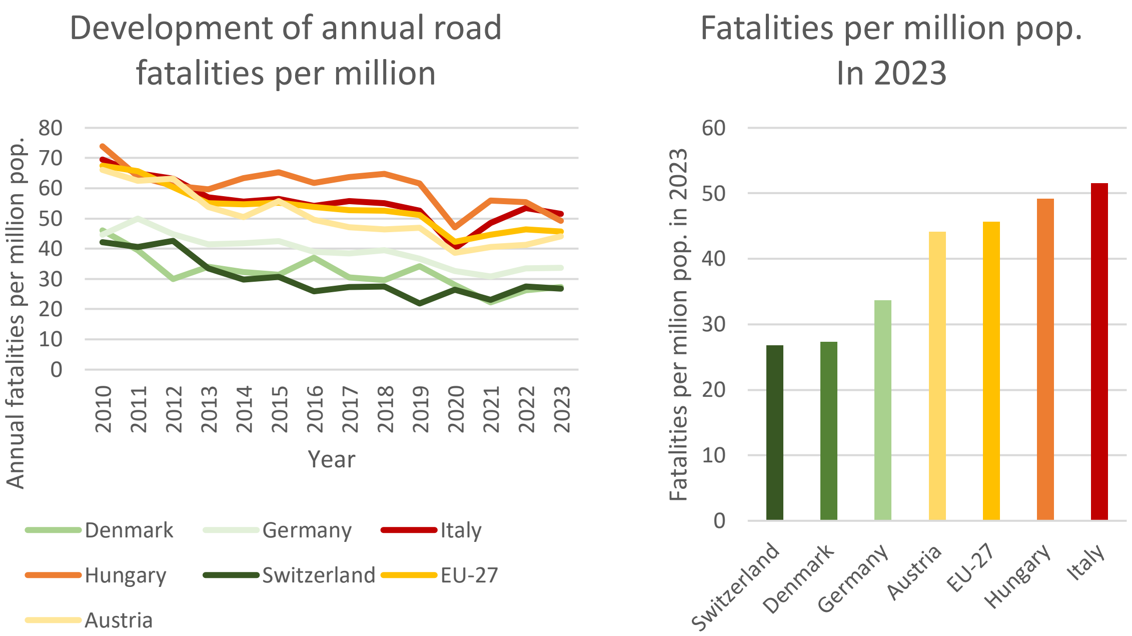


Figure 26: Traffic road safety related outcomes in selected focus countries in Europe

7 Discussion and insights

7.1 KPI reports

7.1.1 Safety

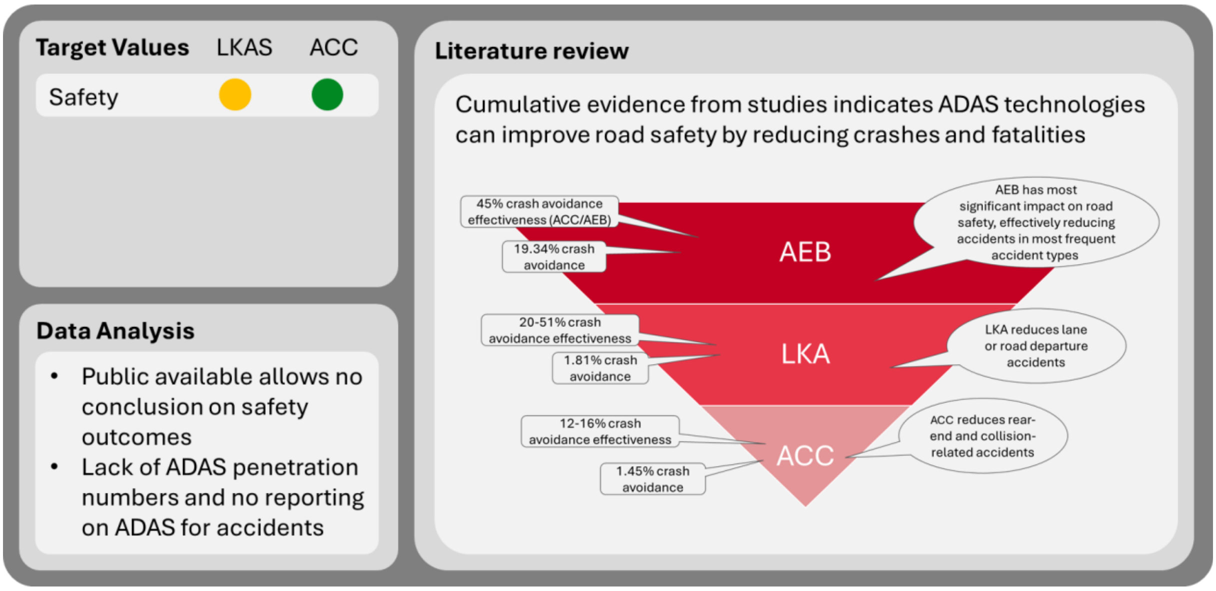


Figure 27: KPI dashboard for safety

7.1.2 Safety perception

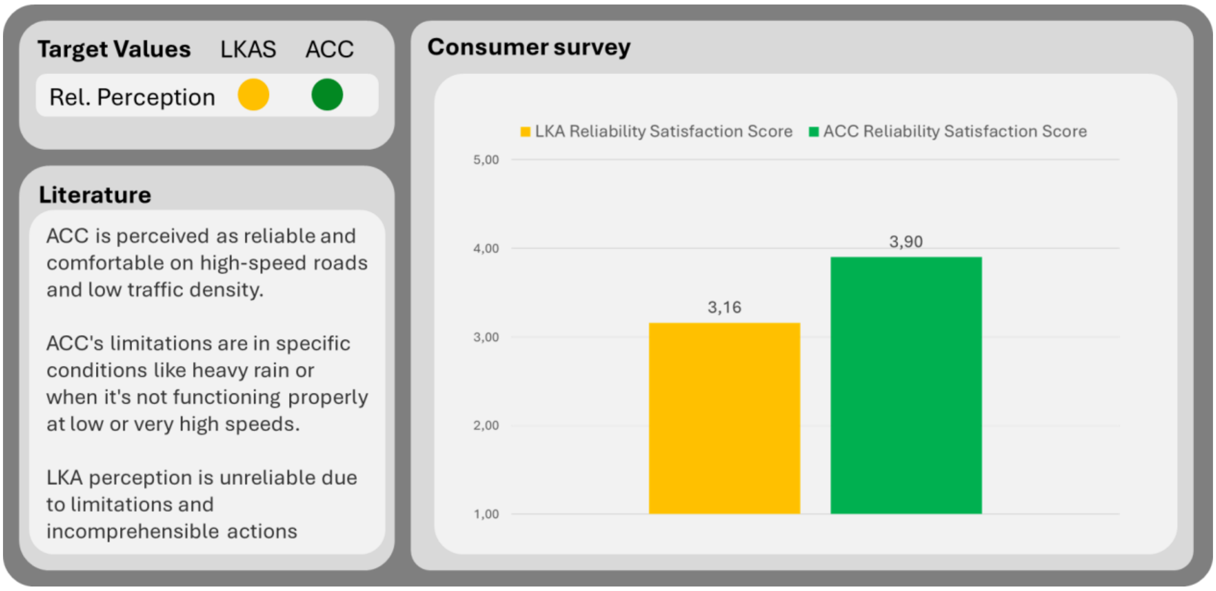


Figure 28: KPI dashboard for safety perception

7.1.3 Reliability

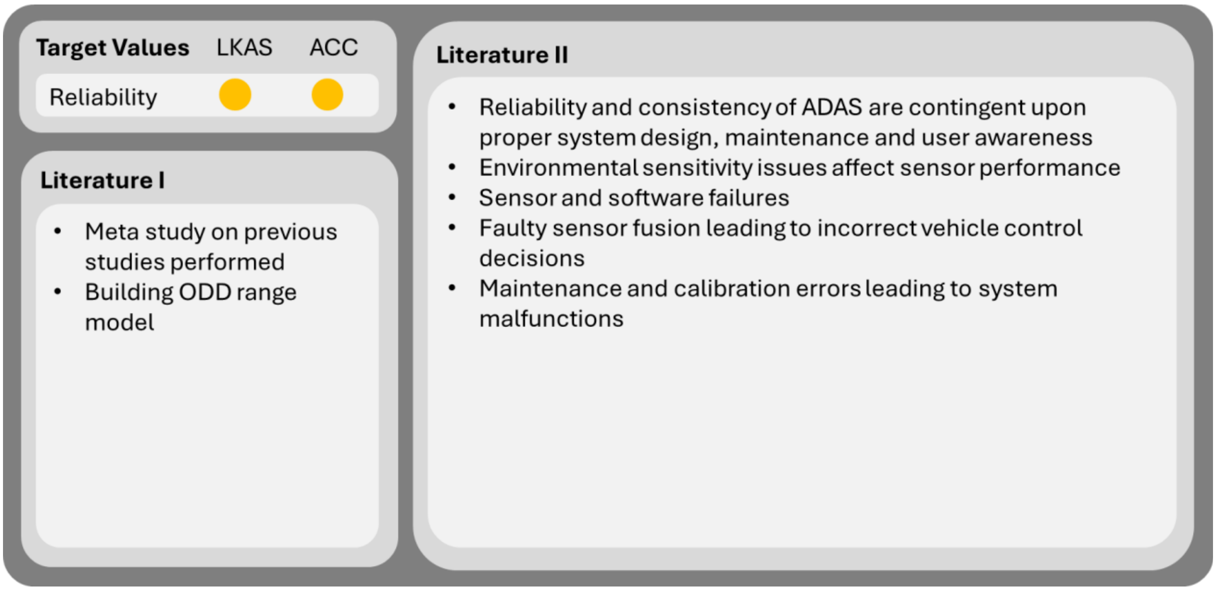


Figure 29: KPI dashboard for reliability

7.1.4 Reliability perception

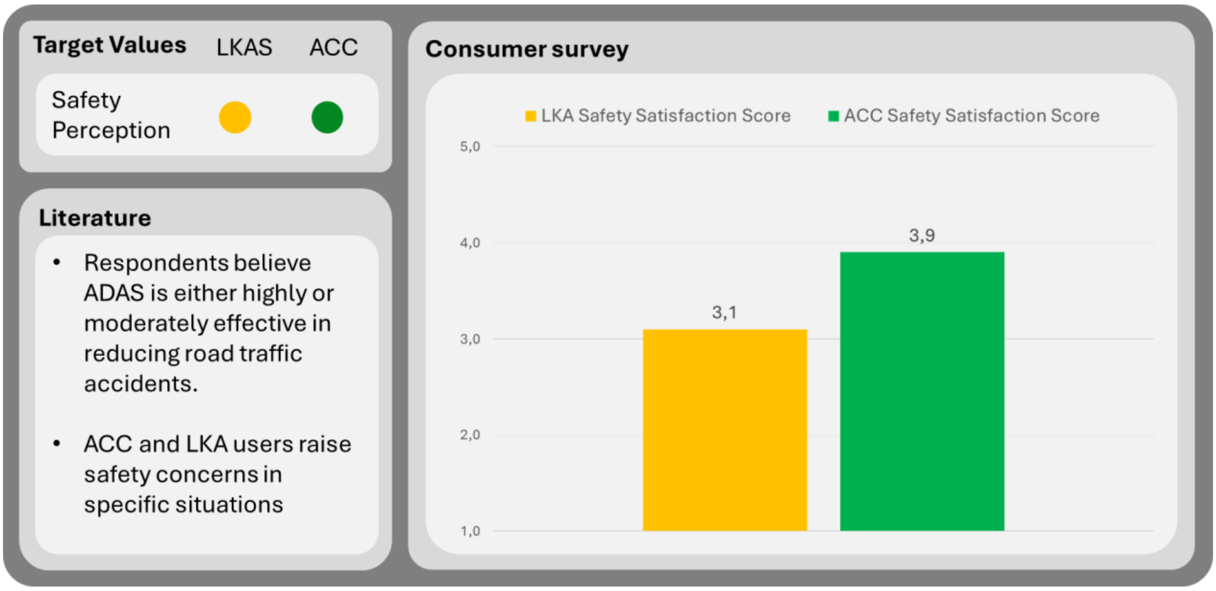


Figure 30: KPI dashboard for reliability perception

7.1.5 Future readiness

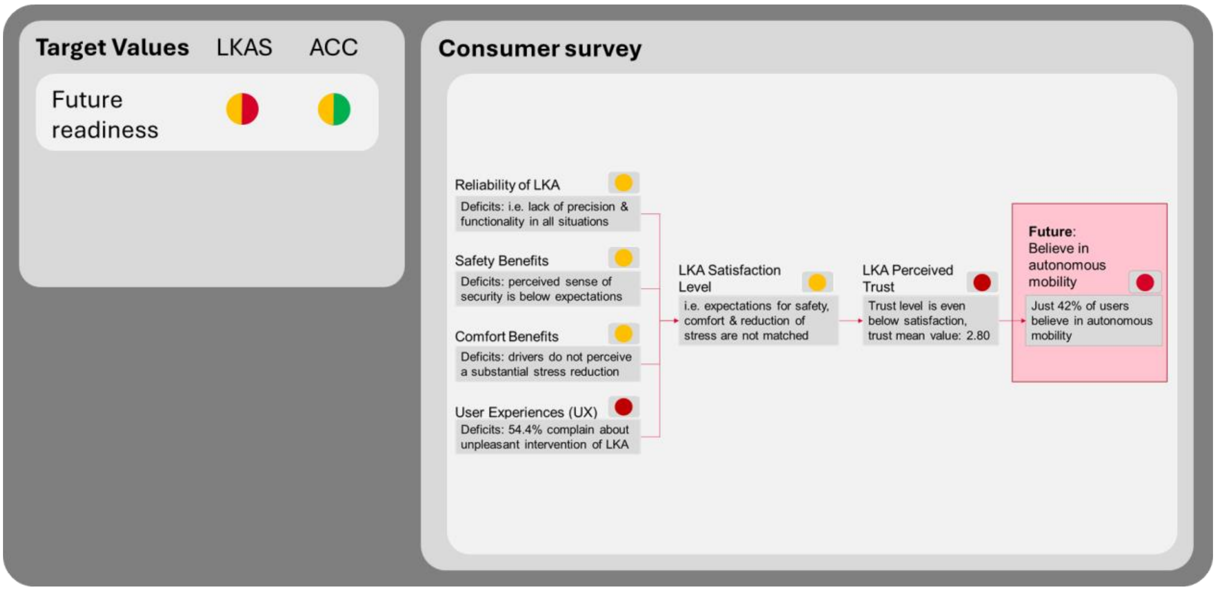


Figure 31: KPI dashboard for future readiness

7.1.6 User Satisfaction and UX

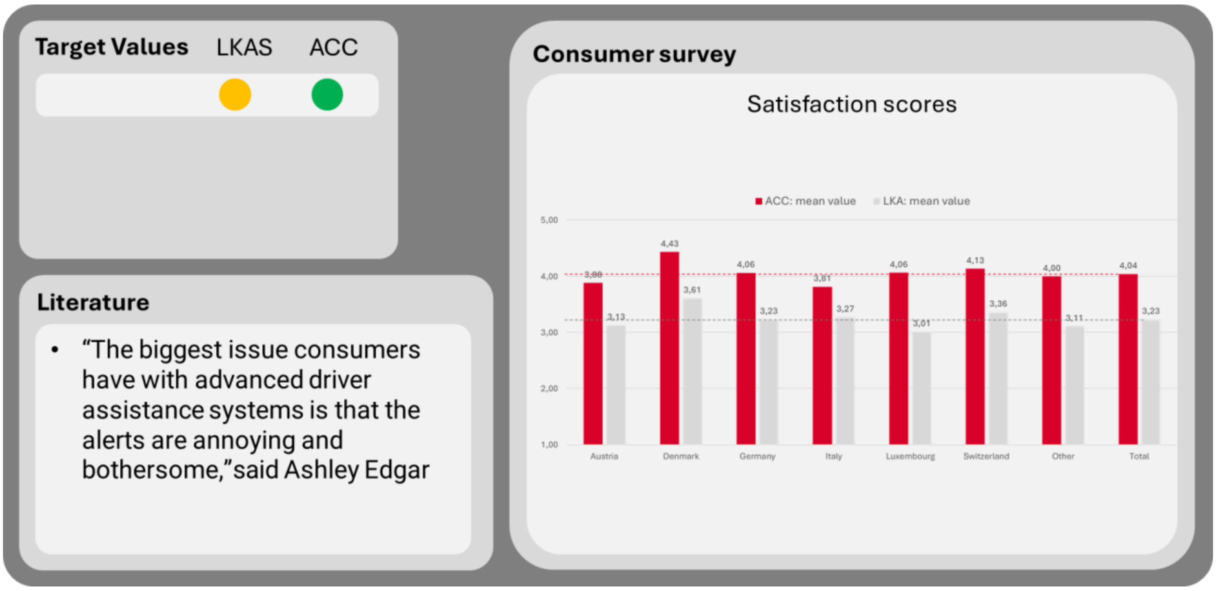


Figure 32: KPI dashboard for UX and satisfaction

7.1.7 Acceptance and Usage

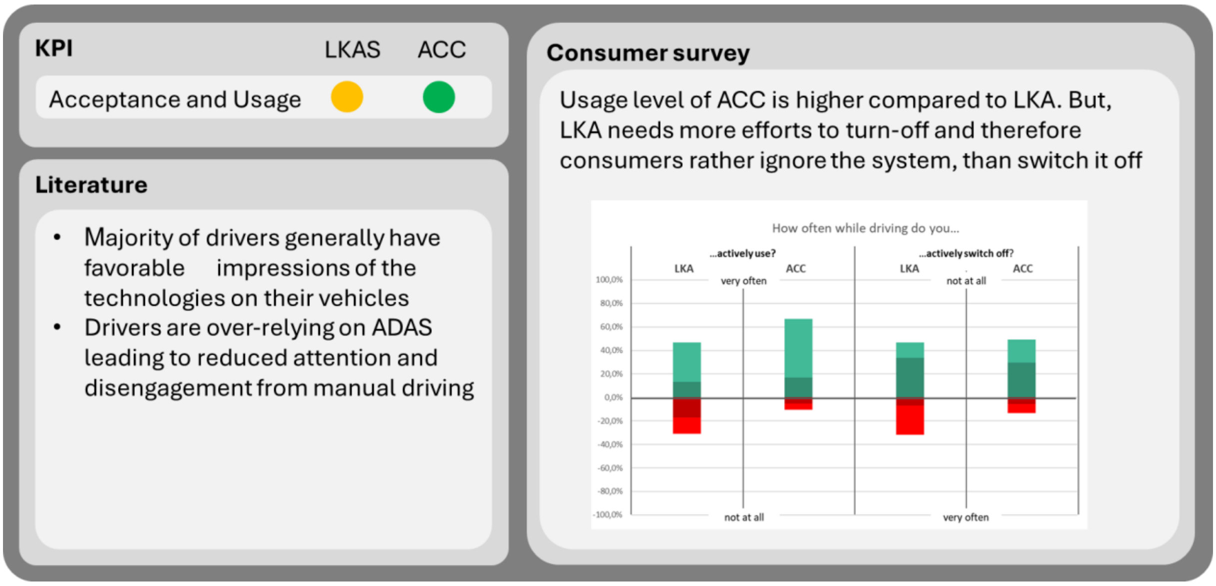


Figure 33: KPI dashboard for acceptance and usage

7.2 European report

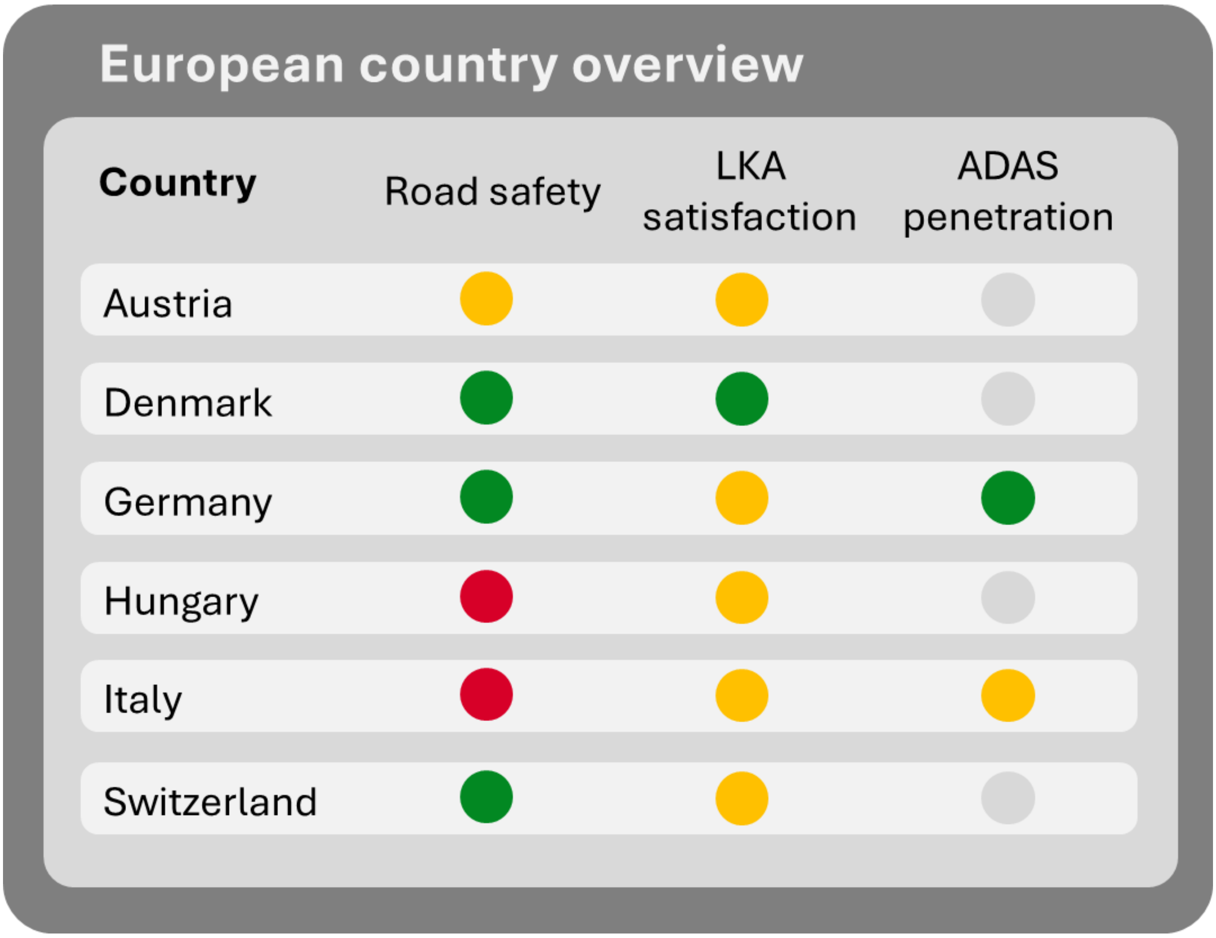


Figure 34: KPI dashboard for European countries in focus

7.3 Predictions on DCAS step 3

Predictions on DCAS step 3 are based on the results conducted during the customer survey. Trust in DCAS like LKA only 45,6% (interpreted as poor) and ACC with 61,66% (interpreted as moderate) do not lead to the assumption that an even higher degree of autonomy will be trusted in by the users. Active usage of DCAS step 2 systems is also poor for LKA (46,7) and moderate for ACC (66,6%). Even with the availability of ACC and LKA systems users prefer to switch-off the assistance system moderately often LKA (31,7 %) and ACC not often (13,5%). According to the data retrieved from the survey, the predictions for a higher degree of automation are not going to grow in a positive direction.

Indicators regarding future acceptance of future autonomy are also poor (42,6%) analyzed from the survey data. Respondents also highlighted their areas of concern for future autonomy which are as follows:

Liability concerns in the event of accidents (63,8%)
Safety concerns (54,3 %)
Data protection (43,2%).

DCAS step 3 is placed between the survey responses of DCAS step 2 and future autonomy as shown in the picture below. Predictions are extrapolated from the survey and result in poor trust, low active use and average to high switch-off rates. According to literature the future autonomy and full ADAS deployment could lead to a beneficial effect on road safety. This statement leaves us with a potential safety increase which cannot be exhausted according to the predictions given.

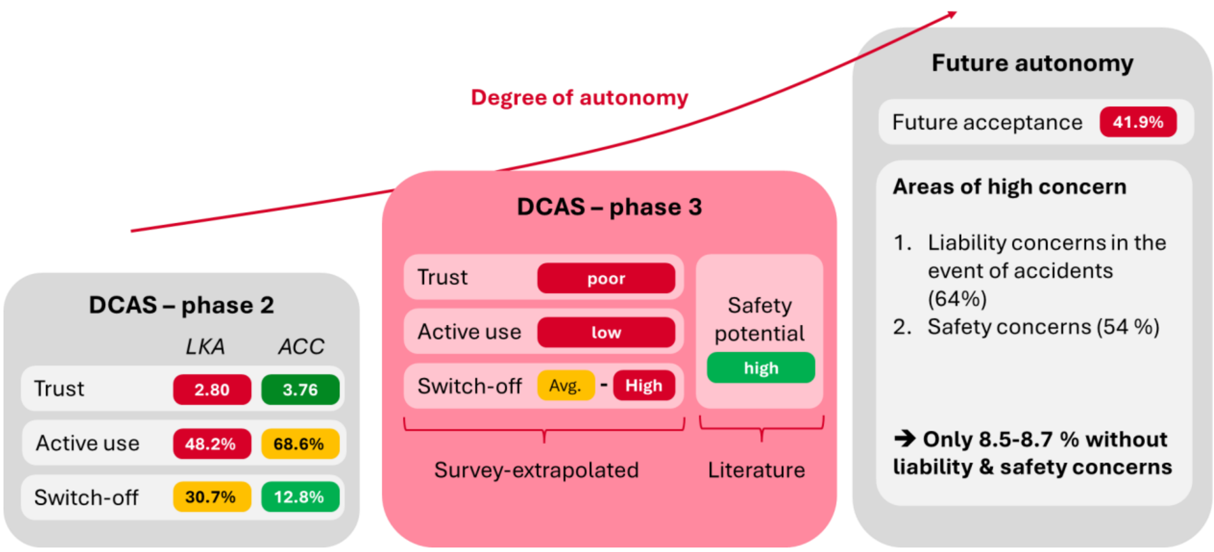


Figure 35: Overview on predicted trajectory for future stages of autonomy

8 Policy recommendations

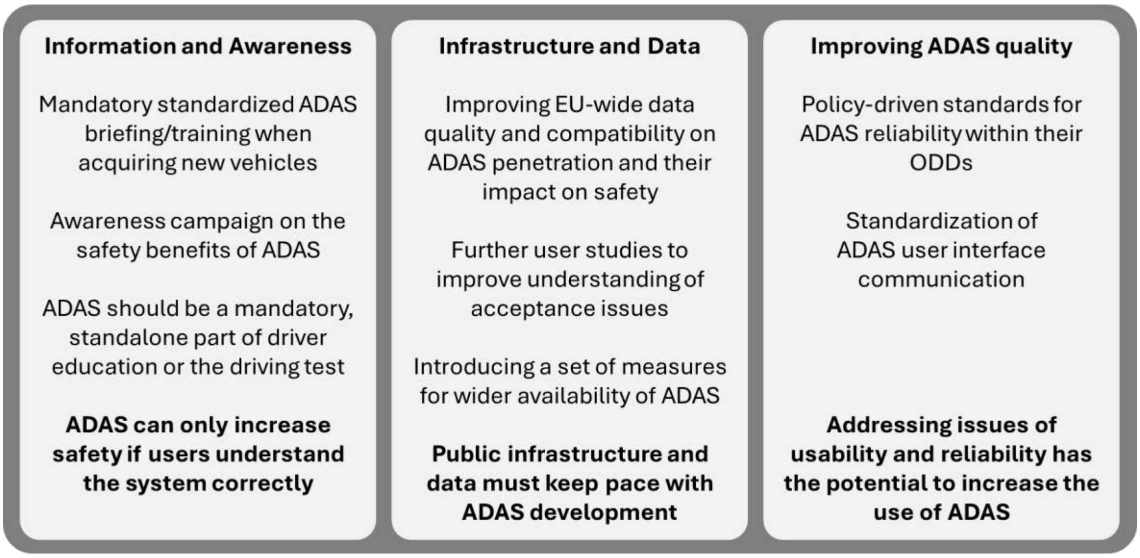


Figure 36: Summary of policy recommendations

8.1 Information and Awareness

8.1.1 Awareness campaigns

Based on survey results, we observe a clash between the safety potential and the perceived safety that participants reported. While low rates of perceived safety can be attributed to factors like insufficient reliability, we propose that a lack of public ADAS awareness is responsible for the relatively low levels of perceived safety.

In a worst-case scenario, an uninformed public might be skeptical of ADAS and in turn avoid ADAS-equipped vehicles or even new vehicles entirely, considering regulations like (EU) 2019/2144 or their successors. Furthermore, extrapolating from survey results, a relatively high amount of survey respondents reporting switching off their ADAS system could indicate that without an appropriate ADAS campaign, future systems such as proposed under DCAS step-3 might face similar fates.

For this, we propose considering EU-wide awareness campaigns on ADAS, focusing on their safety benefits and explaining their limitations. We propose that a better-informed public will in turn be more open to ADAS use and be less likely to misuse systems, avoiding issues like overreliance. Information campaigns on ADAS might also reduce switch-off rates and increase the rates of drivers willing to acquire ADAS-equipped vehicles. A cost-benefit analysis for such an intervention is yet to be made.

8.1.2 ADAS as part of formal driving education

Accounting for the increasing number of ADAS systems on the road and a full fleet penetration in the future, usage of and interaction with ADAS is increasingly becoming a safety-relevant element of the driving task. We therefore propose that newly learning drivers should be as proficient in the usage of ADAS as in any other driving-related task.

We predict that a generation of drivers that learn and practice driving with ADAS from the beginning of their education will be less reluctant to use it, possibly leading to higher usage and lower switch-off rates in the long-term perspective. Not including ADAS in the formal driving education would risk having new drivers unfamiliar with these systems and lose the potential on increased safety that these systems pose.

Therefore, we propose establishing the necessary skillset required to operate ADAS. The elements of the skillset could be developed in terms of a study that would consider expert interviews, user surveys, and regulatory analysis. The skillset can then be transferred to be applied in formal driving education on an EU scale and be taught both in theory and in practice.

8.1.3 Customer briefing after vehicle acquisition

The event of acquiring a vehicle poses many challenges to drivers. New vehicles are equipped with new technology that the individual driver might not be used to from previous vehicles. This is especially the case for ADAS. In this context only 38,3% of the total sample reported that they were familiarized with ADAS by the car dealer – in Germany, Italy and Luxembourg this share is even lower. Denmark as the country with the best satisfaction scores shows again special results in this context – e.g. just 7.5% state “no conscious familiarization with ADAS”. This is by far the lowest share in our sample. It indicates that there is a lost potential to raise awareness of ADAS and reducing usability issues.

Our proposition to tackle this is that either via a policy-driven approach, or by an industry driven joint effort, a standard ADAS briefing is developed and offered to new customers unfamiliar with ADAS or unfamiliar with the usage of ADAS on a specific vehicle. Similarly to our proposed ADAS skillset for formal education, the briefing could be based on three columns: A general briefing on ADAS (theory), a briefing on ADAS operation on the specific vehicle (theory), and then a test drive with the specific vehicle (practice).

8.2 Information and Data

8.2.1 Improving quality and availability of data on ADAS

All efforts to improve traffic safety rely on the principle of interventions and measurement of intervention outcomes. A higher quality of outcome data allows better interventions. In the case of ADAS, the EU and its member states are intervening in traffic safety with ADAS, while the actual public effects can only be measured in limited ways, such as field studies.

We propose that public outcomes should be measured in terms of relevant KPIs and an associated model of influences. One of the most important KPI areas, safety, is lacking a proper set of measurement values available in the member states.

These KPIs include:

- Public reported **ADAS penetration quotas**: Developing a reporting system that allows a clear overview of the type and amount of ADAS present in fleets. This number's quality is also a foundation for improving models to validate intervention outcomes.
- Reporting of **ADAS equipment in case of traffic accidents**: standard police reports typically don't contain reporting on the specific equipment of ADAS in the vehicles involved in traffic accidents. Furthermore, there is no standard procedure to determine involvement of ADAS in accidents.
- Transparency of **manufacturer data**: manufacturers gather, process, and record ADAS data on a big data scale. This information, however, is only industrially available, not homologated, and accounts for no system whereby independent authorities can use data to infer conclusions for policy-driven measures.

8.2.2 Public availability of user studies with ADAS

While a wide set of studies regarding certain aspects of ADAS acceptance are conducted, these studies often follow individual methodologies and are therefore not comparable over time. If usability and the role of the human operator (user) is to be considered, then a reproducible study design is missing.

We therefore propose for organizations advocating consumer-rights or bodies involved in the safety rating of vehicles to regularly conduct user studies to examine the current state of user satisfaction with systems available on the market in a comparative, benchmark-like approach. Such a test could reveal insights on both usability and functional aspects, highlighting areas where development is needed, raising transparency on the comparative performance of different systems for prospective customers and ultimately incentivize developers to improve systems.

8.2.3 Developing a set of measures for wider ADAS availability

While the successful future of autonomy depends primarily on user acceptance and ADAS quality, an important factor to consider is infrastructure. We propose that an infrastructure adapted to the needs of ADAS should be promoted.

The basis of infrastructure – related undertaking is cost-intensive in nature and resources limited. It is therefore useful to conduct a study to identify KPIs to prepare infrastructure for an increasingly autonomous future, investigating areas for improvements by conducting expert interviews and examining literature. Such an analysis could include cost-effectiveness analysis and bring forward a detailed action plan for promoting autonomous mobility from a infrastructure – driven perspective.

8.3 Improving ADAS quality

8.3.1 Policy-driven standards on reliability and ODD

ADAS available on the market have a high degree of differences between systems of different manufacturers. Among other effects, this affects also the available ODD by system and the general system reliability.

We propose that systems with low reliability or insufficient ODD are detrimental to the long-term acceptance of ADAS. Similarly, systems with inconsistent ODDs force the user to readapt from one system's ODD boundaries to another, potentially causing dissatisfaction, a higher mental workload, and ultimately refusal to use a system.

To avoid this, we argue that in regular accordance with technological development a minimum standard for ODD by ADAS given is established. The minimum standard ODDs serve as framework upon which vehicle developers can extend their system's capabilities. Furthermore, a policy-driven testing procedure should be enforced that test the reliability of ADAS within the currently defined ODD standard. We propose that such a procedure be set in place by policy-makers to receive type approval for a system.

8.3.2 Homologizing User Interface elements of ADAS

A further consequence of a multitude of available ADAS from different manufacturers is the presence of a wide range of UI elements. These UI elements are regulated to a certain extent, the user interfaces (Graphic response and input devices) are however strongly differing from each other.

In a current situation in which car – sharing and other non-ownership models driving are increasing in popularity; such differences might increase the mental workload of users when interacting with such systems.

Our proposal to solve this problem is to introduce more standards that regulate the appearance of UI elements, mitigating usability and design freedom of the manufacturer. Such standards can then improve between-vehicle ADAS adaptation, promote long-term learning, and possibly increase usage rates.

List of Figures

List of Tables

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