

Universidade do Minho
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Human Aware Assistance System for Cognitive Vehicles

November 2024

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Ankitkumar Rameshbhai Patel
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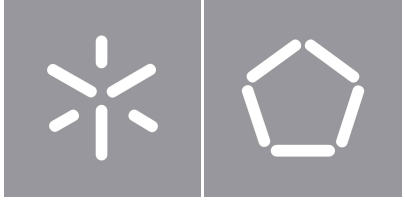


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School of Engineering

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Human Aware Assistance System for Cognitive Vehicles

PhD Thesis
PhD in Electronics and Computer Engineering

Thesis supervised by
Professor Estela Bicho
Professor Sergio Monteiro

November 2024

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As far as my memory is concerned, I have been thrilled throughout the journey of doctoral degrees. The driving factor behind this fascination and desire to work is “how things work” in multifaceted environments. While pursuing a doctorate degree, every student will experience both highs and lows. Having said that, I am fortunate to have two advisors—Professor Estela Bicho and Professor Sergio Monteiro—who have been a constant source of encouragement and insight into potential new research directions. They provide me with ample freedom to pursue my own research interests while also providing me with ongoing assistance, direction, and motivation. They have been an incredible source of motivation and inspiration with their wealth of experience and holistic perspective.

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Statement of Integrity

I hereby declare having conducted this academic work with integrity.

I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

University of Minho, Braga, november 2024

Ankitkumar Rameshbhai Patel

Abstract

The industrial revolution brought many technological breakthroughs, not just in vehicle automation but also in the level of comfort for their occupants. To put it more precisely, it results in "personalization," which not only determines the position of seat or in-vehicle entertainment but also offers services that are based on the preferences of the individual. The transition from human drivers to automated vehicles (AVs) and eventually cognitive vehicles (CVs) is being heralded as a watershed moment in the history of automotive. The future of smart vehicles relies heavily on advanced driver assistance systems (ADAS). Not only is this a giant leap toward complete autonomy, but it also significantly improves safety to the highest possible level. A theoretical and empirical understanding of the various features of ADAS that are "human-aware" for cognitive vehicles has not yet been developed in the limited body of work literature that is currently available. The purpose of this thesis is to contribute to the systematic development of ADAS in a manner that is more humane for vehicles of the future.

That is why this thesis presents a method that shows how users act when it comes to the adaptability of new features that are directly related to ADAS. It does this through three separate studies, which are: (i) To study the elements pertaining to *human drivers*, *automated driving*, and *AVs*, (ii) To explore various vehicle features that are associated with CVs, and (iii) To understand the drivers' perspectives on the human-centered design of ADAS, considering their actual experiences and their expectations.

Keywords Advanced driver assistance systems, cognitive vehicles, driving automation, personalization, users' experience.

Resumo

A revolução industrial trouxe muitos avanços tecnológicos, não só na automação dos veículos, mas também no nível de conforto para os seus ocupantes. Mais precisamente, resulta em "personalização", que não só determina a posição do assento ou entretenimento no veículo, mas também oferece serviços baseados nas preferências do indivíduo. A transição de condutores humanos para veículos automatizados e, eventualmente, veículos cognitivos está a ser anunciada como um divisor de águas na história do automóvel. O futuro dos veículos inteligentes depende fortemente de sistemas avançados de assistência ao condutor. Não só é um salto gigante em direção à autonomia completa, mas também melhora significativamente a segurança ao mais alto nível possível. Uma compreensão teórica e empírica das várias características dos sistemas avançados de assistência ao condutor que são "sensíveis ao ser humano" para veículos cognitivos ainda não foi desenvolvida no limitado corpo de literatura de trabalho atualmente disponível. O objetivo desta tese é contribuir para o desenvolvimento sistemático de sistemas avançados de assistência ao condutor de uma forma mais humana para os veículos do futuro.

É por isso que esta tese apresenta um método que mostra como os usuários agem quando se trata da adaptabilidade de novos recursos que estão diretamente relacionados aos sistemas avançados de assistência ao motorista. Isso é feito por meio de três estudos separados, que são: (i) Estudar os elementos relativos aos motoristas humanos, direção automatizada e AVs, (ii) Explorar vários recursos do veículo associados aos CVs, e (iii) Para compreender as perspetivas dos condutores sobre o design centrado no ser humano de ADAS, considerando as suas experiências reais e as suas expectativas.

Palavras-chave Automatização da condução, experiência dos utilizadores, personalização, sistemas avançados de assistência ao condutor, veículos cognitivos.

Contents

List of Figures **x**

List of Tables **xii**

1 Introduction **1**

1.1 Motivation 1

1.2 Aim and research questions 4

1.3 Thesis outline 5

2 Foundation Nutshell **6**

2.1 Automation 6

2.2 Advanced driver assistance systems 11

2.3 Autonomous vehicles 14

2.4 Cognitive vehicles 16

3 Nexus of Human Driver, Automated Driving, and Autonomous Vehicles **19**

3.1 A brief journey of mobility 19

3.2 Human-out-of-the-loop 20

3.3 Human-in-the-loop 21

3.4 Why study human presence in autonomous vehicles? 22

3.5 Research questions and data collection 25

3.6 Data analysis 25

3.7 Implications of human tendency towards AD and human driver availability in AVs 28
3.7.1 Infrastructure 29
3.7.2 Initially, human required, but with intensive testing not required 30
3.7.3 AVs are for (motorways) highways only, not for city traffic 31
3.7.4 Nature of human intelligence 32
3.7.5 Human intervention due to personal preferences 32
3.7.6 Adapt driver-assistance technologies 32
3.7.7 Health related concerns 33
3.7.8 From the technology point of view 33
3.7.9 All vehicles are AVs, not mix it with conventional vehicles 34
3.7.10 Legal and ethical point of view 34
3.7.11 Cyber-physical Systems concerns 35
3.7.12 Impact on employment, and costing of vehicles 36
3.7.13 Climate change, global warming, electric-vehicles 36
3.8 Limitations of the study 36
3.9 What we gained from the study? 37

4 User Routines and Preferences in the Context of Cognitive Vehicles 38
4.1 What makes user routines crucial? 38
4.2 Personalised user preferences 39
4.3 Why are human-centered assistive systems necessary? 40
4.4 Intent of the work 41
4.5 Methods 42
4.5.1 Survey 42
4.5.2 Data analysis 43
4.6 Results 44
4.6.1 General data on respondents 44
4.6.2 Respondents' expectations 45
4.6.3 Relationship of respondent's opinion and their level of knowledge of HVI and ADAS 45
4.7 Discussion 45
4.8 What we gained from the study? 48

5 Users' Experience and Expectations in the Human-Centered Driver Assistance Sys-

tems **49**

5.1 Introduction 49

5.2 Study Objectives 50

5.3 Methods 52

5.3.1 User - focused interview 52

5.3.2 Data analysis 55

5.4 Results 55

5.4.1 Demographic profiles of the respondents 55

5.4.2 Reliability analysis 57

5.4.3 Descriptive analyses 59

5.5 Discussion 70

5.5.1 Users' experience with current ADAS 71

5.5.2 Users' expectations towards future ADAS 73

5.5.3 Moving ahead with human-centered ADAS design 74

5.5.4 Users' feedback 75

5.5.5 Limitations of the study 76

5.6 Learning experience 77

6 Discussion and Conclusions **78**

6.1 What are the general attitudes towards human driver availability in AVs and people's perception towards AD? 78

6.2 Why personalization is a key enabler for future vehicle users? 79

6.3 What's about users experience and expectations in the context of ADAS? 80

6.4 Limitations and directions for further research 80

6.5 Final conclusions 82

Bibliography **85**

List of Figures

2.1 Driver-automation systems architecture.(adapted from Cho and Hansman (2018)) 9
2.2 Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles (J3016_202104).(adapted from Society of Automotive Engineers (2021)) . 10
2.3 Illustration of various ADASs and sensor systems.(adapted from Gietelink (2007)) 12
2.4 Evolution of ADAS features over time.(adapted from Souweidane and Smith (2023)) . . . 12
2.5 Sensor technologies in autonomous vehicles.(adapted from Center for Sustainable Systems (2023)) 14
2.6 Six levels of autonomous driving.(adapted from Estl (2018)) 15
2.7 Autonomous driving roadmap.(adapted from Jonhston (2015)) 16
2.8 Cognitive car roadmap.(adapted from Aachen (2004)) 17
2.9 The foundations of the cognitive vehicles.(adapted from Smith (2015)) 18

3.1 Percentage of autonomous vehicle adoptions and key milestones.(adapted from Litman (2015)) 20
3.2 Human factors in automated driving 22
3.3 Continent and nation-wise information of respondents. 26
3.4 Overall results for the RQ1 and RQ2. 27
3.5 Percentage of answers to each RQ1 option per continent. 27
3.6 Percentage of answers to each RQ2 option per continent in two different groups according to the answer in the RQ1 ('Good' and 'Bad'). 28
3.7 Implications based on human tendencies towards AD and human driver availability in AVs. 29

4.1 The respondent's opinion on features of the cognitive vehicles 44

5.1 Conceptual model of relation between hypothesized driver characteristics and predictors. 53
5.2 Objective knowledge score plotted as a function of automatic emergency braking. See descriptive results for Tukey HSD. 65
5.3 Objective knowledge score plotted as a function of lane centering. See descriptive results for Tukey HSD. 66

List of Tables

2.1 Levels of autonomy taxonomy for human-computer performance (adapted from Endsley and Kaber (1999)). 8

3.1 Recent surveys on autonomous vehicles and automated driving. 24

4.1 Frequency (and percentage) distributions for question 1 (Q1) to question 19 (Q19) . . . 43

4.2 Results of analyses using the Chi-square tests for independence and Kendall's τ correlation regarding the relationship of respondent's opinion and their level of knowledge about HVI and ADAS 46

5.1 Frequency (and percentage) distributions information. 56

5.2 Reliability analysis with item statistics. 58

5.3 Feeling about technology vs. gender analysis. 60

5.4 Feeling about technology vs. age analysis. 61

5.5 Adjustment of car characteristics vs. gender analysis. 62

5.6 Adjustment of car characteristics vs. age analysis. 63

5.7 ANOVA analysis for drivers' technical sophistication. 63

5.8 ANOVA analysis for perception towards vehicle brand. 63

5.9 ANOVA analysis for perceived ease of use for different ADAS functions. 64

5.10 Tukey HSD analysis for automatic emergency braking (AEB). 65

5.11 Tukey HSD analysis for lane centering (LC). 65

5.12 T-test analysis for individual innovativeness. 66

5.13 T-test analysis for safety worries with respect to ADAS functions. 67
5.14 T-test analysis for preferences after someone drove the vehicle. 67
5.15 T-test analysis for ADAS usefulness. 68
5.16 T-test analysis for future ADAS development. 69

Acronyms

ABS Anti-lock Braking System.

ACC Adaptive Cruise Control.

AD Automated Driving.

ADAS Advanced Driver Assistance Systems.

AI Artificial Intelligence.

AVs Autonomous Vehicles.

BASt German Federal Highway Research Institute.

BSD Blind-Spot Detection.

CAVs Connected and Automated Vehicles.

CVs Cognitive Vehicles.

EAVs Electrical Autonomous Vehicles.

ECUs Electronic Control Units.

ESC Electronic Stability Control.

GHG Greenhouse Gas.

GSM Global System for Mobile Communication.

HITL Human-in-the-loop.

HMI Human-Machine Interaction.

HOOTL Human-out-of-the-loop.

HVI Human-Vehicle Interaction.

ICT Information and Communication Technology.

ISA Intelligent Speed Adaptation.

IVIS In-Vehicle Infotainment Systems.

LCA Lane Centring Assist.

LKA Lane Keeping Assist.

LoA Levels of Automation.

ML Machine Learning.

NHTSA National Highway Traffic Safety Administration.

OEMs Original Equipment Manufacturers.

PIVs Personalised Intelligent Vehicles.

SAE Society of Automotive Engineers.

SMS Short Message Service.

CHAPTER 1

Introduction

An overview of the research area is presented in this chapter, which includes background information as well as a list of research questions that have been identified. Presenting an outline of the thesis serves as the conclusion of this section.

1.1 Motivation

Think about a day without mobility! It is almost impossible for anyone in the current era of busy lives, am I right? When we take this into consideration, we can unequivocally assert that the advent of automobility ushered in a new era of transportation (Johnson, 1997; Oladimeji et al., 2023; Urry, 2004). It has provided many benefits, such as improved accessibility for end-users to move from one location to another (Jamei et al., 2022), more freedom in terms of users' ability to choose their own routes and speeds (Intini, 2016), a variety of mobility options (Machado et al., 2018; Berg and Ihlstrom, 2019), the option to transport passengers using multiple modes of transportation (Kramarz and Pryzbylska, 2021), and a substantial number of other advantages that we are able to count. It is clear that the innovation of the automobile has altered people's lifestyles and business practices due to the advantages stated above.

As of right now, there are approximately 2.2 billion registered vehicles across the globe (Glazener et al., 2022). According to the World Economic Forum, this figure is anticipated to rise in the years to come and

will more than double by the next decade (Safety and Mobility, 2023). This will result in an increased probability of road accidents due to various factors or situations. In order to prevent such accidents and save lives whenever feasible, human drivers need additional information and features in driving automation. **Advanced Driver Assistance Systems** (**ADAS**), which aim to enhance the user's driving experience (Masello et al., 2022; Orlovska et al., 2020b), meet these kinds of requirements. Through the utilisation of these systems, vital information can be provided regarding suggestions of new routes to avoid congestion (Nasution et al., 2021), traffic, information regarding road blockages, driver-passenger comfort needs (Marchau et al., 2001), and other essential details. The ADAS can also detect when drivers are getting too sleepy or drowsy to drive safely and provide them with suitable recommendations and warnings. In this way, we are able to evaluate the driving performance of the driver while simultaneously preventing any accidents from occurring.

More generally speaking, the functionality of ADAS can be divided into two groups:

- Personalized functions: The many generations of the automotive era have seen an increased emphasis placed on personalization. Personalized comfort features are a key aspect of ADAS, aiming to provide drivers with a tailored and enjoyable driving experience (Adomavicius et al., 2008). These features allow drivers to customize various settings according to their individual preferences, ensuring optimal comfort and convenience. For instance, driver profiles can be created to store preferred seating positions, mirror angles, and steering wheel adjustments, which can be automatically recalled when the driver enters the vehicle (Patel et al., 2021). Some ADAS even offer facial recognition technology that can identify the driver and apply their saved settings instantly (Srivastava et al., 2021; Nazira et al., 2021). Adaptive ambient lighting systems can be personalized to create a desired mood or atmosphere within the cabin, with adjustable colours and brightness levels to suit the driver's taste (Huysduynen et al., 2017). Infotainment systems with voice recognition allow drivers to control various functions, such as music playback, navigation, and climate control, without taking their hands off the wheel, enhancing both comfort and safety (Lin et al., 2018). Advanced seat technology, such as massaging and ventilation functions, can be adjusted to the driver's liking, providing relief during long journeys (Chung et al., 2019). Furthermore, some ADAS can learn and adapt to the driver's behavior over time, such as preferred routes, driving styles, and frequently used features, and make intelligent suggestions or automate certain tasks for added convenience (Wojtak et al., 2021). As ADAS technology continues to advance, we can expect to see even more sophisticated personalized comfort features that cater to the unique needs and desires of individual drivers, ultimately transforming the driving experience into a more enjoyable and relaxing one.

- Safety-related functions: Safety features are designed to respond to certain situations and manage some of the vehicle's functions while driving. ADAS have revolutionized vehicle safety by incorporating a range of cutting-edge technologies designed to prevent accidents and protect occupants. These systems leverage sensors, cameras, radar, and software algorithms to constantly monitor the vehicle's surroundings and provide real-time assistance to the driver. One of the most common ADAS features is adaptive cruise control, which automatically adjusts the vehicle's speed to maintain a safe distance from the car ahead, reducing the risk of rear-end collisions (Gelder et al., 2016). Lane departure warning and lane keep assist systems use cameras to detect when the vehicle is drifting out of its lane and alert the driver or gently steer the car back into the center of the lane, helping to prevent accidents caused by distracted or drowsy driving (Nguyen et al., 2021). Automated emergency braking systems use radar and cameras to detect potential collisions and can automatically apply the brakes if the driver fails to respond in time, significantly reducing the severity of frontal crashes (Mannam and Rajalakshmi, 2022; Ucińska and Pełka, 2021). Other ADAS features include blind spot monitoring, which warns drivers of vehicles in their blind spots, and parking assist systems that use sensors to help drivers navigate into tight parking spaces (Nidamanuri et al., 2022). As these technologies continue to advance, ADAS are expected to play an increasingly critical role in improving road safety and saving lives.

People don't rely on automation correctly, which makes it dubious when it comes to operations. For human-automation interactions to be successful, trust is crucial, especially in complicated and unpredictable scenarios when automation surpasses the driver's understandings. So, it's obvious that people depend on automation more when they trust it, and they don't rely on it at all—or even reject it—when they don't trust it completely (Lee and See, 2004). Knowing how to offer a humanized response to automation is crucial in this situation so that people may trust systems sufficiently to rely on them. In fact, there are three things to keep in mind when implementing this solution: (a) if the design involves interacting with a human user, then it's best to make it more human-like; (b) incorporating humanness into designs can help prevent unwanted autonomy; and (c) finding a balance between humanness and autonomy (Visser et al., 2018). As a result, we'll have a car that can match the cognitive capacities of human drivers and operate in the realm of cutting-edge technology, providing accurate data processing. **Personalised Intelligent Vehicles** (**PIVs**), also known as **Cognitive Vehicles** (**CVs**) , are the vehicles that fall within this category (Heide and Henning, 2006).

Cognitive vehicles are designed to provide a highly personalized and adaptive user experience, focusing on the individual needs and preferences of each driver and passenger (Park et al., 2020; Ince et al.,

2024; Patel et al., 2021). One of the key aspects of personalization in cognitive vehicles is the ability to create driver profiles. These profiles can store a wide range of preferences, including seating positions, mirror adjustments, climate control settings, and infotainment options. The vehicle can automatically adjust these settings based on the identified driver, ensuring a comfortable and familiar environment every time they enter the vehicle (Salvucci, 2006; Hiraishi, 2019; Kim et al., 2018). In addition to driver-focused personalization, cognitive vehicles can also adapt to the needs and preferences of passengers. Infotainment systems can offer personalized content recommendations based on the passengers' interests, while climate control systems can optimize the temperature and airflow for individual comfort (Panagiotopoulos and Dimitrakopoulos, 2019). Intelligent voice assistants can understand and respond to natural language commands, allowing passengers to easily control various vehicle functions without the need for manual input (Park et al., 2019; Schmidt et al., 2020). In conclusion, the focus on personalized and adaptive user experiences is a crucial aspect of cognitive vehicles. By leveraging advanced technologies to learn from and adapt to individual users' needs and preferences, these intelligent vehicles have the potential to revolutionize transportation, offering a safer, more comfortable, and more enjoyable driving experience for everyone.

The highlighted aspects do not address the topic of how this knowledge can be applied when considering the "human" as an essential component, and they only show a fraction of the complexity involved in the intricate interaction between the driver and the ADAS.

No previous research has attempted to provide a coherent definition of the aspects that combine human aware ADAS for cognitive vehicles, or has given an in-depth analysis, as far as the author is aware. Consequently, the purpose of this work was to examine, from a human-centered development standpoint, the many aspects of ADAS for cognitive vehicles, such as the actual experiences of users and their aspirations for the future.

1.2 Aim and research questions

This thesis has examined the relationship between ADAS and cognitive vehicles in the context of humanness, specifically focusing on how users have experienced and what their expectations are for future ADAS systems. The primary objective was to contribute towards the systematic development of ADAS from a human-centred perspective. Given the problem description and thesis aim, the following research questions are posed:

RQ1: In the context of automated driving and autonomous vehicles, how do consumers

perceive the concept of "human presence"?

RQ2: Where are human-centered ADAS stand in terms of user attitude, needs, and requirements?

RQ3: How do users feel about the ADAS features they are using now, and what do they expect in the future? What are the basics of human-centered ADAS design, and what features should it include?

1.3 Thesis outline

The present thesis is structured into six distinct chapters, the contents of which are briefly described below.

Chapter 1 introduces a brief explanation of the problem area and the context, which serves as an introduction to the research field. On the basis of this, the research questions and the overall purpose of the study are formulated. The chapter concludes with a concise summary of the structure of the thesis.

Chapter 2 we will focus on underlying knowledge of automation, advanced driver assistance systems, autonomous vehicles, and cognitive vehicles. This will enhance the clarity to the users to understand the thesis in a meaningful way.

Chapter 3 is all about understanding people's attitudes towards automated driving technology and what they are thinking about 'human' driver presence in autonomous vehicles. Indeed, this is a need of the hour, particularly in light of the fact that there has been a significant jump in technological revolution over time.

Chapter 4 tells us more about how crucial user routines are and their preferences when we think about future intelligent vehicles, i.e., cognitive vehicles. It also shows the necessity for human-centered assistive systems and the kind of personalized features users want in their future fleets as cognitive vehicles.

Chapter 5 mention about users' experience and their expectation when we consider about various features of advanced driver assistance systems (ADAS). This means "user" is in the center point of the whole discussion about ADAS features. As we are looking for "cognitive vehicles", where "user" plays an important role along with "vehicle", this chapter will provide insightful information to build vehicles with cognitive abilities.

Chapter 6 is all about discussion on the various avenues of the thesis and finally presented the conclusions along with future directives for further work.

CHAPTER 2

Foundation Nutshell

This chapter is organised into sections based on the core ideas of driver assistance systems and cognitive vehicles, which are at the heart of this thesis. A streamlined overview of the theoretical underpinnings is what this chapter is aiming to provide the reader. This chapter gives a synopsis of the necessary background information and serves as a foundational framework for the reader with relation to automation, autonomous cars, cognitive vehicles, and advanced driver assistance systems. This gives the readers a more in-depth grasp of the things that are being discussed in relation to the subject matter.

2.1 Automation

There has been a noticeable shift in the behaviour of human-centered activities in the areas of travel, work, and leisure as a result of the technological revolution that has taken place in recent years, particularly for digital computers Mokhtarian and Tal (2013). With the advent of low-cost solutions in both hardware and software, as well as a growth in the speed, power, and intelligence of computers, the way people live their lives in the modern period has changed. The term "automation" is responsible for this shift. The word was first used in 1952 in an article published in Scientific American Leontief (1952). Today, we have seen the widespread use of automation in diverse sectors such as automobiles, robots, medical systems, agricultural devices, transportation, instrumentation and control, chemical plants, and space vehicles,

among others. Considering all the aforementioned uses of automation, we can conclude that it is related to the following essential prerequisites Sheridan and Parasuraman (2005):

1. The mechanization and integration of the sensing of environmental variables (by artificial sensors),
2. Data processing and decision-making units (by computers);
3. Mechanical action (by motors or devices that apply forces on the environment), and/or
4. "information action" is the communication of processed information to the user.

These days, we are living in the age of digitalization, and as a result, we are able to take advantage of it for a variety of services. Not only are we able to provide better services, but we are also able to do it with a high level of safety and reliability thanks to automation and digitization Willcocks (2024); Horvat et al. (2019). There is a wide range of potential advantages that may be obtained through the use of automation in the transportation sector. A few of them are given here, among others, including Breton and Bosse (2002):

- The decrease in the amount of the operator's workload
- Automated systems allow operators to focus on other duties that are running simultaneously
- The decrease in the level of stress factor on by the situation's stakes
- The reduction of the fatigue factor
- Automated systems provide a certain level of stability in the execution of a task
- Automated systems can significantly reduce the occurrence of human errors.

These days, automation is nearly ubiquitous and gives the user (operator) information via alerts, warnings, or interactive systems that provide guidance Yun and Yang (2020). An operator who is human may use this knowledge to make system-related decisions that are suitable. In terms of human-automation teaming validation, the following questions remain unanswered, though Kolrep and Onnasch (2018):

- What are the driving factors for automation?
- What current automation problems exist, as well as potential future ones?
- Why is human participation in human-machine teams necessary?

- What qualities distinguish ”good” automation?
- Which approaches could provide guidelines for “good” automation?

Human-machine (here, vehicle) teaming in a complex environment has been discussed using the broad notions of **Levels of Automation (LoA)**. In general terms, the LoA means the task planning within a complex environment between a human operator and a system Draper (1995). Many distinct taxonomies that are used to describe LoA have evolved throughout the course of time. For example, (a) Endsley (1987) discussed the process of human decision-making within the context of expert systems; (b) The LoA encompasses a range of application fields with an emphasis on human-computer performance in the context of cognitive and psychomotor processes Endsley and Kaber (1999) (see 2.1 for detailed taxonomy); and (c) Spath et al. (2009) gave a more concentrated approach to human-centered automation knowledge; as a result, details pertaining to systems that are ”semi-automated” to ”fully” automated were offered.

Table 2.1: Levels of autonomy taxonomy for human-computer performance (adapted from Endsley and Kaber (1999)).

	Levels of Automation	Monitoring	Generating	Selecting	Implementing
1	**Manual Control**	Human	Human	Human	Human
2	**Active Support**	Human-Computer	Human	Human	Human-Computer
3	**Batch Processing**	Human-Computer	Human	Human	Computer
4	**Shared Control**	Human-Computer	Human-Computer	Human	Human-Computer
5	**Decision-Support**	Human-Computer	Human-Computer	Human	Computer
6	**Blended Decision-Making**	Human-Computer	Human-Computer	Human-Computer	Computer
7	**Rigid System**	Human-Computer	Human-Computer	Human	Computer
8	**Automated Decision-Making**	Human-Computer	Human-Computer	Computer	Computer
9	**Supervisory Control**	Human-Computer	Computer	Computer	Computer
10	**Full Automation**	Computer	Computer	Computer	Computer

Every taxonomy and method that has been put out over the years has a distinct function, and sometimes several taxonomies are used in the same area Vagia et al. (2016). This will raise a significant issue with the ”unification” of taxonomies that is relevant to all domains. Similar challenges emerge when discussing the automobile sector, thereby presenting similar difficulties. The issue here is that, in contrast to specialised users, like airline pilots, general purpose users know very little about driving automation and are also not trained to operate driver assistance systems Merriman et al. (2021).

Technology that assists drivers and makes various safety and comfort features easier to utilise is known as driving automation Bengler et al. (2014). Among the many helpful features of these systems are

Anti-lock Braking System (ABS) Soliman and Kaldas (2012), **Blind-Spot Detection (BSD)** Sotelo and Barriga (2008), emergency braking Kudarauskas (2007), **Adaptive Cruise Control (ACC)** Xiao and Gao (2010), **Lane Keeping Assist (LKA)** Ishida and Gayko (2004), **Lane Centring Assist (LCA)** Monkhouse et al. (2020) and collision avoidance Seiler et al. (1998). The human drivers are playing crucial roles in all of the tasks of driving automation, which are to decide the decision-making process based on the situation that is occurring on the road (see Fig. 2.1 for more details).

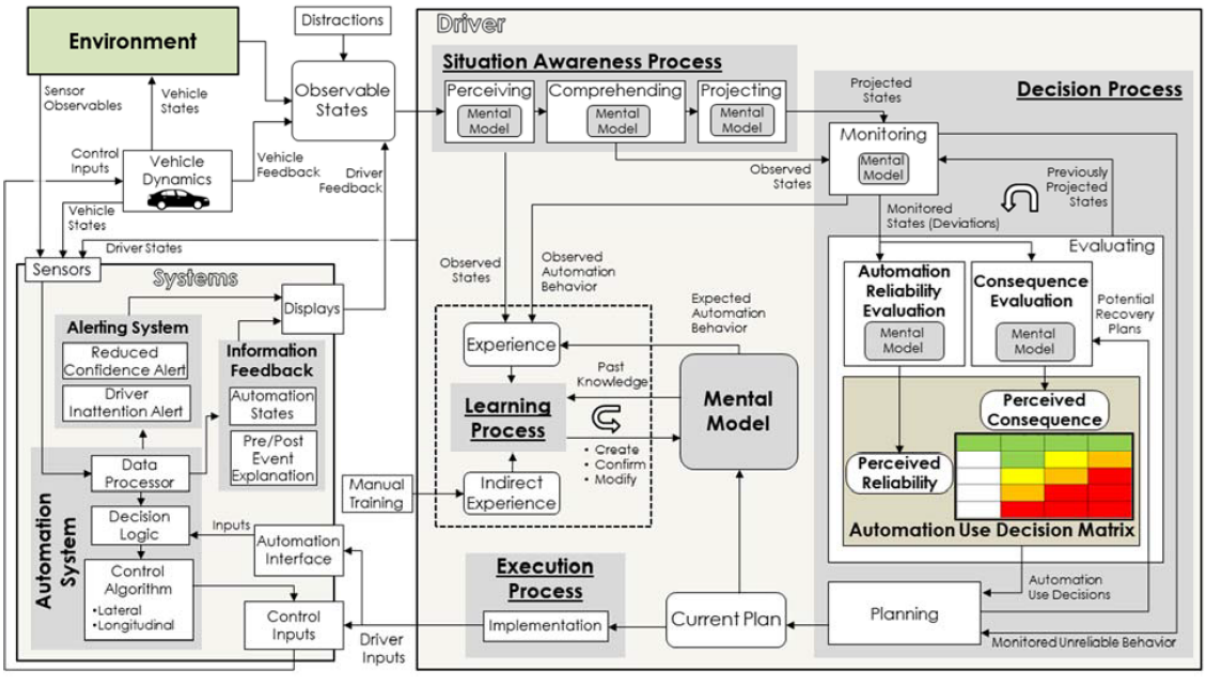


Figure 2.1: Driver-automation systems architecture.(adapted from Cho and Hansman (2018))

It is possible that human activities on the strategic, tactical, and operational levels of a vehicle may alter as a result of the introduction of automotive automation Parasuraman and Sheridan (2000). Whether there will be "none" or "complete" automation is a factor that determines the extent of change that will occur. Numerous agencies have worked on automation levels and defined driving automation levels throughout the years. These includes, the **National Highway Traffic Safety Administration (NHTSA)** National Highway Traffic Safety Administration (2022), the **German Federal Highway Research Institute (BASt)** German Federal Highway Research Institute (2010), and **Society of Automotive Engineers (SAE)**) International Society of Automotive Engineers (2021). The most well-known of them is the SAE taxonomy, which was developed to assist the legislation defining the categorization of the driving automation and to provide a common understanding of the different LoA. (see Fig. 2.2).

The taxonomy describes about the driver support features and automated driving features for on-road motor vehicles. The classification ranges from level 0 (with no driving automation) to level 5 (with full

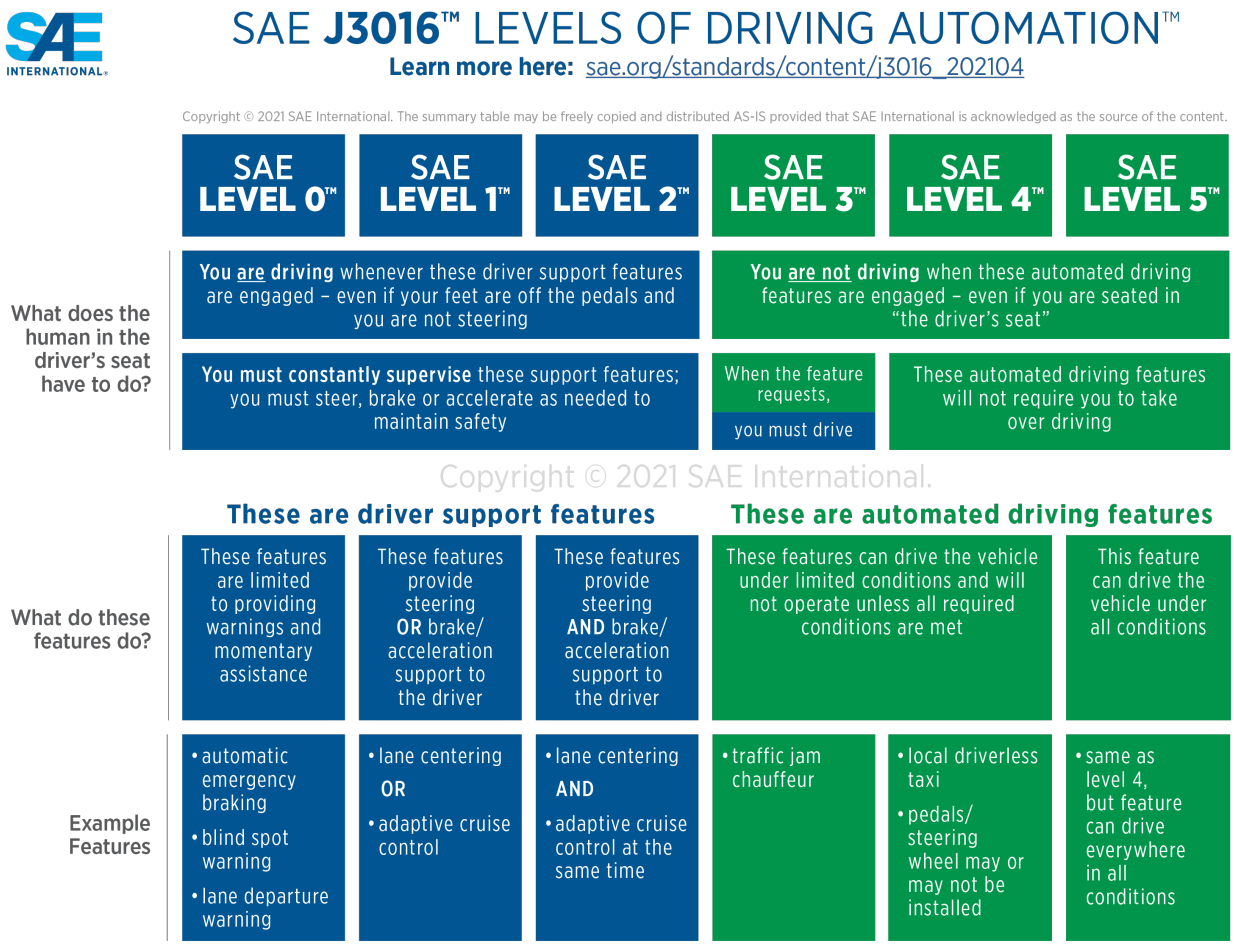


Figure 2.2: Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles (J3016_202104).(adapted from Society of Automotive Engineers (2021))

driving automation), including each levels has distinct features for driver and vehicle.

One common misconception about automation is that it would eventually replace human with machines. Nevertheless, it is clear that automation does not replace human activity; instead, it alters the kind of work performed by human Coombs et al. (2020); Masriadi et al. (2023). The work changes depending on how the design created for a particular automation, whether it is unintended and unanticipated. When taking into consideration the adaptability of autonomy and human perception, it has been found that the connection between human and machine interaction is always shifting Trujillo et al. (2019); Nardo et al. (2020). Human-human models should serve as the foundation for the human-autonomy interaction, which should aim to mimic the complex connections that exist between individuals. Observe the following important details from the discussion above Visser et al. (2018):

- If the design needs to interact and communicate with a human user, then it should be more human-

like.

- To counteract unsavoury levels of autonomy, it may be helpful to include human factors into designs.
- Balance between autonomy and humanness into the design.

Over the last several decades, we have seen automation spread to almost every industry. Progress in critical fields including sensing, computation, communication, networking, **Artificial Intelligence (AI)**, and many more has made this feasible. Simultaneously, there has been a rise in the number of opinions regarding the necessity of automation being socially responsible Khogali and Mekid (2023). This is evaluated in accordance with the two fundamental principles Sampath and Khargonekar (2018): (a) For any kind of technical solution, the 'human' will and should remain vital and integral to the process. This involves a workplace of the future in which it is the responsibility of humans to aid, manage, and even enhance the capabilities of technology; and (b) It is important to recognise that general-purpose technologies, including AI, automation, and machine learning, are merely a means to improve the quality of life for humans.

2.2 Advanced driver assistance systems

One of the most pressing issues facing modern, civilised society is the prevalence of road accidents. Annually, over 50 million injuries are sustained from traffic accidents, with the number of fatalities in 2023 surpassing 1.9 million. In the next two decades, barring the implementation of very efficient plans and policies, relative projections show that these facts will rise by around 65% Safety and Mobility (2023). Still, knowing what causes a collision is essential for preventing them, which is the only way to completely eradicate traffic accidents. Road users, cars, and road infrastructure all interact to create traffic. Given that most accidents are really the consequence of human mistake, the human being is considered the most important factor in this critical position Rasmussen (1990); Bucsuhazy et al. (2020). The purpose of **Advanced Driver Assistance Systems (ADAS)** is to help drivers with both main and secondary duties, especially in emergency circumstances, to prevent accidents.

Driver assistance systems, such as ACC, ABS, **Electronic Stability Control (ESC)**, traction control systems, offer possibilities for improving traffic safety by assisting the human driver in driving tasks. Furthermore, the role of ADAS encompasses enhancing driver comfort, mitigating traffic congestion, increasing road capacity, and minimising energy usage Masello et al. (2022). Fig. 2.3 illustrates the known ADAS features available in current vehicles.

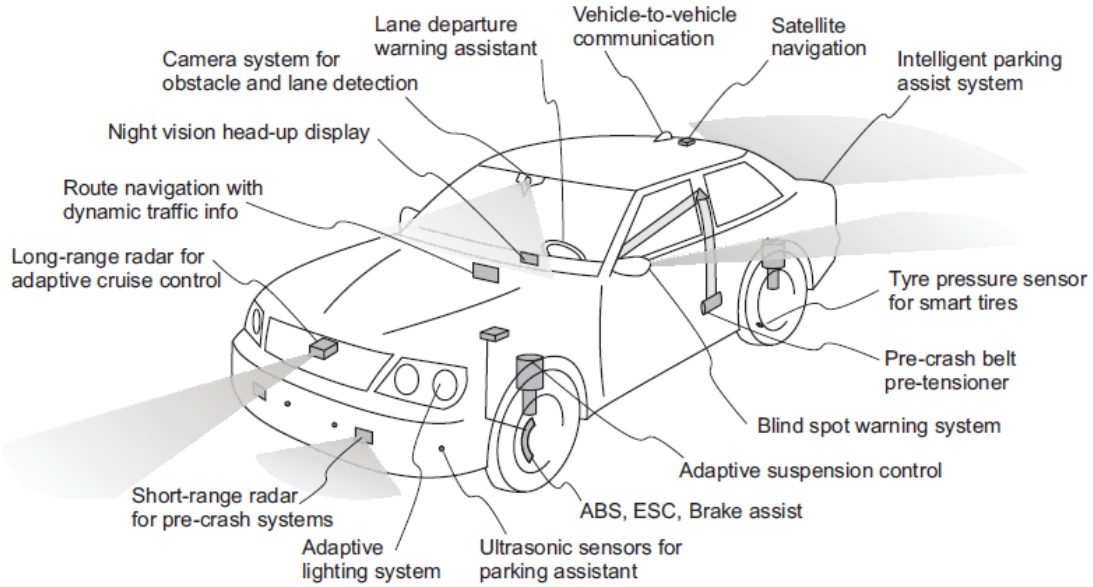


Figure 2.3: Illustration of various ADASs and sensor systems.(adapted from Gietelink (2007))

In the context of driving duties, the ADAS features are further classified into four broad categories based on factors like driving comfort and traffic safety (see evolution of ADAS features over time in Fig. 2.4) Souweidane and Smith (2023)) Tsugawa et al. (1997); Bishop (2005); Shladover (1995):

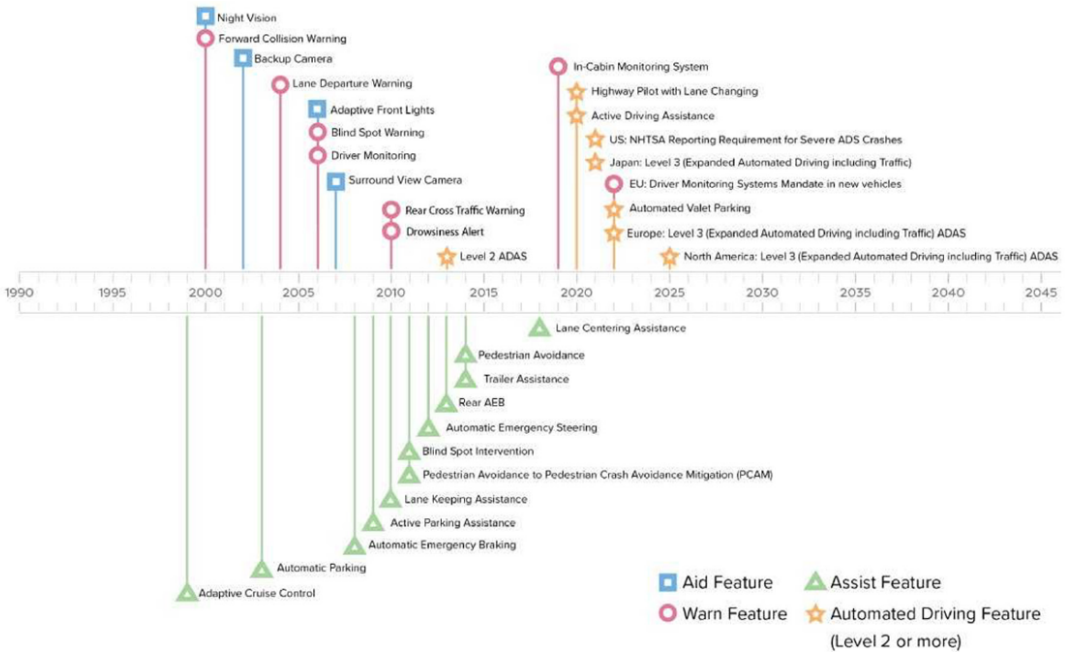


Figure 2.4: Evolution of ADAS features over time.(adapted from Souweidane and Smith (2023))

Driver information systems: These kinds of features provide the driver access to higher level strategic information so they can carry out driving responsibilities more efficiently. The driver's situa-

tional awareness is improved by giving them more information Venhovens et al. (1999); Alyamani and Kavakli (2017). These consist of adaptive light management, traffic signs, night vision, route navigation, and information on traffic congestion.

Driver warning systems: These features provide the driver with extra assistance when manoeuvring and warn them of any possible hazards. Drivers will respond appropriately to lessen or eliminate the hazard based on the alarm signal they get. These features include lane departure warning assistance, forward collision warning, intersection collision warning, blind spot detection, and driver drowsiness alert Panou (2018).

Intervening systems: A control level features of the driving duty is included in this kind of assistance offered to the driver. It encompasses both lateral and longitudinal control of the vehicle, as well as the act of carrying out the appropriate actions in accordance with the circumstances on the road. These include, but are not limited to, **Intelligent Speed Adaptation (ISA)** Blum et al. (2012), ACC Ploeg et al. (2011); Yu and Wang (2021), and LKA Bian et al. (2020); Wei et al. (2023).

Safety systems: In all circumstances, this ensures the safety of vehicles, and it is cooperative in nature. During normal driving, the driver is aware of the surrounding traffic environment and any possible hazards that may be present. It is possible that a warning will be delivered in the event that the driver does not respond to this information, indicating that remedial actions are required. Systems may actively help prevent the collision when the time to collision drops to a few seconds Hu et al. (2015). Aside from traditional passive safety systems that are engaged after an accident, the severity of the collision may be reduced by implementing safety measures prior to the actual impact.

It is important to keep in mind that the driving conditions and the mindsets of drivers in various nations are quite diverse. Additionally, the efficiency of ADAS is reliant on infrastructure; hence, a substantial amount of road infrastructure is required. Most countries, with the exception of developing nations, are struggling with inadequate infrastructure. For instance, lane markers are not even being maintained in the appropriate manner. In the event that these kinds of fundamental infrastructural facilities are satisfied, the scope and scale of the application of ADAS will be increased Lu et al. (2004); Bosurgi et al. (2023). There has been a significant amount of testing that has been necessary in order to assess the capability of ADAS features on a regular basis Abdessalem et al. (2016); Goncalves et al. (2014). Another major concern when considering adding new features to a car is data management across several software and hardware platforms Tatar and Bayar (2023); Park and Choi (2019). To gain insight into the users'

experiences regarding the speed and efficiency with which they acquire knowledge about ADAS features that are evolving and posing challenges in the future Strand et al. (2011); Choy et al. (2022); Molin and Marchau (2004).

2.3 Autonomous vehicles

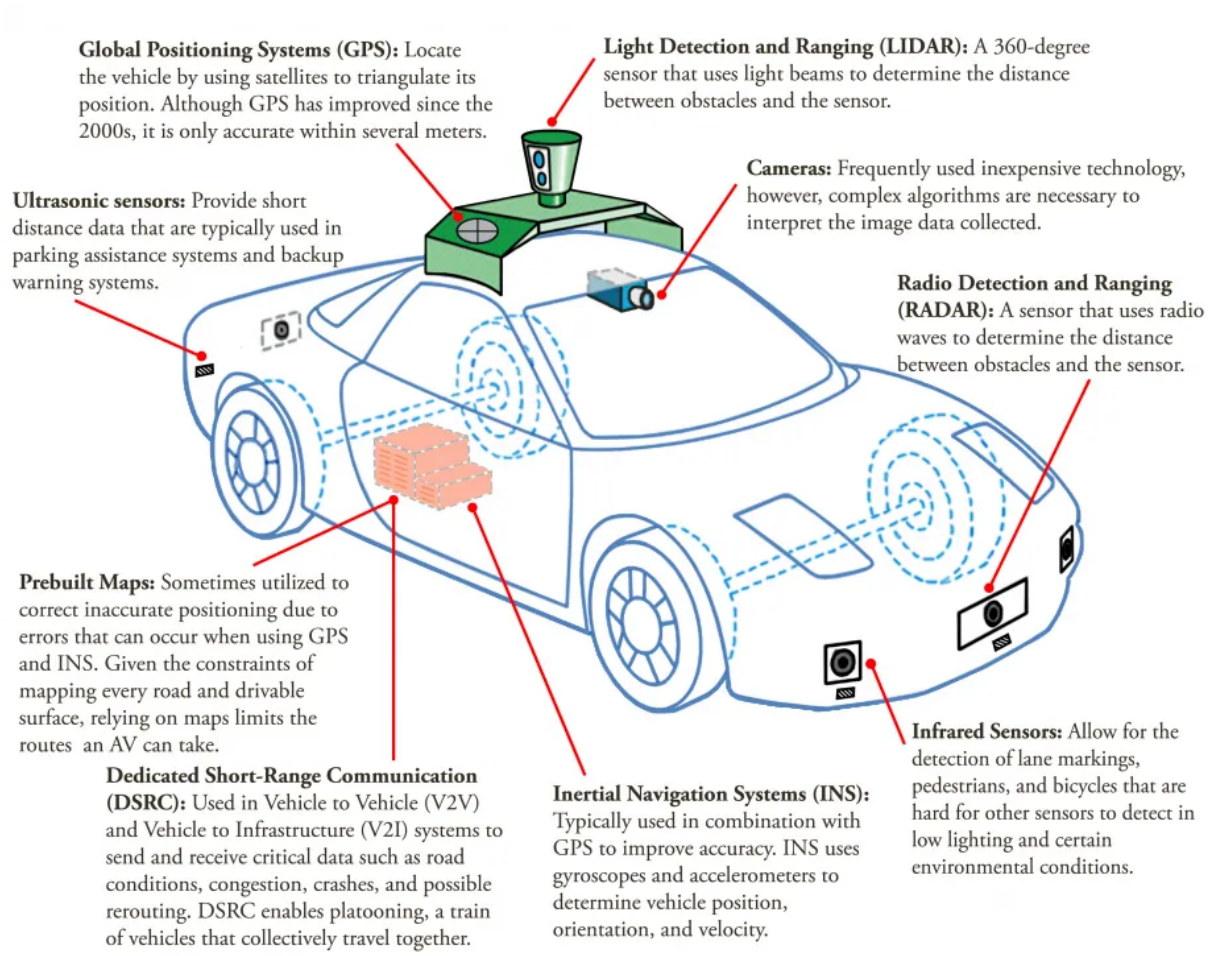


Figure 2.5: Sensor technologies in autonomous vehicles.(adapted from Center for Sustainable Systems (2023))

The notion of "phantom autos," which refers to a remote-control device used to operate the vehicle, gave rise to the first ideas about autonomous automobiles than a century ago in 1920 LaFrance (2016). The U.S. Defence Advanced Research Projects Agency (DARPA) grand challenge programme gave a boost later in the 1980s. Nonetheless, Carnegie Melon University's NavLab programme took the lead in developing autonomous land vehicles in 1986 Kanade et al. (1986). With their "PROMETHEUS Project" [1] in

[1] PROgraMme for a European Traffic of Highest Efficiency and Unprecedented Safety

1987, Mercedes-Benz made a significant advancement in the field of **Autonomous Vehicles (AVs)** by developing a car that was capable of following lanes Project (1987). Autonomous cars are becoming more popular among people all over the globe as a result of the technical advancements that have been made in recent years Zali et al. (2022); Almaskati et al. (2023). These advancements include power computing, **Artificial Intelligence (AI)**, **Machine Learning (ML)**, and other relevant technologies. On the other hand, there is not a single car that successfully satisfies the standards of a completely autonomous vehicle at this time; yet, these vehicles fall within the category of "automated vehicles." The distinction between "automated cars" and "autonomous vehicles" is quite subtle. The difference lies in the fact that in the case of "automated vehicles," human involvement is necessary, but in the case of "autonomous vehicles," there is no need for human intervention Hancock et al. (2019). In accordance with SAE J3016, this indicates that the vehicle is considered autonomous if and only if it reaches the L5 level of autonomy standard. The information that is shown in Fig. 2.5 indicates that the cars that are now classified as automated are equipped with a number of different sensors.

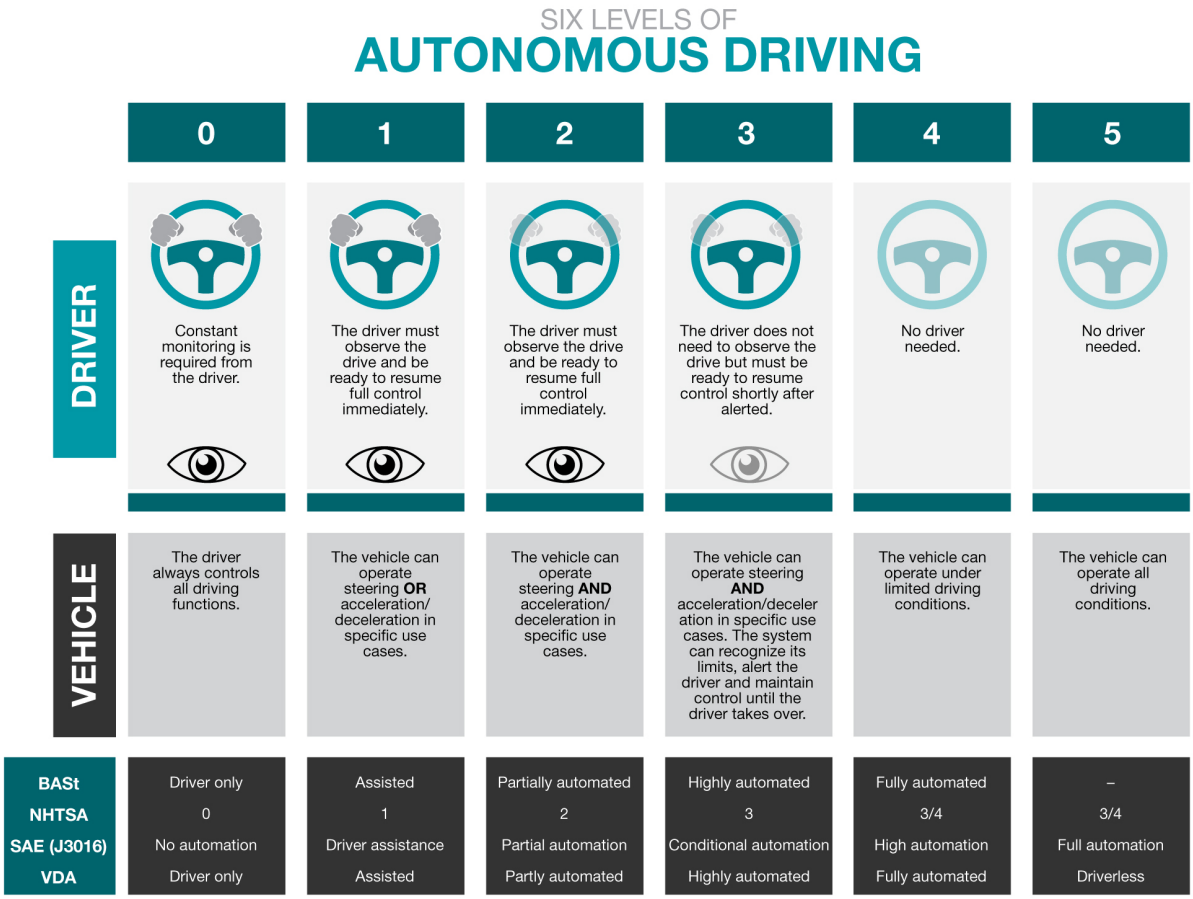


Figure 2.6: Six levels of autonomous driving.(adapted from Estl (2018))

Continual advancements in car technology will bring about new hope for users, enabling them to satisfy their needs of comfort and preferences while they are travelling. This will not only provide new opportunities for customers (in terms of their level of satisfaction), but it will also make it possible for **Original Equipment Manufacturers (OEMs)** to make new features as driver assistance to the fleets that are going to be produced in the near future. The idea of "automated driving" is evolving as this process goes on. It is anticipated that this will result in an improvement in the driving experience of the users. Furthermore, as per the SAE J3016 LoA (see Fig. 2.6), if we increase the technological scale further, namely in the areas of vehicle computers, sensor technologies, and communication systems, it will come into the category of "autonomous driving."

Autonomous driving is widely seen as a crucial factor in determining the future of transportation and improving the quality of life. The key parameters that play a role in it are: (a) Safety, (b) Efficiency, (d) Comfort, (e) Social inclusion, and (f) Accessibility. These elements provide the plan for future autonomous driving capabilities (refer to Fig. 2.7).

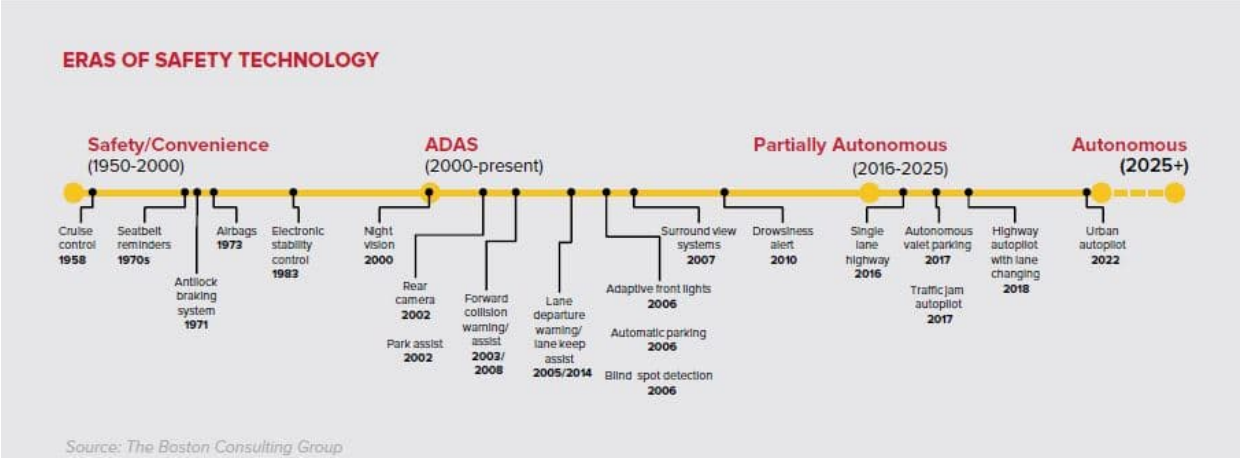


Figure 2.7: Autonomous driving roadmap.(adapted from Jonhston (2015))

2.4 Cognitive vehicles

The function of ADAS is critical for both existing and future fleets because of the rising awareness of safety among users Macadam (2010); Kaye et al. (2022). ADAS's primary function is to facilitate communication between drivers and their vehicles in order to prevent conflicts and, ultimately, safeguard the passengers from accidents. Because of this, ADAS are very intriguing not only for OEMs, but also for other research domain individuals, such as designers, ergonomists, technocrats, and others. In order to ensure that the driver has a lower degree of stress, the objective of the development of a "cognitive vehicle" is to provide

assistance to the ADAS Chung et al. (2019). This implies that in order to prevent accidents on the road, the "cognitive vehicle" will be able to identify, track, and rectify any faults or mistakes made by human drivers Amparore et al. (2014).

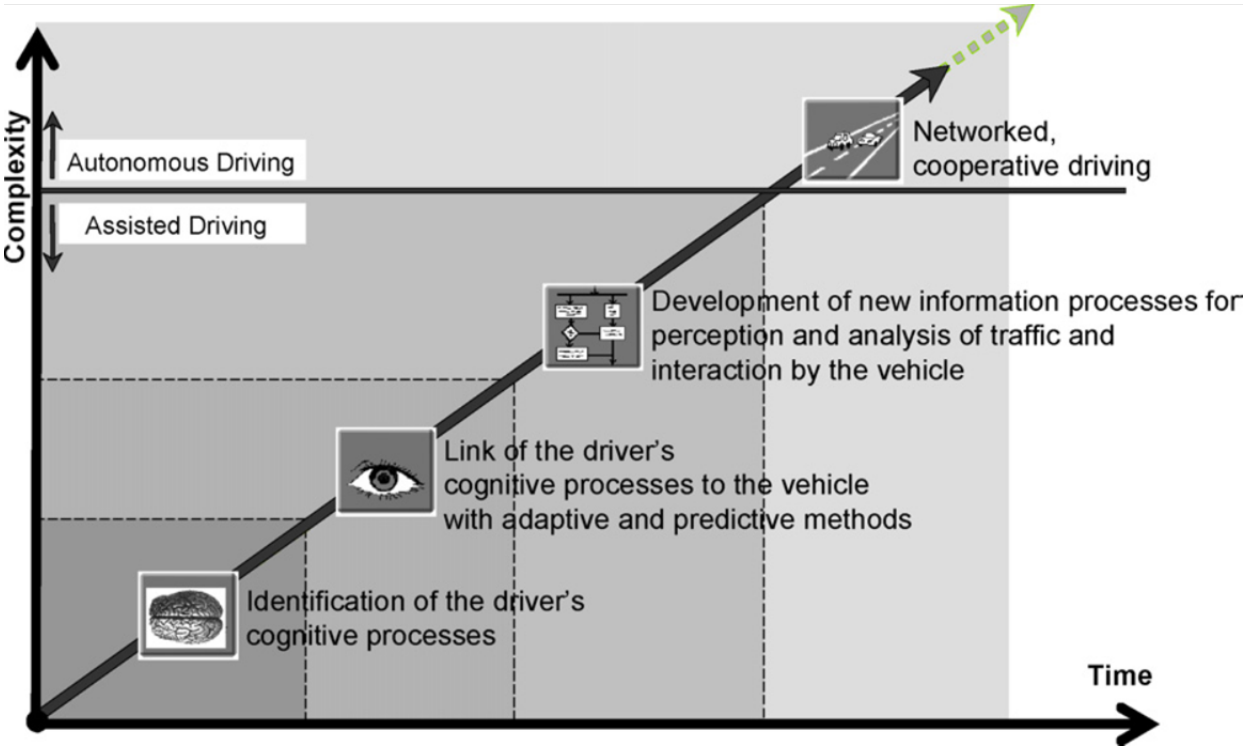


Figure 2.8: Cognitive car roadmap.(adapted from Aachen (2004))

The cognitive cars, in particular, have the capability to adapt to the needs and requirements of drivers. This also includes meeting the requirements for acceptability, relevance, and usefulness in order to lessen drivers' workload and distraction. This will provide a clear concept for "collaboration" between human and technology to improve teamwork Heide and Henning (2006). Thus, the German Research Society defines cognitive vehicles as follows: "The vehicle as a technological system which can perceive itself and its environment, as well as collect and structure information in an autonomous way." Fig. 2.8 illustrates the cognitive vehicles' roadmap in accordance with the previously provided definition Aachen (2004).

The ultimate objective is to render the driving experience "personalised" (henceforth, cognitive vehicles are occasionally referred to as PIVs) and to offer a relief experience to the users in the vehicle's cockpit. This idea is supported by six pillars, which are as follows Smith (2015): (a) self-integrating, (b) self-configuring, (c) self-learning, (d) self-healing, (e) self-driving, and (f) self-socializing. For more information, please refer to Fig. 2.9.

As a result, the cognitive vehicle is centred on the ideas of taking care of its passengers, taking care of itself, and engaging in collaborative efforts with others Brachman (2002). Such a vehicle would finally be

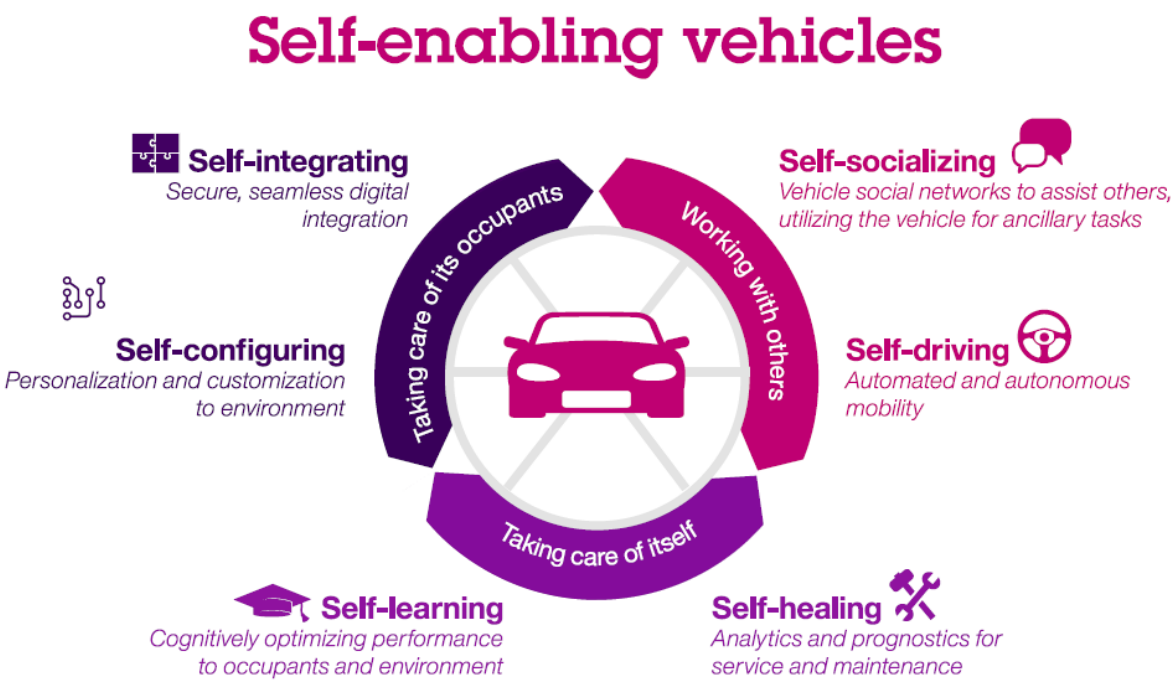


Figure 2.9: The foundations of the cognitive vehicles.(adapted from Smith (2015))

capable of being the kind of cooperative, symbiotic partner in which human driver can trust. Therefore, the ultimate objective of the vehicle is to be classified into the following three categories Panagiotopoulos and Dimitrakopoulos (2019): (a) to collect user and driver profile information and preferences, (b) collected up-to-date driving environment data, and (c) through the previous knowledge and experience (from data collected) take an appropriate decision in a collective manner to ensure the joy of driving during the journey for all occupants.

It is essential to have a solid understanding of the human users' needs, in addition to the terminology that pertains to vehicles and technology. It is possible that this may give rise to a few questions, the most important of which is whether or not the human user will be a component of future cars. And, are new users prepared to embrace autonomous vehicles? The responses to these questions will be addressed in Chapter 3.

CHAPTER 3

Nexus of Human Driver, Automated Driving, and Autonomous Vehicles

This chapter provides an explanation of the reasoning that underpins the relevance of "human" availability in autonomous vehicles. According to the findings of the study, people all over the world have a certain amount of enthusiasm for automated driving, but at the same time, they are somewhat hesitant to use autonomous cars. In light of this, the present chapter provides evidence that demonstrates the ways in which people see their future fleet and the worries that they have.

3.1 A brief journey of mobility

Every living thing on our planet needs air, water, and food in order to breathe and stay alive. Air is readily available and abundant without any expense, and water is likewise easily accessible. However, obtaining food requires effort and mobilisation. In this sense, mobility is an integral part of one's life. Since the beginning of time, we have seen that a human being is able to travel from one location to another by using a variety of instruments (transport alternatives) for mobility. As a result of the advent of the industrial revolution, there has been a shift in the manner in which mobility is used Bainbridge (1983). There has been a dramatic shift in the vehicle industry over the last several decades as a result of the introduction of automation, which allows for little human interaction and has therefore modified

transportation possibilities. AVs are the new mobility options that have emerged as a result of this transition. In 2007, the first ever benchmarking promotional event for autonomous cars was organised in California, United States of America, as part of the Defence Advanced Research Projects Agency (DARPA) Urban Challenge Urmson et al. (2009); Montemerlo et al. (2008). This event represents a significant milestone in the history of the industry.

AVs have enormous potential to allow for more productive use of time spent in a vehicle and to reduce crashes Sun et al. (2006), traffic control Luettel et al. (2012), costs of congestion Bouroche et al. (2006), energy consumption Saust et al. (2012), and pollution. Fig. 3.1 indicates the key technical adoptions and milestones for the autonomous car industry.

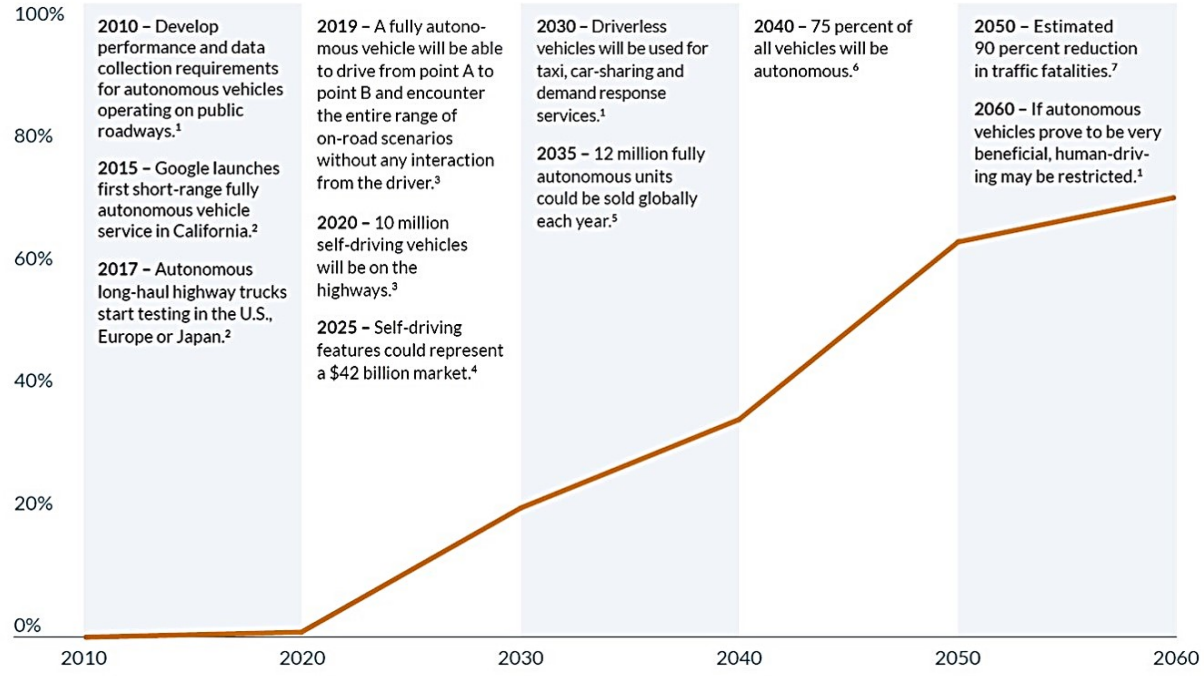


Figure 3.1: Percentage of autonomous vehicle adoptions and key milestones.(adapted from Litman (2015))

3.2 Human-out-of-the-loop

By simply putting the human agent into the loop is not cent percent assurance that a human agent will understand everything and do all the duties given without an error. The term "out-of-the-loop" was used in the field of aviation Kaber and Endsley (1997), in the sense that removes the human operator from control loop and handling of automation/ control by the system considering minimal human-machine interaction. It also has been taken into consideration respect to physical and cognitive aspects, where the

human driver hands off during the driving and not much aware about the driving-related tasks as in the monitoring position Louw et al. (2015). Nowadays, frequent use for **Human-out-of-the-loop (HOOTL)** in the military weapon systems, where weaponize systems operate without human presence. Inspired by this phenomenon, OEMs are trying to deploy HOOTL vehicles in the near future with confidence that machines are more powerful than humans. The HOOTL also has some open questions including:

- In case of *failure of automation*, how to handle the control of a vehicle as the human operator is out-of-the-loop?
- How to overcome the issues related to *information breaching* in the cyber-physical environment?
- What about *legal concerns* related to issuing a license, insurance, etc.?
- To how much extent, do we believe in the process of *decision-making* relevant to the situation?
- How, when and where to *update* the system software?

3.3 Human-in-the-loop

For a long time, we have been a witness and to be a part of master-slave kind of automation Mouri and Kawasaki (2007); Yokokohji and Yoshikawa (1994). With the advent of **Human-Machine Interaction (HMI)**, this relationship changed to a 'teammate', in which a human agent has been getting enough information about the surrounding for successful interaction. As the systems become more advanced (for example, with increasing the levels of automation), the way of information exchange between the human-machine shifted from one level to another depending upon the task given. Therefore, the system needs to cater to sufficient information that properly cultivates the current situation awareness. So that, generally system architectures and designers put a **Human-in-the-loop (HITL)** to cope with unexpected events while driving a vehicle.

Moreover, technological challenges are on the route but at the same time, crucial issues related to human factors have to be elucidated. There are enough examples which show that automation is substantially influenced by human factors Lee and Seppelt (2009); Merat and Waard (2014); Drury (2001). Various human factors, which play a crucial role in the **Automated Driving (AD)** are depicted in Fig. 3.2. Human factors will, therefore, play a crucial role in the future of technological advances, where a human driver and a system (a vehicle) are being fused more closely and more effectively than ever before. There is no confusion that for the human-centered design, the presence of human factors is scientifically essential Bannon (2011); Harte et al. (2017); Abubakar and Wang (2019); Sheridan and Parasuraman (2005).

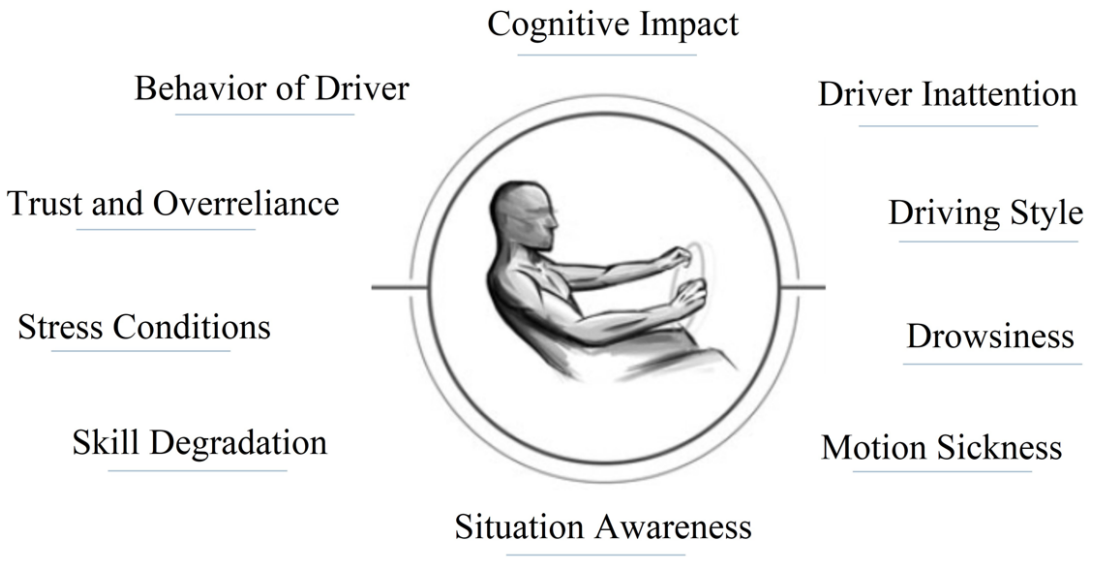


Figure 3.2: Human factors in automated driving

This is due to by applying the principles of psychology and physiology one can enhance the strengths and limitations of the human. Besides these, there are questions that remains unsolved while considering HITL including:

- How do we ensure the reliability of the human-machine interaction in a meaningful way?
- What parametric criteria to judge the quality of effective HMI?
- How do we determine and measure the level of trustworthiness between the human agent and a vehicle?
- What kind of autonomy will control the vehicle in which scenario?
- In case of a change in the design or any information update, who will adapt to the new environment, and at what speed?
- Who will be responsible for any mishap?

3.4 Why study human presence in autonomous vehicles?

Driving is a decision-making process by humans, and factors like stress can cause changes in decisions, reactions, and concentration capabilities Healey and Picard (2005); Rigas et al. (2012); Stanton and Young

(2007). Hence, it is substantial to know the peoples' opinions about what they are thinking about new technologies. We are living in the era of ADAS, which has mainly four cognitive decision-making tasks Groeger (2000): (a) assess and situation, (b) identify the available options, (c) determine the costs and benefits (relative value) of each, and (d) select the option of the lowest costs and highest benefits. With such kind of tools, a vehicle is more intelligent and has the capabilities to make decisions based on near to real-time situations. This could eliminate driver errors and lead to fewer accidents on the road. On the other hand, this opened up wings for the new development in the sector of automobile, especially for the AVs. AVs have many features like useful in traffic control (e.g., management of traffic control in an effective way), manage the costs of congestion in urban areas, improve fuel economy, provide a new direction for future cities planning, a boon for people who are physically impaired, among others. However, the success of the AVs will depend on the various factors of social-demographic environment, the way of people accept or reject the technology, whether the regulatory policies are enough to protect the rights of humans or not.

It is abundantly evident that the process of putting AVs on the road is not a procedure that can be completed in fortnight. It is thus necessary for there to be a genuine public debate among politicians, regulatory organisations, and manufacturers over the LoA. Since inception and emergence of AVs on-road, there were so many debates on their functionality with respect to design, development, and deployment. Specifically, a number of recent surveys (refer Table 3.1) clearly pointing out the issues of trust, privacy, acceptance, ownership, and pricing of vehicle, among others. In the recent years there has been considerable progress toward connected vehicles to foster new challenges in the sector of transportation Elliott et al. (2019); Rios-Torres and Malikopoulos (2017); Unlemann (2015). Indeed, there is no doubt on the functionality of AVs, but one can predict that these vehicles will play a vital role in reshaping transportation due to its socio-economic impact on the society. We need to have these kinds of conversations before we let AVs into public spaces and everyday use in the future.

Table 3.1: Recent surveys on autonomous vehicles and automated driving.

Reference	Year	Method	Location (No. of Participants)	Description
Tan et al. (2024)	2024	Online	China (4112)	Knowledge and public support for AVs
Silvestri et al. (2024)	2024	Online	Italy (406)	Expectations and attitude for owning, sharing, and riding AVs
Swain et al. (2023)	2023	Offline + Online	Australia (39), USA (2), Germany (2), Netherlands (1), UK (1)	Attitudes and opinions on emerging AV technologies plus societal impacts
Lee and Hess (2022)	2022	Online	USA (914)	Safety, privacy, and data security concerns
Gupta and Sharma (2022)	2022	Twitter	World (32976)	Perception towards AVs
Schneble and Shaw (2021)	2021	Interview	Switzerland (16)	Smart vehicles with human presence
Hilgarter and Granig (2020)	2020	Interview	Austria (19)	Attitude to AVs, safety, and integration of AVs in mixed traffic
Bazilinskyy et al. (2019)	2019	Online & Questionnaires	128 nations (18970)	When all cars will be fully automatic?
Correia et al. (2019)	2019	Online	Netherlands (For AV 252, Chauffeur 250)	Travel choice by conventional car, AVs with office and leisure interior
Braun et al. (2018)	2018	Online	Europe & North America (170)	Emotion of driver in AVs
Charness et al. (2018)	2018	Online	USA (441)	Attitude towards AVs based on age, gender, prior knowledge, and personality
Presthus and Sorum (2018)	2018	Online	Norway (216)	Consumer privacy in AVs
Awad et al. (2018)	2018	Online	Worldwide (40 million)	Morality issues by AVs
Nordhoff et al. (2018)	2018	Online	116 nations (7755)	Acceptance of driverless vehicles
Hyde et al. (2017)	2017	Online	UK (233)	Consumer attitudes towards AVs
Technologoes (2017)	2017	Questionnaires	USA & Germany (2000)	Consumer acceptance with (a) Autonomous Car as-a-Product, and (b) Autonomous Car as-a-Service
Piao et al. (2016)	2016	Online	France (425)	Implementation of AVs in urban areas
Kyriakidis et al. (2015)	2015	Online	109 nations (5000)	Acceptance, willingness, and concerns to buy partially, highly, and fully AVs
Schoettle and Sivak (2014)	2014	Online	USA, UK, and Australia (1596)	Awareness, benefits, and willingness to pay for AVs

3.5 Research questions and data collection

These days, a vehicle is not just for going from one point (origin) to another point (destination), but rather delivers a holistic experience that revolves around our daily activities, with the future being the autonomous vehicle. Due to this new experience in mobility, new trends begin in shared rides and vehicles may lead us from owner to an on-demand experience Beiker (2016); Steiner and Irnich (2020). Although the technology has advanced to the point where many OEMs are doing the first test, the harsh truth is that there is currently not completely AV accessible for the service on the road. However, there are different acceptance criteria by people around the globe, as it depends on the various factors. Considering all these modalities, we carried out an online survey where participants (N=3139) from the 146 nations gave their opinion (see Fig. 3.3). The survey performed from February 14, 2019, to July 10, 2019, with two key research questions, and to the best of our knowledge, this kind of work is the first time combining the parameters of both automated driving and human driver presence in the AV. The research questions are as follows:

RQ1 Whether automated driving is good or bad (in terms of reducing the driver stress, technological advantage, etc.) for mankind in a long run?

RQ2 Whether the presence of a human driver is required (considering all levels of driving automation) in autonomous vehicles?

3.6 Data analysis

As it is very clear that to investigate the research questions asked, the age and driving experience plays a key role. Considering this, we just consider the answer of people with driving experience and with age higher than 18 years old. Furthermore, double responses and in some cases the responses not appropriate (e.g., the difference between age and years of driving experience less than 18) were excluded. Finally, we only consider 2080 responses as useful for further analysis. Taking this into consideration, the answers to RQ1 and RQ2 are shown in Fig. 3.4.

The data were cross-tabulated and chi-square (χ^2) analyses were performed to estimate the statistical strength of association between continents, and answers to the research questions. The level of statistical significance is set at *p-value <.05*.

For all continents the proportion of people who answered that automated driving is something good was high (greater than 76%, see Fig. 3.5). However, significant differences were found for the percentage

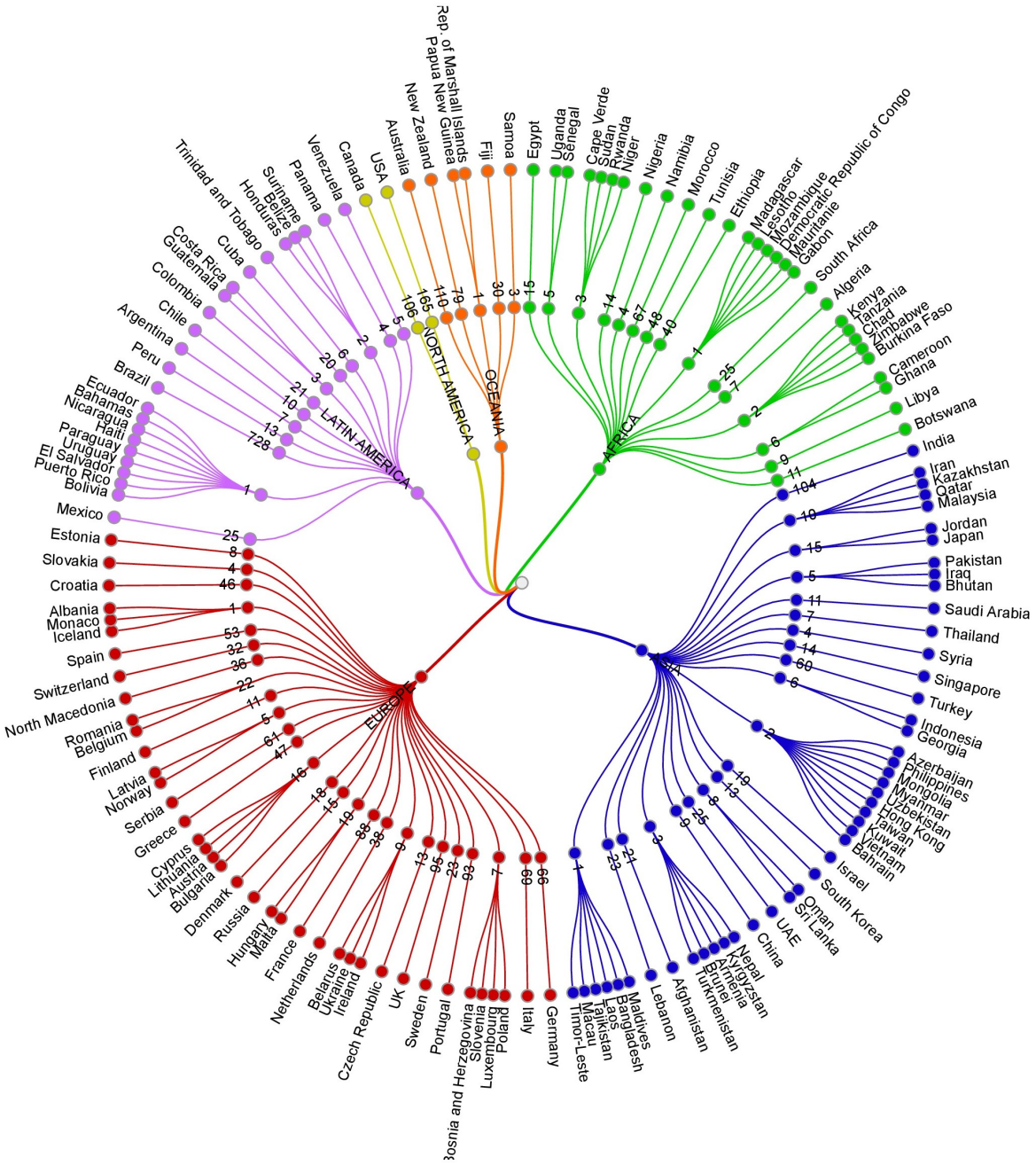


Figure 3.3: Continent and nation-wise information of respondents.

of answers between the six continents ($\chi^2 = 32.79, df = 5, p < .0001$). While in Africa the percentage was about 76.2% and in Latin America the percentage goes up to 90.6%.

Fig. 3.6 presents the percentage of answers to each RQ2 option per continent in two different groups according to the answer in the RQ1 ("Good" and "Bad"). In the group of "Bad" answers in RQ1, no evidence of the relationship between continents and RQ2 answer was bound ($\chi^2 = 10.97, df = 10, p =$

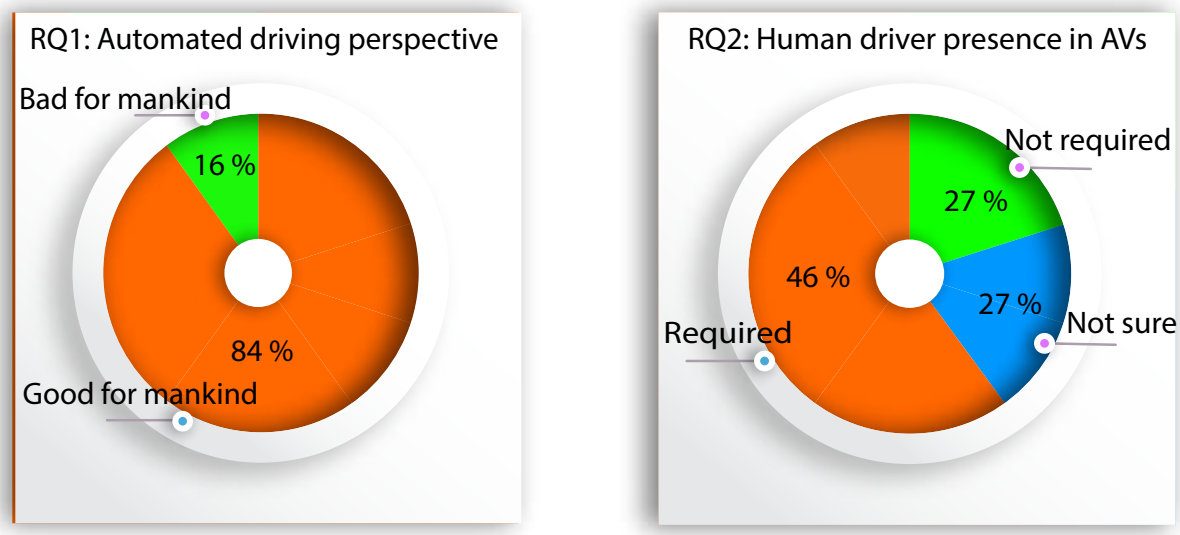


Figure 3.4: Overall results for the RQ1 and RQ2.

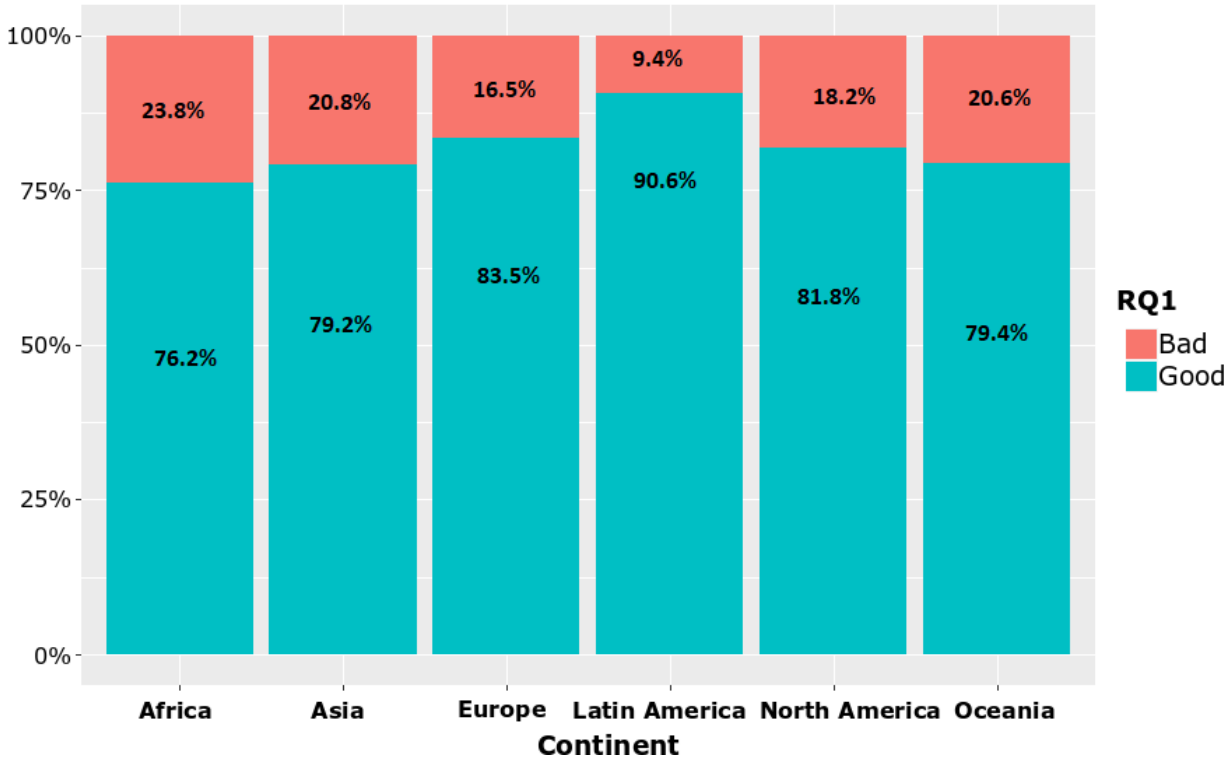


Figure 3.5: Percentage of answers to each RQ1 option per continent.

.360). However, amongst the group of "Good" answers in RQ1 significant evidence of the relationship between continents and RQ2 answer was bound ($\chi^2 = 60.56, df = 10, p < .0001$). While in Africa 64.9% answer "Required" and just 14.9% answer "Not Required", in Europe and Latin America the percentage of "Required" and "Not Required" were less than 40% and more than 30% respectively. Comparing the percentage of answers to each RQ2 option between the group that answer "Good" in RQ1 and the group

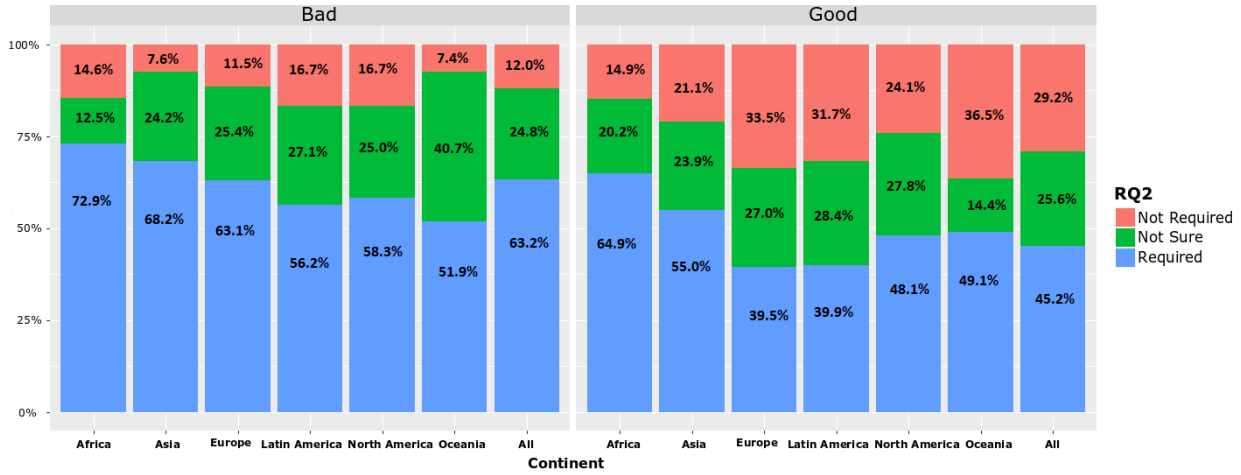


Figure 3.6: Percentage of answers to each RQ2 option per continent in two different groups according to the answer in the RQ1 ('Good' and 'Bad').

that answer "Bad" in RQ1 for all answers, strong evidence of the relationship between RQ1 and RQ2 was found ($\chi^2 = 51.79, df = 10, p < .0001$). In fact, while 63.2% of the group that answer "Bad" in RQ1 answer "Required" in RQ2, just 45.2% of the group that answer "Good" in RQ1 answer "Not Required" in RQ2.

3.7 Implications of human tendency towards AD and human driver availability in AVs

The focus of this section is to explore the new avenues besides the RQ1 and RQ2 in terms of participant's implications (see Fig. 3.7). It is quite clear how these factors are helpful in defining and developing new human-vehicle based technologies for the upcoming intelligent vehicles (or even future 'cognitive vehicles') that cope up with every situation. They also indicate knowledge gaps between diverse areas where future efforts should be carried out.

Our methodology was developed and adopted in two steps. First, during the survey period, it is based on the discussion with the participants through online platforms, for example, LinkedIn, Facebook, WhatsApp, etc. And secondly, as a collection of viable feedback from the participants. We are quite conscious about not including any policy reports on automated driving and autonomous vehicles produced by the governments or any other organizations as a part of implication.

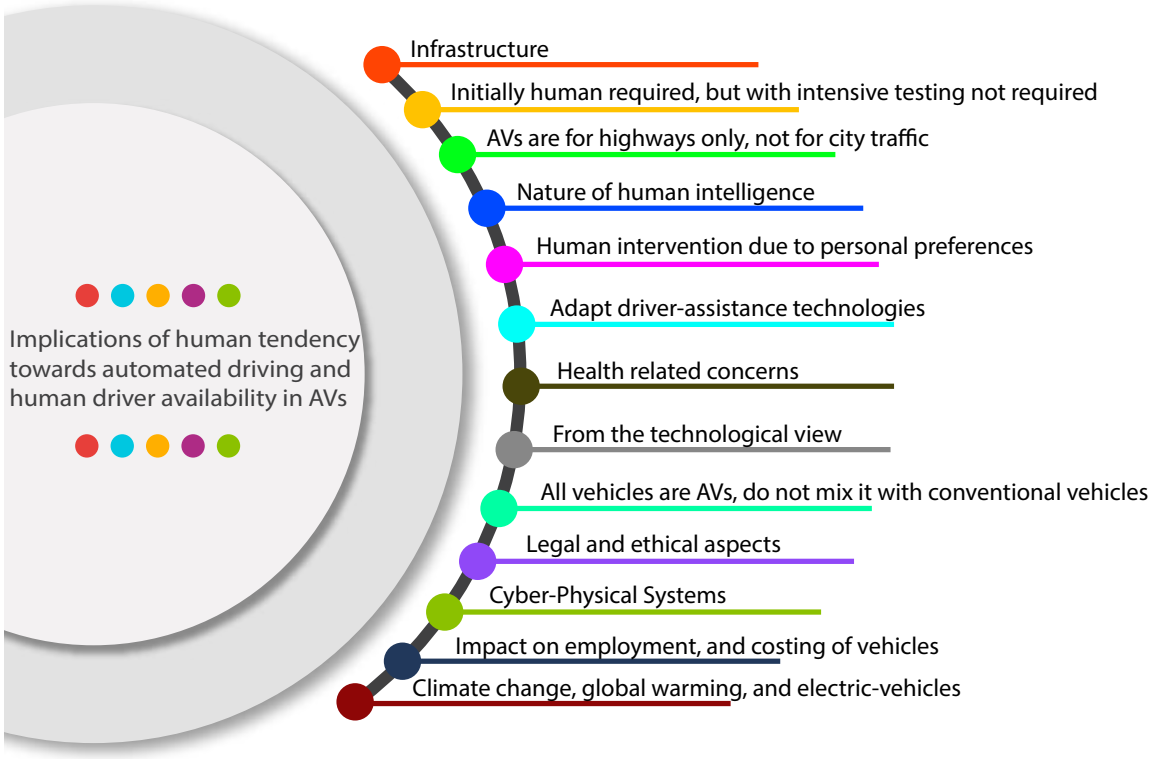


Figure 3.7: Implications based on human tendencies towards AD and human driver availability in AVs.

3.7.1 Infrastructure

Infrastructure is the entity where physical and digital worlds meet together. For the successful deployment of autonomous vehicles on the road, a dedicated infrastructure facility is needed, which also supports the levels of automated driving Carreras et al. (2018). It is split into two categories: (a) physical infrastructure and (b) **Information and Communication Technology (ICT)** enabled infrastructure.

Physical infrastructure:

Currently available physical infrastructure is designed based on conventional (non-autonomous) vehicles and somehow considering the human drivers' cognitive abilities. It was also noted that building a new infrastructure that will support autonomous vehicles on the road is a little easier for developing and undeveloped nations, as they have to start with scratch compared to developed nations were already having heavy traffic on the road. The pace at which autonomous vehicle technology developed and achieved this level of penetration will clearly indicate more investment to be needed in the physical infrastructure Har-

rington et al. (2018); Tengilimoglu et al. (2023). Despite the fact that the nature of this infrastructure will be complex, who and how will maintain the infrastructure under which conditions? This means that whether the infrastructure will be maintained by government agencies or by the vehicle manufacturers or by the other private organizations. A reformed infrastructure includes road markings and signs, enough charging stations in case of electric autonomous mobility, crash barriers, speed signs are among the others. It is also taking care that the visibility of the said steps has to be maintained in all the seasons.

Physical infrastructure must enable and support not only autonomous vehicles, but also different players including pedestrians and cyclists Laird et al. (2013). A key challenge is to have dedicated areas for walking and cycling that will create a liveability, especially in urban spaces. By doing so, guarantees that the infrastructure will cope with the other traffic players and hence allow fleets more efficient along with socially acceptable and safer.

ICT-enabled infrastructure:

In addition to physical infrastructure, we have to look after ICT based infrastructure owing to its features including to provide an accurate vehicle localization during the journey, assist a lane-keeping in the case of **Connected and Automated Vehicles (CAVs)**, managing traffic information flows between the traffic management center are among others.

To meet the requirements of rapid improvement and expansion of the current autonomous vehicle technology, a future ICT based infrastructure will be enabled by consistent connectivity between the vehicles and outside partners (e.g. Pedestrians, cyclists, other vehicles, etc.). With the emergence of 5G technology, which assures high-speed data connectivity and downloading facilities, is expected to resolve all the issues of connectivity in the ages of intelligent transportation.

3.7.2 Initially, human required, but with intensive testing not required

AVs will be a game changer in redefining mobility, at the same time requires a lot of development which ensures the safety at all levels and in all conditions. Just to switch from manual to an autonomous vehicle will solve all the current road problems related to safety is not yet guaranteed profoundly with the present development of technology, for example, the latest fatalities by Tesla Wattles (2019), and Uber Lubben (2018). This will come with a new discussion, whether the reliability of autonomous vehicles defined by the number of miles traveled, and if so, how to calculate it Robert Jr. (2019).

Considering these situations, currently, a human driver is required for testing and safety point of view, however, as the technology grows up the need for a human driver will subside. A completely cloud

controlled traffic system would be much safer and more efficient than any system involving human control. The hard part is the transition phase, in which human drivers are inevitable, but AVs need to be able to cope with these factors. Studies show that more than 90% of accidents have been occurring today due to human error Intini et al. (2014). The push for autonomy is to focus on the reduction in the number of Killed and Seriously Injured (KSI) and reduce road-related fatalities. There are multiple other benefits such as reduction or elimination of driver fatigue, freeing up of time spent driving, which could increase productivity or free time, more efficient traffic flows through the cities and optimization of the use of road infrastructure. It is also true that correctly developed and deployed AVs could reduce the number of vehicles required if shared use and ride-sharing is promoted in an effective way.

When looking at AVs, we are still in the phases of adapting and learning. Before adopting this vehicle to be a part of our routine life, the software and hardware must have been well-tested for many levels to avoid any malfunctions. However, in the short-term, there may be a need to build trust, which is one of the challenging parts for the successful deployment of vehicles on the road in a mass volume Raats et al. (2020); Hoppe et al. (2023); Kaur and Rampersad (2018). Thus, human presence may be seen as a good way to win trust. Still, how long a human driver required is not cleared yet, and hence it is quite early to tell about the absence of the human driver in the AVs in the near future. Altogether, in the coming time, it is a challenge for the vehicle manufacturers to develop layouts that support both human driver and driverless configurations at least for the next few decades.

3.7.3 AVs are for (motorways) highways only, not for city traffic

The key question with respect to AVs is that they occupy the same space as today's conventional vehicles. If so, then it is highly recommended that AVs are deployed firstly only on motorways with stronger rules, for example, no human driver car quickly coming on the motorways. This is because of future city centers might be very limited with vehicular transportation in order to give more space for pedestrians and other road users. In these limited-access centers, AVs can be used as a complementary service to some specific areas and tasks. The implementation of fully AVs in an urban environment is highly unlikely to occur to a wide scale because of the complexity which lies in the interactions between vehicles for busy city streets, pedestrians, other modes of transport as well as unpredictable behavior of different road users Faisal and Yigitcanlar (2019); Tengilimoglu et al. (2023).

3.7.4 Nature of human intelligence

There is no doubt that technological innovations increase productivity, but are they enough mature to compete with human intelligence in all conditions, especially, in the case of road accidents. Despite numerous similarities between accidents, it is not possible to find even two identical events (accidents) in which their parameters are exactly the same. Human intelligence should never be replaced by machines, as there are situations where algorithms are not capable of learning as a human can Cremer and Kasparov (2021). Hence, automation is great progress and opportunity to improve drivers' skills, however, that has to enhance the drivers' capabilities not to replace them.

3.7.5 Human intervention due to personal preferences

Apart from other technical modalities, people want the control of a vehicle for their hands and not to the machine (here, an AVs) Sio et al. (2023); Calvert et al. (2019). This is due to their mentality, routine habits, and at the same time raise questioning the current regulatory and infrastructure concerns. If the system is totally automated and works as a boss, but in some uncertain situations where machines are not capable to anticipate the situation correctly, hence human intervention is necessary to regain the smooth and safe travel as a supervisory agent.

3.7.6 Adapt driver-assistance technologies

While autonomous vehicles have enormous potential to benefit society, care will need to be taken to optimize these benefits of the whole transport system. Nowadays, automotive majors are rushing into filling the streets with autonomous vehicles predicted to be in the near future, where they compete with each other to prove their technological superiority, rather than cooperating to overcome the existing challenges that still lay ahead. Effort should be spent on driver-assistive technologies, where there is a huge potential to improve and save human lives. We have seen in the last decade that the rapid development and the speed of deployment of different driver-assist technologies in the vehicles is astonishing. This is not only due to only safety concerns, but provide comfort to the driver in day-to-day driving operation, and control the vehicle in an indeterminate state. Today drivers use more than 90% of automatic technologies, in the case of **In-Vehicle Infotainment Systems (IVIS)** to automatic lane changing and braking systems, while driving to manage the conscious and unconscious state Freymann (2009); Shaout et al. (2011). This way one can travel through quite long periods of time for minimal risk and an optimal amount of mental workloads. It is also observed that the accessibility of the driver-assist systems is increasing day by day,

and will continue until the fully automatic vehicles developed which will work in all conditions. We should give surety to make a balance between automation and human intelligence with the effective integration of human factors in the process of design and development of such systems Palac et al. (2021).

3.7.7 Health related concerns

In light of the transition to conventional to autonomous mobility, we should have to take care of health-related issues while and after deployment of the system. If a driver is in a passive role or having no role in active driving due to automated driving, especially considering SAE Level 3-5, over the time he/she forget how to drive a vehicle and will cause numerous health-related issues Rojas-Rueda et al. (2020). The use of AVs by very ill people along with their pets will increase illness in the cities. Individual AVs are not solutions to all these kinds of social trouble, the solution is to aware people to use more and more public transport, which is autonomous in nature Sohrabi et al. (2020).

3.7.8 From the technology point of view

If we explore the autonomous vehicles for the technological advancement point of view, of course, there are two sides of the coin, (a) Trust in technology, and (b) Is the technology mature enough to trust?

Trust in technology:

In the era of the fourth industrial revolution where the growth of computational power and sensor data is tremendous, hence, automation and AI are inevitable. Where manpower has to be used for other productive purposes to make society more livable and responsible. A person is smarter than a machine, but it depends on a case by case basis. When we are doing repetitive tasks, we generally tend to become easily distracted or tired. AVs are able to maintain the same level of alertness all the time, if well designed. For example, in the military application, it is proven that automation and artificial intelligence-based weaponry system works well, with or without human presence for a long time. Altogether, machines are definitely behaving better than a human if we trained to learn them in all the situations as well as improve them to take the foolproof decision providing the design are trustworthy Dikmen and Burns (2017); Raats et al. (2024).

Is the technology mature enough to trust?:

No machine can rival human judgement, especially if it is based on emotions and values. The judgement on an autonomous vehicle is only based on data given by sensors that are not comparable to human

senses in terms of quality, reliability, trust, and self-assessment. There will always be an indistinct case which will be vague to interpret Farmer et al. (2023); Widen and Koopman (2022). For example, a fully autonomous system may get troubled or even failed by wrong inputs and create dangerous situations. AI is still in the learning phase (e.g. To recognize road signs, obstacles, the difference from a bike rider and a pedestrian crossing the road, etc.) and mistakes may still be made. The technology is not yet matured enough to work in case of heavy fog, snowfall, bad weather, and hence to adhere to all these will take time depends on how the automation and AI develop over the years Zang et al. (2019).

3.7.9 All vehicles are AVs, not mix it with conventional vehicles

It is a nightmare to give a 100% guarantee that no accident will occur with the adoption of AVs for the roads of the future with mixed traffic conditions Mahdinia et al. (2021). Therefore, if all the vehicles on the road are autonomous (considering SAE Level 5) then there is no human driver really necessary. In such a condition, there will be no interaction of driver behaviors (as no human driver presence on the road in any of the vehicle) and the AV will remedy all the safety and operational issues. And hence, great potential for passengers to use their time productively, as all the AVs on the network can produce system having optimal solutions with regard to travel time and energy consumption too.

3.7.10 Legal and ethical point of view

Legal matters:

In the realm of safety and digitization of the transportation system, for example, intelligent traffic management systems and effective tracking systems, require the establishment of specific legal backgrounds and strict regulations. As of now, the deployment of AVs for mixed traffic systems is not studied well due to a lack of legal framework. There are still, some open questions that pointing out legal liability include Patel et al. (2023b), (a) Who will be accountable in case of malfunctions? Be a software provider? Be the manufacturer? Be the owner of the vehicle? (b) How to handle different contexts? Are manufacturers enabling to develop a different vehicle for different countries owing to infrastructure, traffic regulations, driver habits, etc.? (c) How to adopt autonomous vehicles to match with the mindset of pedestrians and drivers in different geographical aspects? (d) Who is liable in case of an accident of fully autonomous and non-autonomous vehicles? Answers to such questions are not clear yet and to be discussed or to be considered before framing any legal road-map and deployment of an autonomous vehicle on the road.

The development and deployment of autonomous vehicles are going to change the nature of the

insurance service sector. Decision making in extreme and unavoidable cases that end with a fatal accident is the key question of the time. While human beings are judgmental and condemnable subjects, the decision on a pre-programmed algorithm does not work all the time. Cases like this where insurance plays a vital role and in which the algorithm developer will predetermine the collateral damage in case of an accident and this will generate a different insurance coverage.

Ethical issues:

Transition to fully automated driving will require regulations that will restrict some personal freedom and it is not clear if that is balanced by the benefits. There are many parameters to be considered and taken into account for this to be acceptable to every user, especially in complex situations involving the ethical factor as a prime Bonnefon et al. (2016). Yet moral choice solutions not made available, for example, in case of an emergency situation (a) Whether a vehicle ended up on a wall or to the person on the road? (b) Would the death of children be more important than an elder? (c) Should a pregnant woman count as two lives? Lastly, in the case of an accident which causes only injuries, but no fatalities, whether the pre-programmed algorithms are enough to define the priority of the decisions by severity, types of injuries as well as life affected by it?

3.7.11 Cyber-physical Systems concerns

We all know that driving is a complex task and to make it easy or smoother will need plenty of programming capability in case of the AV. By doing this, the system has the issue of vulnerability. The efficiency and reliability of AVs totally depended on the computing power, competency and network effectiveness, which can fail or even hack by the hacker. In the context of malware and ransomware putting into the system during the up-gradation of software, how to protect the vehicle? Intelligent vehicles have several **Electronic Control Units (ECUs)**, which are connected with an internal network of the fulfillment of various tasks Islam et al. (2023); Giannaros et al. (2023). Attacking these ECUs and breaching the data line will cause numerous unknown complications which never happened before. On the way of deployment of such vehicles issues related to the infringement of data is not resolved yet. Broadly, the open questions related to data privacy include Nguyen et al. (2022), (a) Who will keep the data? (b) What is the size of data storage (e.g. Daily, weekly, etc.)? (c) Who provides security to store data? (d) If data is stolen, by which law one can be punished?

3.7.12 Impact on employment, and costing of vehicles

Driving is a socioeconomic entity, and hence, by the implementation of an AV on the road will create serious employment issues in many countries. If so, it will push out some sort of criminal activity and increase the poverty level in society. In particular, developing nations will face drastic changes in their political domain as a number of people are going to unemployed suddenly Nikitas et al. (2021); Beede et al. (2017); Pettigrew et al. (2018). Deployment of an AV for the developing nations is not feasible due to infrastructure facilities, and especially they have already fought with a higher unemployment rate. In light of these, the governments have to find some suitable way of employment before adapting an AV.

Although, there is a tremendous development during the recent time for the AV technology, still, the costing of a single unit is not predicted well enough. There are lots of factors affecting the costing, include what kind of the infotainment system provided, what level of security provided, where the unit is manufactured, and what is another extra package demanded by the customer Bosch et al. (2018).

3.7.13 Climate change, global warming, electric-vehicles

AV technology came up with the revolutionary change in the day to day life. Of course, it comes up with a profound effect on the environment, but whether it is good or bad will depends on the regulatory authorities that how they will manage and/or define the rules and regulations. In the midst of various driver-assist and AV technology development, one of the greatest challenge comes across is global warming. This is because yet not clear whether the **Greenhouse Gas (GHG)** and emission reduction guaranteed by adopting AVs Liu et al. (2019). It depends on how many AVs are on the road, nature of congestion on road, and fuel efficiency per mile traveled by the AVs are among the other prime factors. One of the solutions is to prepare the future road to **Electrical Autonomous Vehicles (EAVs)**. EAVs should be integrated with the vehicle sharing and public transport system to ensure the reduction in the level of emission.

3.8 Limitations of the study

As the survey was conducted via different web-based platforms, hence, there are no specific participatory restrictions imposed on participants. That's why it has seen that we recorded a high number of responses from one part of the world, while it is not true for the rest, for example, the total number of respondents counted from Brazil was 728 and at the other end only single respondents from counties like Ecuador, Paraguay, Haiti, etc. which may affect the results of whole Latin America. Furthermore, it was assumed

that adequate information provided with the survey page was enough for the participants to understand the concept of automated driving and autonomous vehicles. Although, we were available online for any kind of help throughout the time of the survey period. It may be observed that findings from the survey conducted are largely based on descriptive and qualitative. Hence, future research is needed to comprehend and investigate diverse analyses based on the near real-time or simulator-based study to ensure the facts presented.

3.9 What we gained from the study?

The way in which it portrays the usefulness of automated driving and the importance of autonomous vehicles for the society as a next-generation intelligent transportation system, there is no doubt that it will work largely for the benefit of a common man. But, in a journey of driver-assistance to driver replacement, we should not forget the key player 'human'. By considering these implications, it will help to the policymakers and regulatory authorities to put autonomous vehicles in more acceptable and meaningful ways.

CHAPTER 4

User Routines and Preferences in the Context of Cognitive Vehicles

The significance of one's routine and preferences is paramount in every individual's existence. When discussing user routine, important considerations include cost-effectiveness, route satisfaction, and vehicle operating efficiency. In the modern day, one of the most significant components of in-vehicle technology is the element of personalisation. In light of these two aspects, the present chapter offers illuminating information on the manner in which users behave in relation to these aspects, as well as the personalised options that they are looking forward to having for their future fleets.

4.1 What makes user routines crucial?

Within the context of everyday transportation, user routines are important because they provide a foundation for creating transit systems that are reliable, efficient, and user-friendly. Planning for peak traffic periods, frequently travelled routes, and customer preferences helps transportation planners allocate resources and schedules more effectively Muller et al. (2024). For instance, if I go to my institution every day at 9:00 in the morning, the vehicle needs to be aware of my routines and, using that knowledge, notify me about my belongings and other noteworthy details that I should never forget. Additionally, integrating transportation options with user routines enhances convenience and satisfaction, encouraging the use of public transit over private vehicles. In the event that a user has to switch modes of transportation for their

trip, for instance, the alignment of bus timetables and train arrivals reduces wait times and facilitates a smooth travel experience. Insights into daily transportation patterns can aid in the creation of focused initiatives, including the implementation of carpool lanes to lessen traffic during peak hours or the promotion of bike-sharing programs in regions with heavy commuter traffic Liao et al. (2007). In general, employing user routines in transportation planning promotes a more sustainable and user-centred transit environment, in addition to increasing operational efficiency. The ultimate objective of routine is to guarantee that the number of sites visited will be taken into consideration during the subsequent visit and that they will be there in a way that is budget-friendly. In addition, it is of equal significance to remember the locations that have been visited. This will undoubtedly provide the user with a certain degree of clarity when they are searching for their next excursion, such as a visit to a shopping mall, vegetable markets, movie theatres, and other similar establishments.

4.2 Personalised user preferences

The concept of personalisation has emerged as a crucial facilitator for users in the new age of automobile technology. Using new technologies and making use of data to provide a more personalised experience is a primary objective for OEMs. In addition, the development of modern technology has made it possible for automobiles to adjust to the preferences of individual drivers, therefore converting the driving experience into one that is user-centric and highly customised Kasteren and Vredenborg (2022). The driver is welcomed with their chosen seat positions, mirror adjustments, and temperature control settings upon entering the car. These settings are all automatically customised depending on the driver's personal profile. This rapid customisation removes the need for manual changes, which not only saves time but also improves comfort. Infotainment systems are able to remember the radio stations, playlists, and volume settings that are most preferred by the user, guaranteeing that their preferred entertainment options are always within reach, whether by a touch or a voice command.

Furthermore, modern automobiles are outfitted with intelligent connection technologies that are designed to operate in a seamless manner with the digital environment of the driver. Personalised navigation systems, for instance, are able to forecast and recommend routes based on regularly frequented locations, current traffic conditions, and even the driver's previous preferences for routes that are more picturesque or take less time Iwasaki et al. (2007). Voice-activated controls provide an additional level of convenience by enabling drivers to make hands-free calls, send messages, and operate a variety of operations inside the vehicle without engaging in any distractions. These systems are able to recognise individual voices

and answer with personalised alternatives, which makes the interaction more user-friendly and effective. Additionally, ADAS provides personalised safety features like ACC and LKA that are individualised to the preferences and comfort levels of the driver Hasenjager et al. (2020). By tailoring the functions of the vehicle to the preferences of the driver, this high degree of customisation not only enhances the overall driving experience but also makes the trip safer and more pleasurable for the individual Chen et al. (2023). As technological advancements continue, it is expected that the breadth of personalisation in automobiles will increase, therefore providing users with ever more sophisticated options to improve their level of comfort and convenience.

4.3 Why are human-centered assistive systems necessary?

ADAS have become more potent in recent years due to increasing computational power and various data-driven technologies. When the system has purely technology-driven dependency, there is no human touch, and the power of reasoning is absent. Therefore, there is the risk that purely technology-driven developments will not fulfil the expectations of the end-user. In this connection, the need for research and development of personalized human-centered assistive systems is even more evident today. Importantly, there may be a decline in trust between the two agents if the assistive systems do not fully meet user expectations. Hence, a personalized **Human-Vehicle Interaction (HVI)**, which has the ability to make interactions more intuitive Yi et al. (2020); Ponomarev and Chernysheva (2019) by means of cognitive capabilities (i.e., it learns user routines and preferences), is inevitable. A smart world also encompasses smart transportation systems, which also comprise smart/cognitive vehicles aware of their users' routines and preferences. Consequently, introducing cognitive abilities as a part of vehicle interaction ensures smooth and safe driving, and in doing so, we can enhance the quality of life of vehicle occupants.

Human-centered assistive systems play a key role amid the current strong competition that is seeking to provide new ADAS features Maguire (2001); Trentesaux and Millot (2016). Indeed, users are more likely to have higher expectations from assistive systems, as they provide different features like alert systems Sarala et al. (2018b), human motion recognition Nakazato et al. (2006), human recognition Erzin et al. (2006), and assurance of safety on the road Zhou et al. (2014). There are two main reasons for this. First, digitization allows seamless connections between users and vehicles, and as a result, the relationship between a vehicle and its driver becomes stronger, more reliable, and personal. Second, users expect the experiences that they have with a vehicle to be as good as those they have with other smart devices.

One of the key concepts of ADAS is to provide interaction in a more personalized manner. Initially,

this increases the trust between a driver and the vehicle, and it helps drivers execute the decision-making process in any task they undertake. Of course, this could be achieved by making more accurate user-centric models and developing personalized interactions Hasenjager et al. (2020). In recent years, all stakeholders have been interested in knowing user routines and preferences, as these will be helpful in introducing new assistive features in the coming years. By leveraging user routines Liao et al. (2007); Banovic et al. (2016), it is possible to detect anomalies Sun et al. (2023) and monitor the performance of the driver Shi et al. (2012) and his/her behavior Banovic et al. (2017). In normal daily life, we are not changing our preferences drastically, including before starting a trip, en route, and at the end of the journey. This could lead to repetitive tasks (i.e., by means of learning) being performed within a vehicle. Clearly, preferences play a prominent role in the design of ADAS Paiva et al. (2021).

Prior works have shown that vehicles' cognitive capabilities have gained more attention from vehicle manufacturers and car users Hoch et al. (2007); Vitello et al. (2017); Goebl and Farber (2008). However, none provided clear investigation-based evidence to support this assertion. As far as is known, this is the first investigation of this subject area. Therefore, the results may be used as a reference for the development of future cognitive vehicles (CVs).

4.4 Intent of the work

The objective of this research was to gather public opinion on the expectation of endowing future (semi-)autonomous cars with social and cognitive behavior, such as the ability to learn drivers' routines and preferences in order to make decisions and perform actions in preparation for the (next) journey and to manage comfort within the cockpit without explicitly being commanded to do so.

Major demographic characteristics such as age group, gender, education, occupation, and car driving experience information were used to ground the analysis of the responses and draw statistically significant results. The survey was intended to address some questions regarding drivers' acceptance of cognitive vehicles, with respect to the following use-cases:

Use case 1: Learning routines of different drivers with timestamps, and more specifically, where a driver intends to go next, when she/he intends to depart, when she/he expects to arrive at the destination, and how long she/he intends to stay at that destination.

Use Case 2: Anticipation of comfort inside the cockpit. A cognitive vehicle could learn the different seat positions, mirror adjustment settings, and preferred cockpit temperature of each driver. The prediction of when the driver intends to depart (using Case 1) and the learned preferences could be used to create

comfort inside the cockpit anticipatorily, thus saving time.

Use Case 3: Vehicle usage optimization after learning the routines of its different drivers (using Case 1). For example, the vehicle could propose the car's availability, when it is parked at a specific location, to another user/family member for a certain period of time.

Use Case 4: Vehicles' ability to avoid users making mistakes, such as forgetting objects when entering or exiting. As different users take different objects in and out of the vehicle at different times and destinations, the vehicle could learn these dynamics and alert the driver if they are about to forget an object.

4.5 Methods

4.5.1 Survey

A survey containing 27 questions (Table 4.1 and Fig. 4.1) was developed using the online tool QuestionPro (`www.eu.questionpro.com`) to explore solutions to the research question. From August 5 to December 20, 2020, participants were invited to complete this online survey via a link shared on various social media platforms, including Facebook, LinkedIn, and Twitter. University mailing lists were also used to reach out to academic and research-business-oriented communities.

Relevant information about CVs was provided to the respondents, along with consent and a data assessment agreement. The survey consisted of the following essential parts:

1. First, an introduction with questions regarding socio-demographic profile. The survey also asked the respondents about their travel mode choices and trip information and their willingness to share their travel modes with family or non-family members.

2. There was a group of questions about their car driving experience and license-related information. This is important because a person with more driving experience can better understand the various driving-related functions alongside HVI and ADAS.

3. A group of questions (Q20-Q27) about specific expectations, which were developed using the five-point (1 = strongly disagree, 5 = strongly agree) Likert-scale with two parameters (first, useless to useful, and second, undesirable to desirable). As the manufacturing industry is looking for consumer-centric products, they inevitably need to satisfy the wishes and expectations of the customer through the vehicles' cognitive capabilities. These questions focus on providing viable solutions for CVs considering two key factors: user routines, and user preferences.

Table 4.1: Frequency (and percentage) distributions for question 1 (Q1) to question 19 (Q19)

Question	Variable	Items-Responses n (%)
1	Continent-wise responses	Africa - 73 (11)
		Asia - 162 (25)
		Europe - 267 (41)
		Latin America - 54 (8)
		Oceania - 36 (5)
		North America - 65 (10)
2	Gender	Male - 372 (56.62)
		Female - 281 (42.77)
		Prefer not to say - 4 (0.61)
3	Age	18 to 24 - 119 (18.11)
		25 to 34 - 280 (42.63)
		35 to 44 - 151 (22.98)
		45 to 54 - 65 (9.89)
		>54 - 42 (6.39)
4	Education	Up to higher secondary - 10 (1.52)
		Bachelor degree - 128 (19.48)
		Master degree - 270 (41.10)
		Ph.D. - 241 (36.68)
		Other - 8 (1.22)
5	Employment	Full-time employed - 409 (62.26)
		Part-time employed - 46 (7.00)
		Unemployed - 38 (5.78)
		Retired - 6 (0.91)
		Student - 145 (22.07)
		Other - 13 (1.98)
6	Car driving experience	None - 96 (14.61)
		Less than 2 years - 83 (12.63)
		2 to 5 years - 95 (14.46)
		More than 5 years - 383 (58.30)
7	People live in a household (including you)	1 - 82 (12.48)
		2 - 130 (19.79)
		3 - 155 (23.59)
		4 or more - 290 (44.14)
8	People in a household have a car driving license (excluding you)	None - 87 (13.24)
		1 - 212 (32.27)
		2 - 211 (32.12)
		3 - 89 (13.55)
		4 or more - 58 (8.82)

Question	Variable	Items-Responses n (%)
9	Cars do you usually drive	None - 152 (23.14)
		1 - 333 (50.68)
		2 - 133 (20.24)
		More than 2 - 39 (5.94)
10	Cars drive in terms of possession	Private/household car - 551 (83.87)
		Car provided by company/organization - 23 (3.50)
		Other - 83 (12.63)
11	Main role in a car	As a driver - 466 (61.26)
		As a passenger - 191 (38.74)
12	Mode of transportation use in daily life	Private/household car - 439 (43.59)
		Company car - 30 (2.98)
		Taxi (e.g., Uber, Lyft, Ola, etc.) - 138 (13.70)
		Public transport (e.g., Bus, Train, etc.) - 308 (30.59)
		Other - 92 (9.14)
13	Average trips travel per day during workdays	None - 54 (8.22)
		1 to 5 - 557 (84.78)
		6 to 10 - 31 (4.72)
		More than 10 - 15 (2.28)
14	Average trips travel per day during weekends	None - 51 (7.76)
		1 to 5 - 559 (85.08)
		6 to 10 - 38 (5.79)
		More than 10 - 9 (1.37)
15	Ride-sharing within family members	Most of the times - 265 (40.33)
		Occasionally - 290 (44.14)
		Never - 102 (15.53)
16	Car-sharing within family members	Most of the times - 291 (44.29)
		Occasionally - 204 (31.05)
		Never - 162 (24.66)
17	Car-sharing outside family members	Most of the times - 120 (18.26)
		Occasionally - 252 (38.36)
		Never - 285 (43.38)
18	Knowledge of Human-Vehicle Interaction (HVI)	Very familiar with - 167 (25.42)
		Somewhat familiar with - 298 (45.36)
		Not familiar with - 192 (29.22)
19	Knowledge of Advanced Driver Assistance Systems (ADAS)	Very familiar with - 380 (57.83)
		Somewhat familiar with - 202 (30.75)
		Not familiar with - 75 (11.42)

4.5.2 Data analysis

Data was analyzed with descriptive statistics, including frequencies and percentages. Bivariate analysis was conducted by performing Chi-square tests for independence to explore the relationship between the respondent's opinion on questions Q20-Q27 and the level of knowledge of HVI and ADAS. Kendall's Tau-c (tau_c) correlation coefficient was calculated to assess the strength of the relationship. The significance level was set at 0.05. The Statistical Package for Social Science (SPSS) software (version 26.0 for windows) was used for statistical analysis.

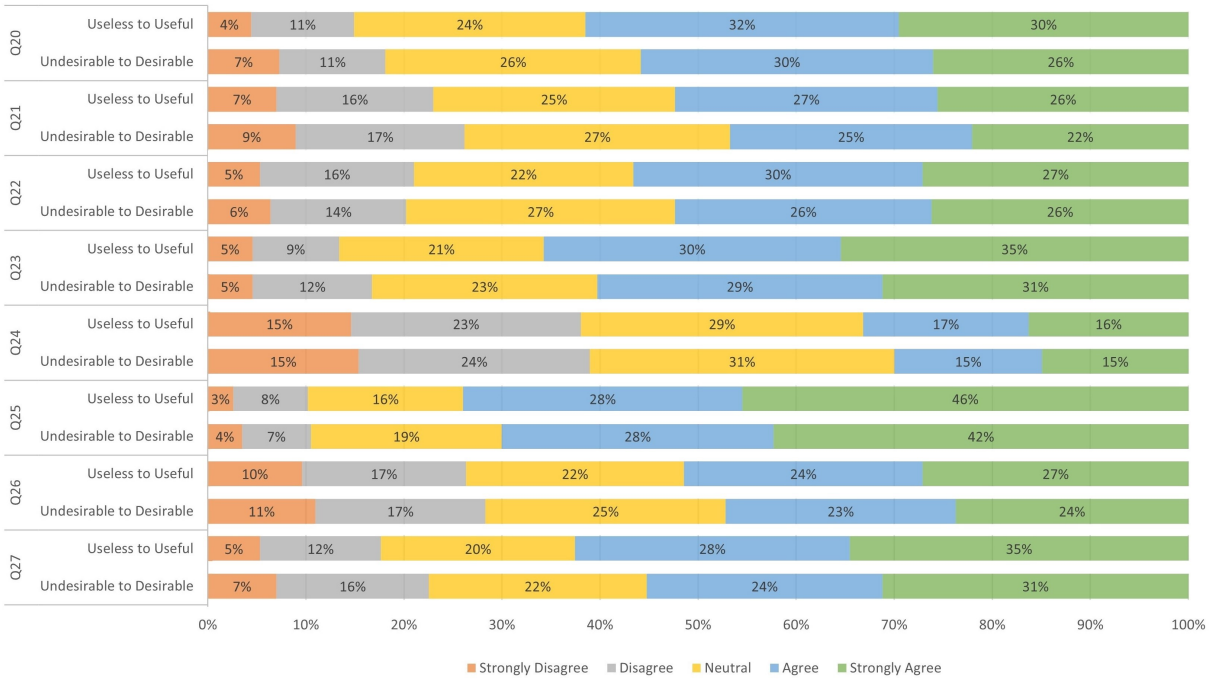


Figure 4.1: The respondent's opinion on features of the cognitive vehicles

Q20: Predict when you want to depart/go to a certain destination and accordingly prepare the trip.

Q21: Learn the timestamps of your routine and predict your next destination, pre and during the trip, for both single-user and collaborative scenarios.

Q22: Learn the timestamps of your routine and automatically set the appropriate temperature inside the cockpit before it expects you to leave to your next destination.

Q23: Learn the timestamps of your routine and defrost the windows/windshield when needed before it expects you to leave to your next destination.

Q24: Remind you about your expected daily/regular passengers.

Q25: Learn the driving habits (seat position, mirror adjustment) of its different drivers and automatically change these settings according to the next expected driver.

Q26: Learn the time slots and locations when the car is parked (i.e. not in use), and hence, remind you that other potential drivers can use it.

Q27: Learn and remind the users about their daily items/objects to be carried, dropped, or forgotten (e.g. laptop, wallet, purse, school bag, gymnasium sack, etc).

4.6 Results

4.6.1 General data on respondents

In total, 657 valid responses (from 977 in total) were considered for technical analysis from 93 nations worldwide. The completion rate was 67.25%, and the average time to complete the survey was 6 minutes. The distribution of responses to questions Q1-Q19 is presented in Table 4.1.

Apart from the socio-demographic characteristics of the respondents (including age and gender), other information was collected that may be helpful in future studies. Most respondents (around 85%) made an average of one to five trips per day on workdays and during the weekends. About 84% of respondents

share a vehicle for journeys with family members most of the time or occasionally. A high percentage of respondents (about 75%) answered that family members share family-owned cars with other family members most of the time or occasionally. This percentage decreased to about 57% when asked about their willingness to share their own vehicle with other users.

4.6.2 Respondents' expectations

The percentage distribution of responses to questions Q20-Q27 is presented in Fig. 4.1. Except for Q24, more than half of the respondents agreed or strongly agreed that the referenced features in CVs are useful. These percentage are slightly lower when asked in terms of desirability. However, more than 47% of respondents agreed or strongly agreed that the features mentioned are also desirable. In particular, most respondents (more than 70%) found the idea of having a vehicle that learns their driving preferences (seat position, mirror adjustment) and automatically adjusts these settings, in anticipation of the next driver, to be useful and desirable (i.e., agree or strongly agree with the statement, Q25). The idea of having a vehicle that reminds the driver about their daily expected regular passengers (Q24) was found less useful and desirable by the respondents (33% and 30% agree or strongly agree, and 29% and 31% were neutral in terms of usefulness and desirability, respectively).

4.6.3 Relationship of respondent's opinion and their level of knowledge of HVI and ADAS

The analysis of the Chi-square tests for independence showed that the respondent's opinions on Q21 and Q26 were significantly related to their level of knowledge of HVI (Table 4.2). Additionally, using the analysis of Kendall's Tau-c correlation, a significant and positive correlation was found only between respondent's opinions on Q21 and the level of knowledge of HVI ($\tau_c = 0.112, p = 0.001$ and $\tau_c = 0.101, p = 0.004$). However, there is evidence of a relationship between the knowledge of ADAS and respondent's opinions on all questions (Table 4.2). A moderate positive correlation ($0.14 < \tau_c < 0.29, p < 0.001$) was found in all cases.

4.7 Discussion

The study aimed to analyze how to assist the drivers considering their daily routines and preferences in cognitive vehicles. The respondent's opinions support the idea that customers are interested in a vehicle with the capability of learning their routines and, based on that, predict their next destination.

Table 4.2: Results of analyses using the Chi-square tests for independence and Kendall's τ correlation regarding the relationship of respondent's opinion and their level of knowledge about HVI and ADAS

Question		Knowledge of Human-Vehicle Interaction (HVI) (low/medium/high)				Knowledge of Advanced Driver Assistance Systems (ADAS) (low/medium/high)			
		Chi-square		Kendall's τ_c correlation		Chi-square		Kendall's τ_c correlation	
		$\chi^2(df)$	p	τ_c	p	$\chi^2(df)$	p	τ_c	p
Q20	Useless to Useful	14.71(8)	0.065	0.082	0.022	73.41 (8)	<**0.001**	0.257	<**0.001**
	Undesirable to Desirable	7.33(8)	0.502	0.083	0.019	83.34 (8)	<**0.001**	0.283	<**0.001**
Q21	Useless to Useful	16.99(8)	**0.030**	0.101	**0.004**	64.89 (8)	<**0.001**	0.251	<**0.001**
	Undesirable to Desirable	16.07(8)	**0.041**	0.112	**0.001**	75.47 (8)	<**0.001**	0.264	<**0.001**
Q22	Useless to Useful	11.19 (8)	0.191	0.080	0.026	62.01 (8)	<**0.001**	0.204	<**0.001**
	Undesirable to Desirable	9.76(8)	0.283	0.071	0.049	55.32 (8)	<**0.001**	0.208	<**0.001**
Q23	Useless to Useful	14.90 (8)	0.061	0.087	0.015	68.97 (8)	<**0.001**	0.182	<**0.001**
	Undesirable to Desirable	14.91 (8)	0.061	0.065	0.070	61.90 (8)	<**0.001**	0.174	<**0.001**
Q24	Useless to Useful	8.46 (8)	0.390	0.052	0.139	33.48 (8)	<**0.001**	0.185	<**0.001**
	Undesirable to Desirable	11.35 (8)	0.183	0.045	0.200	38.82 (8)	<**0.001**	0.198	<**0.001**
Q25	Useless to Useful	9.01 (8)	0.342	0.077	0.025	36.64 (8)	<**0.001**	0.140	<**0.001**
	Undesirable to Desirable	14.83 (8)	0.063	0.077	0.026	40.69 (8)	<**0.001**	0.156	<**0.001**
Q26	Useless to Useful	24.89 (8)	**0.002**	0.054	0.142	34.87 (8)	<**0.001**	0.156	<**0.001**
	Undesirable to Desirable	25.51 (8)	**0.001**	0.043	0.255	32.08 (8)	<**0.001**	0.150	<**0.001**
Q27	Useless to Useful	8.21 (8)	0.413	0.058	0.108	43.29 (8)	<**0.001**	0.181	<**0.001**
	Undesirable to Desirable	5.55 (8)	0.697	0.038	0.280	36.90 (8)	<**0.001**	0.188	<**0.001**

χ^2: Chi-square statistics, df:degrees of freedom, p: level of statistical significance, τ_c: Kendall's τ_c correlation.

Previous studies advocated that occupants are looking for a scope in which their vehicle will predict the next destination through persons' intention sitting inside the cockpit Gan et al. (2020), and on pre-trip and en-route information Froehlich and Krumm (2008); Krause and Zhang (2019); Simmons et al. (2006); Fernandes and Ferreira et al. (2020) is highly desirable to choose their future mobility plans. Furthermore, there is enough evidence to suggest that the level of comfort decides the acceptance of AVs Paddeu et al. (2020). Indeed, in the coming years, comfort level defined by the preferences of the users, and design of a vehicle or how a vehicle provides the necessary information to its occupants when necessary. Think how appealing it would be if, based upon daily routines, a vehicle sets the appropriate temperature of the vehicle. More than half of the respondents found the possibility of having a vehicle able to set the appropriate temperature automatically useful and desirable. Likewise, more than 50% of the participants believe that it would be helpful if the vehicle defrosts the windshield before it expects to leave for the next destination. There are previous studies on defrosting the windows Lee et al. (2010); Kang et al. (2011),

yet no provision for learning user's timestamps. A perfect seat position setting is one of the preferred factors for a safe and comfortable ride Mastrigt et al. (2017). In recent years, facial recognition-based seat adjustment techniques Vamsi et al. (2020), and mirror adjustment through driver's pupil Rho et al. (2002) were studied. From the participants' opinions, it is also highly desirable to include adjusting the seat position and mirror according to the next expected driver.

User routines are one of the critical moderating variables for choice-based decisions. There is evidence showing that routines are a sequence of actions through which we can predict future actions Banovic et al. (2016). The outcome of the survey provides impetus to developing features like the reminder about items to be carried, dropped, or that may be forgotten. Some recent works on child-like object detection Hallberg and Wessberg (2018), and in-vehicle object and occupancy detection Dodia and Kumar (2023); Nowruzi et al. (2019) have given significant endorsement to the proposed feature. In particular, this is a substantial habitual change, as in their current busy lives, people often accidentally leave items inside the vehicle or forget to put items into the vehicle before starts the journey.

We have witnessed during the past years that the growth of car-sharing is exponential worldwide as the cost of owning a private car is becoming increasingly expensive Shaheen and Cohen (2013); Roos (2024). One of the main benefits of car-sharing is to give drivers a choice to drive different types of vehicles. Moreover, car-sharing would reduce the number of vehicles on the road if a significant number of users give up vehicle ownership Chapman et al. (2020). There are many studies on car-sharing, including the choices for car-sharing considering consumer's cultural behavior Magnani et al. (2018); a driver's willingness to share a car Panagiotopoulos and Dimitrakopoulos (2019); Barbour et al. (2020); Suel et al. (2024); booking a vehicle through **Global System for Mobile Communication (GSM)** or **Short Message Service (SMS)** Mannan (2001); car-sharing on a rental basis Barbour et al. (2020); Formentin et al. (2015); and blockchain technology-based methods Valastin et al. (2019). However, user's routine-based car-sharing methods have not been found so far. Findings from the survey showed that people already have a habit of sharing the car with family members and, despite being less often, with other persons. Furthermore, more than 47% of respondents found it useful and desirable to have a vehicle that reminds them when other potential drivers can use the car according to time slots and locations where the car is parked.

In general, the level of knowledge and experience with technology has been associated with greater acceptance of AVs Banovic et al. (2017); Hoch et al. (2007). In this study, significant positive associations between the level of knowledge of ADAS and the respondent's opinion concerning the referred possible abilities of the CVs (Q20-Q27) were found. These findings suggest that the level of knowledge of ADAS may influence the acceptance of AVs and CVs.

Besides the qualitative and quantitative analyses of the results, this survey has some limitations due to its online nature. First, the sample profile is not representative of the total population, as 97% of respondents have a minimum graduate degree. Second, as the cognitive vehicle-based technology is in the initial phase of development, respondents did not physically interact with the mentioned features, which may bias results.

4.8 What we gained from the study?

Broadly, respondents revealed an overwhelmingly positive attitude towards the possibility of having a cognitive vehicle that learns their daily routines (e.g., usual destination, routine timestamps, regular driver and passengers, and their items). Then, depending upon the preferences of the driver and occupants, the cognitive vehicle performs appropriate actions to assist the driver (e.g., prepares the trip, reminds them about a possible forgotten passenger or object, and adjusts seat position and mirrors according to the next expected driver). Moreover, the results give some evidence that the higher the level of knowledge of ADAS, the higher the probability of the respondents having the opinion that the CVs' abilities are desirable and useful. The results give a relevant view of user expectations and needs that are useful for all stakeholders involved in developing future CVs.

This research raises several interesting avenues for further research. First, to develop a prototype based on the presented features of CVs. Second, to go for a simulator-based studies for further investigation into each feature. This will provide a better understanding from the human perspective towards such features. Third, it would be important to check the co-existence of a developed prototype and simulator-based results in real-time, i.e., on-road experiments.

CHAPTER 5

Users' Experience and Expectations in the Human-Centered Driver Assistance Systems

The development of ADAS has brought about improvements in passenger comfort and the ability to personalise their features. It has been recommended to thoroughly investigate things by going through the driver's experience in order to measure its effectiveness and reliability. Additionally, user input is crucial for exploring what the user needs in terms of future developments. Considering these two aspects, i.e., users' experience and their expectations, is the core of this chapter. Based on this study, we can recommend about the future fleets have what kind of features with cognitive ability.

5.1 Introduction

The introduction of ADAS is a significant step that establishes a level of trust between the driver and the vehicle (Lubkowski et al., 2021; Hartwich et al., 2021). Also, when considering the design of human-machine interaction from a design perspective, the level of trust is a crucial consideration (Lee and See, 2004). Importantly, ADAS is to provide the driver with aid in a variety of different ways and to potentially contribute to the safety of the driving environment. In this sense, ADAS is participating in the driving operations by informing and warning the driver about extraneous chores that need to be accomplished. This is done so that the driver can maintain control of the vehicle.

More confidence in the vehicle's ability to keep its occupants safe has been gained by recent research on in-vehicle technologies, especially ADAS (Lau et al., 2020). Conceptual knowledge gives users the ability to anticipate the behavior of the automation based on their previous experiences (Beggiato et al., 2015). There is a correlation between having a deeper conceptual understanding of automated systems and having better supervision over driver assistive systems (Venkatesh et al., 2003). In addition to this, research has shown that when individuals comprehend the reasoning that underpins how a system operates, their performance levels increase (Nunes, 2003). The evaluation of ADAS functionality based on the driver's use of ADAS and the driving situation is clearly described in the existing body of research (Orlovska et al., 2020b). Also, there is a clear indicator that suggests that vehicle drivers are ready to embrace automated driving and various ADAS facilities, but they are not ready for autonomous vehicles (Patel et al., 2020). According to (Greenwood et al., 2022), the knowledge of ADAS is affected by preferences for various sources of information, and the attitude towards technology is well debated among all age groups of drivers in the United States.

There are many questions about ADAS and the trust that users have in each other, it include the following: (a) What different sorts of ADAS-features are used today? (b) From a technology standpoint, what are users' thoughts on the experience of the end users? (c) In what ways might ADAS serve as a helpful companion to increase driver safety while operating a motor vehicle? (d) Once a user has driven a car, what parameters may they adjust to customize their experience? (e) How will users think about their future automobiles, keeping in mind the preferences and conveniences that are important to them? (f) What are the users' expectations for the future functions of ADAS installed in the vehicle? It is vitally important that drivers are aware of the functional boundaries imposed by automation to make full use of ADAS. Drivers are required to acquire, employ, and properly monitor the ADAS systems installed in their vehicles for these systems to be of any actual benefit to the overall safety of the roads. To succeed in this endeavour, extensive study of the user-centered design and development process is required. This research focuses on how users interact with and perceive different ADAS-based functionalities, as well as how those interactions inform their hopes for a future human-aware support system tailored to their individual driving preferences and life experiences.

5.2 Study Objectives

This research has two main objectives: (i) to find out the users' personal viewpoints regarding how they have experienced the ADAS while driving their vehicle, and (ii) to determine users' needs and expectations

regarding future developments of human-centered ADAS. The purpose of the focus user interviews was to answer some questions about how drivers perceive the human-centered design of ADAS, specifically in relation to the following two use-cases:

Use case 1 (User Experience): The majority of vehicles on the road today are likely to be outfitted with multiple advanced driver aid systems or driving automation systems, each of which may be programmed at a different level of automation. However, there is a need to investigate more how the users' experiences have been while utilizing it. Understanding the user's experience is essential in order to gain a profound understanding of the user's values, motivations, requirements, and desires (Choy et al., 2022; Neuhuber et al., 2022; Strand et al., 2011). This will also provide valuable information regarding the existing ADAS features and where there are opportunities for improvement. In the current technological era, it is apparent that technology plays a critical role in ADAS. However, when it comes to developing new features for ADAS, one of the most important elements for OEMs is the users' experience. Additional factors that contribute to the acceptance of ADAS include the user's prior experience with the technology (Kaye et al., 2022). Taking everything into consideration, we are able to assert that the interaction of the experiences of users with ADAS paved the way for the future of personalized driving (Patel et al., 2023a; Delmas et al., 2024; Ponomarev and Chernysheva, 2019).

Use Case 2 (User Expectations): As was discussed in use case-1, nearly all modern automobiles are fitted with ADAS technology. As ADAS technologies continue to evolve and become more advanced, meeting user expectations will be crucial for their successful adoption and meaningful impact on road safety and efficiency. Users' expectations are shaped by their experiences with current ADAS features, as well as their understanding of the potential capabilities of future systems (Houtenbos et al., 2005; Pettersson, 2017). If ADAS fall short of these expectations, it can lead to frustration, mistrust, and a reluctance to embrace the technology fully. On the other hand, by actively considering and addressing user expectations, automakers and technology providers can design ADAS that align with real-world needs and desires. This includes intuitive interfaces, clear communication of system capabilities and limitations, seamless integration with driving experiences, and the ability to personalize and adapt to individual preferences (Engstrom et al., 2004).

As ADAS progresses towards higher levels of automation and autonomy, meeting user expectations will become even more critical as the relationship between drivers and vehicles undergoes a fundamental shift (Novakazi et al., 2020). By prioritizing user expectations, the automotive industry can ensure that future ADAS are not only technologically advanced but also widely accepted, trusted, and effectively utilized, ultimately paving the way for safer and more efficient transportation systems.

5.3 Methods

5.3.1 User - focused interview

The aim of user-focused interviews is to collect vital information from the beneficiaries (Knott et al., 2022; Morgan, 2012; Nyumba et al., 2018) about how they experience the current functionality and what about their expectations are about future requirements of ADAS. User-focused interviews tend to be smaller in number because they are purpose-built to collect input for a specific job. Nevertheless, user-focused interviews, even when conducted with a small sample size, can be a useful tool for data collection due to the open conversation and exploration of several perspectives they foster (Nicholson and Philip J., 2022; Jung and Eunseok, 2019).

The importance of the user experience in various driving settings rises in direct proportion to the number of ADAS technologies included in each car. In order to investigate the users' experience, we conducted interviews with focus groups to test the hypothesis that a driver's technical sophistication, brand point of view, perceived ease of use, personal innovativeness, safety concerns, and holistic parametric view, preferences as the vantage point, in terms of ADAS's usefulness, and future ADAS with focus on the user's comfort, choices, and personalized things can be predicted by a combination of demographics.

Our sample consisted of 38 people who were from various parts of India (demographic diversity) but currently resided in the state of Gujarat. It is important to note that every individual who took part in this research is currently operating a vehicle that is outfitted with an ADAS, so they are all very knowledgeable about the functions that this system is capable of. There are a total of 31 male candidates out of the total number of participants, while there are only 7 female candidates. Having a minimum of one year's worth of driving experience equivalent to approximately one thousand kilometer's is strongly encouraged but not required. It has been brought to our attention that not a single one of them has any prior experience with self-driving or automated vehicles. Even though the participants are already familiar with ADAS, pertinent information regarding ADAS was presented to the respondents, along with a consent and data assessment agreement form. After the completion of the study, all of the participants were gathered together for a conversation about the expectations they have for the development of ADAS-based systems in the future. And so on, the later part of the chapter will be devoted to discussing some recommendations that were derived from the responses provided by the participants.

The current study investigated evidence regarding the eight hypothesized driver characteristics in relation to the predictors, as shown in Fig. 5.1. For the purpose of grounding the analysis of the responses

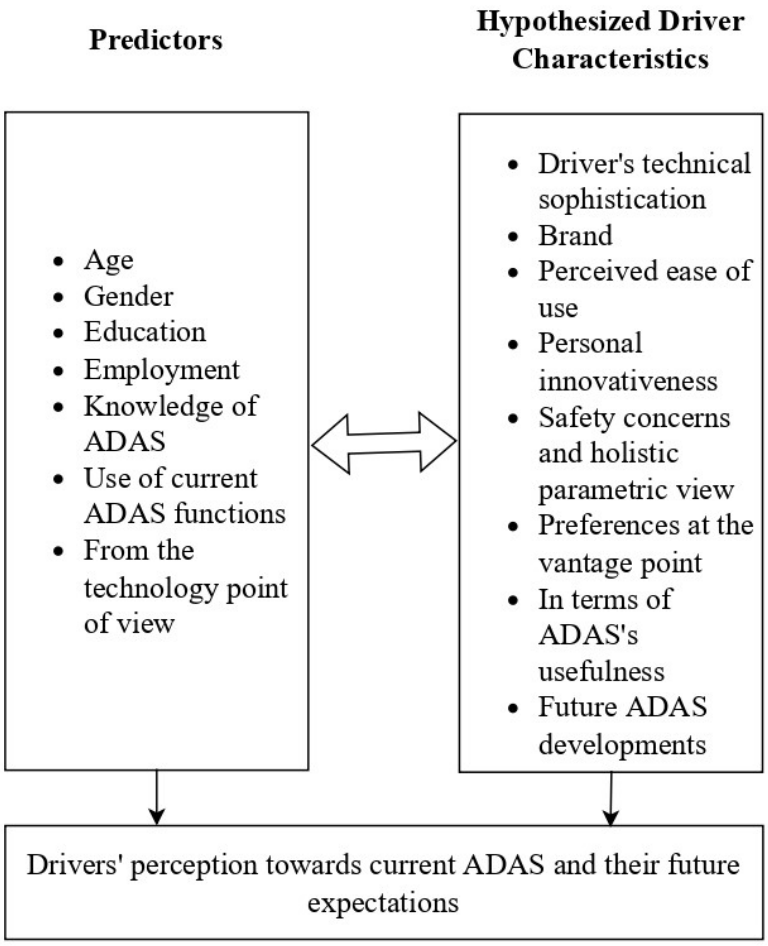


Figure 5.1: Conceptual model of relation between hypothesized driver characteristics and predictors.

and drawing statistically meaningful conclusions from it, major demographic data such as age group, gender, education, and occupation, as well as information regarding car driving experience, were utilized. The following features of the drivers were hypothesized and evaluated during the user-focused interview:

1. *Driver's technical sophistication (Q6):* In order to get further along the path of user-centered design for ADAS, it is essential to have a good idea of how long drivers have been operating their vehicles with ADAS features installed.

2. *Brand point of view (Q7):* In many cases, the importance of a brand can be attributed to the fact that it acts as a trust-based tuning bridge between a driver and a vehicle (Abraham et al., 2017). In addition, it will be helpful to investigate which car brand is in high demand because of the ADAS capabilities it offers.

3. *Perceived ease of use (Q8):* The degree to which a person believes that using a piece of technology will be effortless and will result in increased reliability for the user is referred to as the perceived

ease of use of the technology (Venkatesh, 2000). It is dependent on an individual's evaluation of the amount of effort required to utilize the various functions of the ADAS system (Trubswetter and Klaus, 2013).

4. *Personal innovativeness (Q9):* Because nearly all modern automobiles are fitted with ADAS features, it is essential to have a comprehensive grasp of whether or not the user is prepared to make use of these capabilities (Jun et al., 2019). We can estimate the level of happiness and safety by determining their level of acceptance, which is important.

5. *Safety concerns and holistic parametric view (Q10):* The numerous ADAS functionalities will always be beneficial to access safety due to their ease of comprehension (Jimenez et al., 2016; Viktorova and Matus, 2018). It will also aid in understanding the driver's mental and technological functional status in order to use ADAS capabilities methodically and seamlessly (Sullivan et al., 2016; Voinea et al., 2020; Maag et al., 2011; He et al., 2014).

6. *Preferences as the vantage point (Q11):* After a person has driven a vehicle, their personal preferences have a significant impact, particularly on the driver aid systems. To improve the future design of ADAS, preferences are one of the direct impacts that will be considered (Paiva et al., 2021). Other factors include the attitudes of humans toward technology (Patel et al., 2021) and making ADAS more personalized (Hasenjager et al., 2020).

7. *In terms of ADAS's usefulness (Q12):* As a result of the fact that various users have varying preferences for the options available to them, we can safely state that their perspectives on the implementation and utilization of the technology will vary from one another (Orlovska et al., 2020a; Palac et al., 2021; Nylen et al., 2019). It has been observed that memory functions, in which the car will know your previous journeys and, based on them, will assist you (the driver) with the generation of the route is present (Ferreira et al., 2019).

8. *Future ADAS with focus on the user's comfort, choices, and personalized things (Q13):* It will be possible to improve the overall quality of the driving experience and provide a high degree of comfort within the vehicle by utilizing ADAS, which will ultimately result in a trip that is more enjoyable. Because of this, we will arrive at the conclusion that the level of comfort is controlled not only by the design of the vehicle but also by the technologically advanced components that are incorporated into it (Adomat et al., 2003; Arpit et al., 2022). A design decision has a significant impact on the degree to which drivers are satisfied with their vehicles and prepared to adopt new technologies.

Furthermore, stated user preferences will be helpful for original equipment manufacturers (OEMs) to create future in-vehicle ADAS capabilities, which will have an interface that is easier to grasp and operate (Abraham et al., 2018; Marchau et al., 2001; Molin and Marchau, 2004). One of the most important things that can be done to increase people' trust in vehicles is to equip them with individualized features. As new developments in in-vehicle technologies emerge on a daily basis, users are searching for preference-based personalized control as a means of interacting with these new features (Panou, 2018; Yi et al., 2020).

5.3.2 Data analysis

Descriptive statistics, such as frequencies and percentages, were used to examine the gathered data. The purpose of the reliability test, known as Cronbach's alpha, is to measure the internal consistency or reliability of the instrument. A bi-variate analysis was carried out by performing Chi-square tests for independence to investigate the relationship between (i) opinion on technology and gender, (ii) opinion on the technology and age, (iii) adjustment of car characteristics and age, and (iv) adjustment of car characteristics and gender. This was performed to determine whether there was a correlation between these four factors. To determine the strength of the connection between two variables, a correlation coefficient known as Kendell's tau-c (tau_c) was computed. The level of significance was set at $p < 0.05$. We used an ANOVA to examine the relationships between (i) drivers' technical sophistication, (ii) importance of brand, and (iii) perceived ease of use for different ADAS functions found in modern vehicles. Furthermore, a one-sample t-test was performed to analyze (i) individual innovativeness, (ii) safety worries with respect to ADAS parameters, (iii) preferences after someone drove a vehicle, (iv) the usefulness of ADAS, and (v) potential ADAS-based systems in the future. Statistical analysis was performed using the Statistical Package for Social Science (SPSS) software (specifically version 29.0 for Windows).

5.4 Results

5.4.1 Demographic profiles of the respondents

The demographic profiles of the participants are presented in Table 5.1 (Q1-Q9) in accordance with the categories to which they belong. In addition to the socio-demographic characteristics of the respondents, additional pertinent information has been gathered for the purpose of further investigation.

Table 5.1: Frequency (and percentage) distributions information.

Question	Variable	Item	Response (n)	Percentage (%)
1	Gender	Male	31	81.58
		Female	7	18.42
2	Age	19 to 28	8	21.05
		29 to 38	15	39.47
		39 to 48	13	34.21
		49 and above	2	5.26
3	Education	No schooling	0	00.00
		High school	1	2.63
		Bachelors	6	15.79
		Masters	18	47.37
		PhDs	13	34.21
4	Job profile	Employed	28	73.68
		Unemployed	3	7.89
		Student	5	13.16
		Retired	2	5.26
5	Driving hrs./week	Less than 10	21	55.26
		Between 10 to 20	11	28.95
		More than 20	6	15.79
6	ADAS experience	Less than 2 years	31	81.58
		2 to 5 years	3	7.89
		More than 5 years	4	10.53
		Kia	3	7.89

		Tata Motors	7	18.42
		Mahindra	2	5.26
		Morris Garages	1	2.63
7	Motor vehicle company	Honda	4	10.53
		Hyundai	5	13.16
		Maruti	11	28.95
		BMW	1	2.63
		Others	4	10.53
		ACC	25	30.86
		LDW	8	9.88
		LKA	10	12.35
		FCW	7	8.64
8	ADAS features	AEB	9	11.11
		HBA	8	9.88
		TSR	4	4.94
		BSD	8	9.88
		LC	2	2.47
		Happy with technology	18	47.37
		Like most of the features	6	15.79
9	Feeling about technology in current vehicle	Like some of the features	9	23.68
		Unhappy with the technology	1	2.68
		No option for choice due to built-in features	4	10.53

5.4.2 Reliability analysis

Cronbach's Alpha is a reliability test that can be run within SPSS in order to measure the internal consistency, or reliability, of the measuring instrument. This test was developed by Kolmogorov and Cohen. When questionnaires are developed using multiple statements on a 5-point Likert scale, which is most commonly done to determine whether or not the scale is reliable, this method is used most commonly.

The reliability statistics of the sample date are presented in Table 5.2, which uses a sample size of 38. When we look at this particular data, we can see that Cronbach's Alpha is 0.805, which is a value that is greater than 0.60 (Sekaran and Roger, 2019), which indicates that our scale has good internal consistency when we use this particular sample size.

Table 5.2: Reliability analysis with item statistics.

Question	Item	Mean	SD
	Adaptive Cruise Control (ACC)	.66	.481
	Lane Departure Warning (LDW)	.21	.413
	Lane Keep Assist (LKA)	.26	.446
	Forward Collision Warning (FCW)	.18	.393
8	Automatic Emergency Braking (AEB)	.24	.431
	High-Bean Assist (HBA)	.21	.413
	Traffic Sign Recognition (TSR)	.11	.311
	Blind Spot Detection (BSD)	.21	.413
	Lane Centering (LC)	.05	.226
	ADAS improves my driving performance	4.00	.615
	ADAS increases my safety	4.29	.611
	I understand ADAS clearly	4.00	.838
10	ADAS is difficult to use	2.84	1.103
	Interacting with ADAS not required additional mental efforts	3.74	.760
	Adjusting ADAS settings are time consuming	2.95	1.038
	Air conditioning	3.42	1.266
	Navigation systems	3.13	1.277
	Seat positions	3.92	1.075
	Steering wheel position	3.50	1.084
11	Headrest	3.08	1.323
	Wing mirrors	3.79	1.166
	Rear-view mirror	3.68	1.165
	Sound system settings	2.87	1.339

	Music/radio settings	3.00	1.336
	Gearbox settings	2.66	1.341
	Like car which adjust itself to my preferences	3.84	.855
	Experienced safety hazards as a consequences of not properly adjusted car char.	3.55	.950
12	I enjoy to adjust car settings based on my preferences	3.55	.950
	I have no interest to adjustment of car settings	2.53	1.109
	Memory function required for frequent drivers	3.82	.955
	Seat position adjust based on my comfort	3.89	.894
	Steering wheel adjust before entered into car	3.87	.875
	Cockpit temperature adjust based on my own preferences	3.92	1.050
	Mirrors adjust based on drivers needs	4.21	.704
	Smooth handling of calls while driving	3.84	1.079
13	Provide adequate information about personalized things when leaving the vehicle	3.92	.882
	Touchscreen settings as per drivers' choice	3.89	1.060
	Adjust automatic voice control for vital applications	3.63	.913
	Unfreeze the window before entering into car	3.58	1.222
	Removing dust from windows before starting a car	4.24	.820
	Window demisting before start a car	3.89	1.085

Q8: Which kinds of ADAS-based features are you using?

Q10: Kindly give your opinion with respect to the given ADAS parameters.

Q11: Adjust car characteristics to your preferences after somebody else drove your vehicle?

Q12: To what extend do you agree with the following statements in connection to ADAS?

Q13: Factors for future ADAS.

5.4.3 Descriptive analyses

Three types of tests—the Chi-square (χ^2), the ANOVA, and the t-test—were primarily considered for the descriptive analyses.

Table 5.3: Feeling about technology vs. gender analysis.

Chi-square (χ^2) tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-square	7.316[a]	4	.120
Likelihood ratio	6.885	4	.142
Linear-by-Linear Association	.422	1	.516

Kendall's tau-c			
Value	Assmp. Std. Error[b]	Approx. T[c]	Approx. Sig.
.139	.132	1.052	.293

[a] 8 cells (80.00%) have expected count less than 5. The minimum expected count is .18.

[b] Not assuming the null hypothesis.

[c] Using the asymptotic standard error assuming the null hypothesis.

Analysis based on Chi-square (χ^2)

- *Feeling about technology vs. gender:* One can see the results of the chi-square test for whether or not respondents' attitudes toward the car's technological features vary with their gender in Table 5.3. As can be seen, the chi-square value is lower than the threshold (9.488) required to reject the null hypothesis (α=0.05). As a result, we conclude that respondents of either sex had similar opinions regarding the car's technological features.

- *Feeling about technology vs. age:* From what can be seen in Table 5.4, the chi-square value of 16.930 is lower than the threshold value of 21.026 (α=0.05). Since this sentiment does not vary with respondent age, we conclude that the respondent's age does not influence their opinion of the vehicle's technological features.

- *Adjustment of car characteristics vs. gender:* The observed value of 1.072 (from Table 5.5) for the chi-squared statistic is lower than the threshold value of 7.815 (α=0.05). Therefore, we conclude that the gender of the respondent makes no difference in the way that car features are modified.

Table 5.4: Feeling about technology vs. age analysis.

Chi-square (χ^2) tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-square	16.930[a]	12	.152
Likelihood ratio	16.073	12	.188
Linear-by-Linear Association	.033	1	.857

Kendall's tau-c			
Value	Assmp. Std. Error[b]	Approx. T[c]	Approx. Sig.
.006	.108	.051	.959

[a] 19 cells (95.00%) have expected count less than 5. The minimum expected count is .05.

[b] Not assuming the null hypothesis.

[c] Using the asymptotic standard error assuming the null hypothesis.

- *Adjustment of car characteristics vs. age:* Chi-square = 15.588, which is less than the critical value of 16.919 (assuming α = 0.05) as shown in Table 5.6. We conclude that the respondent's age plays no role in the customization of the vehicle's features.

Analysis based on ANOVA

- *Drivers' technical sophistication:* A main effect of test score was found for determining drivers' level of technical expertise (F(2,35)=2.634, *p=.086*) as in Table 5.7. There is insufficient evidence to reject our assumption statistically, as the *p-value* is greater than 0.05. We conclude that the respondents' opinion regarding the provided ADAS parameters is unrelated to how long each respondent has been using his or her vehicle.

- *From the brand perspective:* There was no significant interaction between test score and brand preference (F(2,35)=.119, *p=.888* in Table 5.8). The *p-value* is greater than 0.05, so there is not enough evidence to statistically reject our assumption. We draw the conclusion that the respondents' perception of the provided ADAS parameters is independent of the vehicle manufacturer.

Table 5.5: Adjustment of car characteristics vs. gender analysis.

Chi-square (χ^2) tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-square	1.072[a]	3	.784
Likelihood ratio	1.791	3	.617
Linear-by-Linear Association	.061	1	.805

Kendall's tau-c			
Value	Assmp. Std. Error[b]	Approx. T[c]	Approx. Sig.
.025	.109	.230	.818

[a] 6 cells (75.00%) have expected count less than 5. The minimum expected count is .37.

[b] Not assuming the null hypothesis.

[c] Using the asymptotic standard error assuming the null hypothesis.

- *Perceived ease of use for different ADAS parameters:* As seen in the Table 5.9, we have observed that various ADAS parameters like ACC (F(2,35)=.118, *p=.889*), LDW (F(2,35)=.507, *p=.607*), LKA (F(2,35)=2.179, *p=.128*), FCW (F(2,35)=.452, *p=640*), HBA (F(2,35)=2.153, *p=.131*), TSR (F(2,35)=1.842, *p=.174*), BSD (F(2,35)=1.279, *p=.291*) have the *p-value* is greater than 0.05. So that, there is not enough evidence to statistically reject the assumption. Hence, we can conclude that there the given parameters are independent. On the contrary, AEB (F(2,35)=7.344, *p=.002*) and LC (F(2,35)=5.711, *p=.007*) which has *p-value* lesser than 0.05, which means there is a significant difference. Therefore, the Tukey post hoc test is applied to these two factors to find the exact area of these differences.

As seen in the Fig. 5.2 the difference in means between the factors important for the future ADAS and automatic emergency braking. It is observed that the mean for strongly agree (MD_N= .514 and MD_A=.619) is the highest and differs significantly as seen in the Tukey test (see Table 5.10). This suggests that those who already have automatic emergency braking view it as a crucial safety feature and hope that it will continue to improve with time. The largeness of the confidence interval for strongly agree is due to the

Table 5.6: Adjustment of car characteristics vs. age analysis.

Chi-square (χ^2) tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-square	15.588[a]	9	.076
Likelihood ratio	12.735	9	.175
Linear-by-Linear Association	4.438	1	.035

Kendall's tau-c			
Value	Assmp. Std. Error[b]	Approx. T[c]	Approx. Sig.
.235	.108	2.163	.031

[a] 13 cells (81.20%) have expected count less than 5. The minimum expected count is .11.

[b] Not assuming the null hypothesis.

[c] Using the asymptotic standard error assuming the null hypothesis.

Table 5.7: ANOVA analysis for drivers' technical sophistication.

	Sum of squares	df	Mean square	F	Sig.
Between groups	2.069	2	1.035	2.634	.086
Within groups	13.747	35	.393		
Total	15.816	37			

Table 5.8: ANOVA analysis for perception towards vehicle brand.

	Sum of squares	df	Mean square	F	Sig.
Between groups	3.254	2	1.627	.119	.888
Within groups	478.114	35	13.660		
Total	481.368	37			

small sample size.

Fig. 5.3 illustrates the differences in significance that exist between the factors that will be important

Table 5.9: ANOVA analysis for perceived ease of use for different ADAS functions.

		Sum of squares	df	Mean square	F	Sig.
Adaptive Cruise Control (ACC)	Between groups	.057	2	.029	.118	.889
	Within groups	8.495	35	.243		
	Total	8.553	37			
Lane Departure Warning (LDW)	Between groups	.178	2	.089	.507	.607
	Within groups	6.138	35	.175		
	Total	6.316	37			
Lane-Keep Assist (LKA)	Between groups	.816	2	.408	2.179	.128
	Within groups	6.552	35	.187		
	Total	7.368	37			
Forward Collision Warning (FCW)	Between groups	.144	2	.072	.452	.640
	Within groups	5.567	35	.159		
	Total	5.711	37			
Automatic Emergency Braking (AEB)	Between groups	2.030	2	1.015	7.344	.002
	Within groups	4.838	35	.138		
	Total	6.868	37			
High-Beam Assist (HBA)	Between groups	.692	2	.346	2.153	.131
	Within groups	5.624	35	.161		
	Total	6.316	37			
Traffic Sign Recognition (TSR)	Between groups	.341	2	.170	1.842	.174
	Within groups	3.238	35	.093		
	Total	3.579	37			
Blind Spot Detection (BSD)	Between groups	.430	2	.215	1.279	.291
	Within groups	5.886	35	.168		
	Total	6.316	37			
Line Centering (LC)	Between groups	.466	2	.233	5.711	.007
	Within groups	1.429	35	.041		
	Total	1.895	37			

for the development of ADAS and lane centering. It has been discovered that the mean for strongly agreeing is the highest (MD_N= .286 and MD_A=.286) and that there is a significant difference between the two, as shown by the Tukey test (see Table 5.11). This suggests that the majority of individuals who possess Lane Centering believe that it is an important feature for the future. The low number of respondents in the

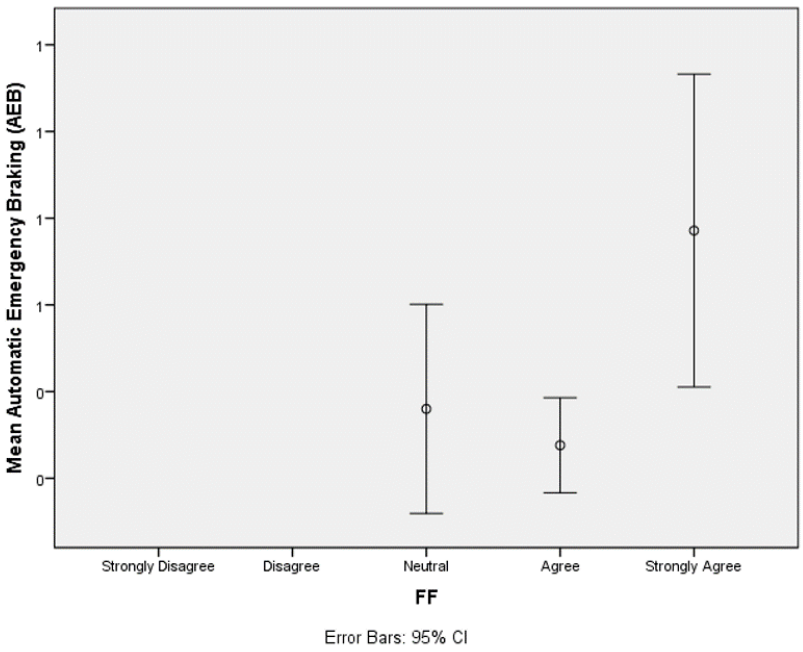


Figure 5.2: Objective knowledge score plotted as a function of automatic emergency braking. See descriptive results for Tukey HSD.

Table 5.10: Tukey HSD analysis for automatic emergency braking (AEB).

(I) FF	(J) FF	Mean-Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Agree	.105	.143	.745	-.24	.45
Neutral	Strongly Agree	-.514*	.183	.022	-.96	-.07
	Neutral	-.105	.143	.745	-.45	.24
Agree	Strongly Agree	-.619*	.162	.022	-1.02	-.22
	Neutral	-.514*	.183	.022	.07	.96
Strongly Agree	Agree	-.619*	.162	.002	.22	1.02

* The mean difference is significant at the 0.05 level.

sample accounts for the wide margin of error seen in the strongly agree category.

Table 5.11: Tukey HSD analysis for lane centering (LC).

(I) FF	(J) FF	Mean-Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Agree	.000	.078	1.000	-.19	.19
Neutral	Strongly Agree	-.286*	.100	.019	-.53	-.04
	Neutral	.000	.078	1.000	-.19	.19
Agree	Strongly Agree	-.286*	.088	.007	-.50	-.07
	Neutral	.286*	.100	.019	.04	.53
Strongly Agree	Agree	.286*	.088	.007	.07	.50

* The mean difference is significant at the 0.05 level.

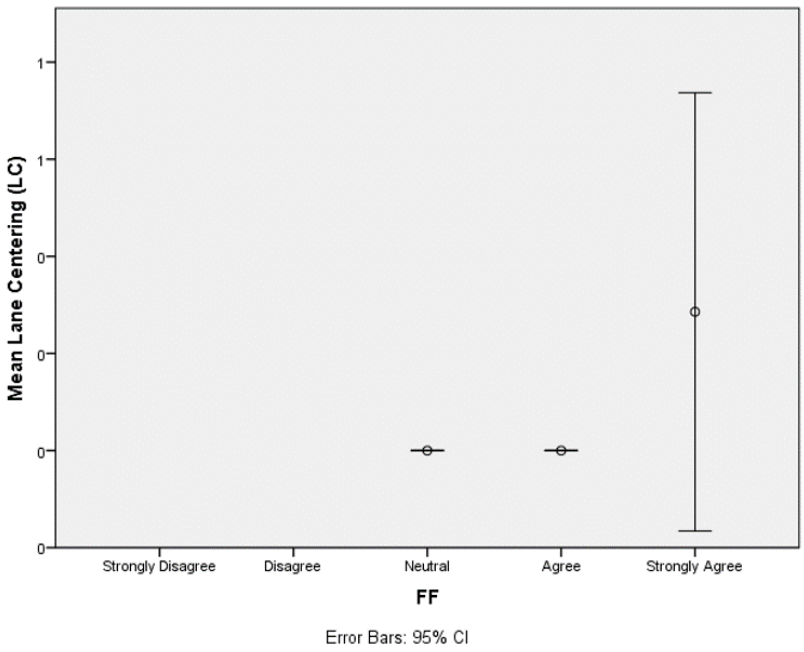


Figure 5.3: Objective knowledge score plotted as a function of lane centering. See descriptive results for Tukey HSD.

Analysis based on t-test

Table 5.12: T-test analysis for individual innovativeness.

	t	df	Sig. (2-tailed)	MD	95% Confidence Interval	
					Lower Bound	Upper Bound
Technological feeling	9.813	37	.000	2.132	1.691	2.572

- *Individual innovatiness:* The value of the t-test, when taking into account the value of α=0.005, is 9.813, and the *p-value* is equal to *.000*, as shown in Table 5.12. This demonstrates a significant level of statistical significance. What this means is that users have a better understanding of how they react to the technology when they are using it.

- *Safety worries with respect to ADAS parameters:* All of the parameters that fall into the safety zone show a high level of statistical significance (*p-values* of all the parameters are less than $<$*0.001*) as per Table 5.13. Particularly noteworthy is the fact that the t-value for the parameter "ADAS increase my safety" is the highest (t=43.272, *p=.000*) of those found among all. This suggests that the users have a very broad understanding of the concerns regarding safety.

Table 5.13: T-test analysis for safety worries with respect to ADAS functions.

	t	df	Sig. (2-tailed)	MD	95% Confidence Interval	
					Lower Bound	Upper Bound
ADAS improves my driving performance	40.086	37	.000	4.000	3.80	4.20
ADAS increase my safety	43.272	37	.000	4.289	4.09	4.49
My interaction with ADAS is clear and understandable	29.415	37	.000	4.000	3.72	4.28
ADAS is difficult to use	15.877	37	.000	2.842	2.48	3.20
Interacting with ADAS does not require a lot of mental effort	27.820	37	.000	3.737	3.46	4.01
I find it easy to get the ADAS to do what I want them to do	30.312	37	.000	3.737	3.49	3.99
I do not like adjusting the settings of ADAS to my preferences because it takes too much time	17.497	37	.000	2.947	2.61	3.29

Table 5.14: T-test analysis for preferences after someone drove the vehicle.

	t	df	Sig. (2-tailed)	MD	95% Confidence Interval	
					Lower Bound	Upper Bound
Air conditioning	16.663	37	.000	3.421	3.01	3.84
Navigation system settings	15.116	37	.000	3.132	2.71	3.55
Seat position	22.483	37	.000	3.921	3.57	4.27
Steering wheel position	19.898	37	.000	3.500	3.14	3.86
Headrest	14.386	37	.000	3.079	2.64	3.51
Wing mirrors	20.032	37	.000	3.789	3.41	4.17
Rear-view mirror	19.496	37	.000	3.684	3.30	4.07
Sound system settings	12.205	37	.000	2.868	2.43	3.31
Music/radio settings	13.847	37	.000	3.000	2.56	3.44

- *Preferences of the user after someone drove the vehicle:* In a similar vein, the level of safety and preference of the user after someone has driven the vehicle demonstrates a high level of statistical significance, which means that the *p-value* for each preference is lower than *0.001* in each case (see Table 5.14). The particular preference that users change the most frequently is referred to as the "seat position," and its t-test score is 22.483. This indicates that users will typically adjust the seat position before entering a vehicle because doing so is the first thing they do before driving a vehicle after another person has used it.

Table 5.15: T-test analysis for ADAS usefulness.

	t	df	Sig. (2-tailed)	MD	95% Confidence Interval	
					Lower Bound	Upper Bound
I like the car to adjust itself to my preferences when I use it	27.699	37	.000	3.842	3.56	4.12
I have experienced safety hazards or implications as a consequence of not properly adjusted car characteristics	23.052	37	.000	3.553	3.24	3.86
I enjoy adjusting car characteristics to my preferences after somebody else drove it	23.052	37	.000	3.553	3.24	3.86
I have no interest in adjusting car characteristics because I do not consider it necessary	14.048	37	.000	2.526	2.16	2.89
A memory function is a helpful device which facilitates frequent changes of drivers	24.643	37	.000	3.816	3.50	4.13

- *ADAS usefulness:* According to Table 5.15, the respondents exhibit an extremely high level of confidence in the term "ADAS usefulness." It demonstrates a high level of statistical significance for all of the parameters, which can be expressed as the fact that the *p-value* is lower than *0.001* for all of the cases. With a t-value of 27.699 and a significance level of 0.001, the statement "I like the car to adjust itself to my preferences when I use it" is considered to be of critical importance. It indicates

that the users have given their preferences adjustment the highest possible priority before riding the vehicle.

Table 5.16: T-test analysis for future ADAS development.

	t	df	Sig. (2-tailed)	MD	95% Confidence Interval	
					Lower Bound	Upper Bound
The seat position will adjust depending on my comfort	28.852	37	.000	3.895	3.60	4.19
The steering wheel will adjust before I get inside the car	27.246	37	.000	3.868	3.58	4.16
Temperature adjusted in accordance with my preference	23.028	37	.000	3.921	3.58	4.27
Mirrors can be adjusted according to driver needs	36.891	37	.000	4.211	3.98	4.44
Handling of telephone calls during the journey	21.956	37	.000	3.842	3.49	4.20
Effectively provide information about takeout items when leaving the vehicle	27.414	37	.000	3.921	3.63	4.21
Touchscreen placement settings according to drivers' choice	22.648	37	.000	3.895	3.55	4.24
Adjust automated voice control settings for vital applications	24.520	37	.000	3.632	3.33	3.93
Unfreeze the window before entering into a vehicle	18.052	37	.000	3.579	3.18	3.98
Removing dust from windows before starting a vehicle	31.857	37	.000	4.237	3.97	4.51
Window demisting before you start a vehicle	22.122	37	.000	3.895	3.54	4.25

- *Future ADAS systems:* The fact that users have such a high level of education and that their attitudes toward technology have become sufficiently developed will directly show up in all of the parameters of their expectations regarding the development of ADAS in the future. The aforementioned assertion is supported by the data presented in Table 5.16, which demonstrates statistically strong significance thanks to the fact that all of the *p-values* are lower than *0.001*. In addition, the parameters "mirrors can be adjusted according to driving needs" and "removing dust from windows before starting a vehicle" have a significant impact because of the unique requirements of individual drivers and the environmental conditions in their respective regions, as indicated by their respective t-values of 36.891 and 31.857.

5.5 Discussion

The exponential growth of technology in recent decades has contributed greatly to the rapid development of driving automation, particularly in the area of ADAS. Therefore, ADAS have proven their efficacy in increasing highway safety, and as a result, we are able to avoid numerous collisions. However, drivers have many misconceptions about using ADAS in their daily driving due to supervision and/or functionality issues (Braitman et al., 2010; Onnasch et al., 2014). One of the main focuses of demonstrating ADAS's capabilities was the driver's psyche, so the system will function as a cockpit co-pilot to ease the strain of difficult driving conditions (Inagaki and Makoto, 2013; Brookhuis et al., 2001; Hagl and Dongo Remi, 2020; Bequet et al., 2020). Providing operators with information about automation reliability allows them to calibrate their attention to different automation signals. Research has shown that when people are able to comprehend the reasoning that underpins how a system operates, not only do their performance levels increase, but so does their level of satisfaction with the system (Oviedo-Trespalacios et al., 2021; Biondi et al., 2018; Fleming et al., 2019).

We conducted user-focused interviews while keeping key parametric aspects in mind so that we could find solutions to all of these problems and gain a deeper understanding of them. All eight of the hypothesised drivers' characteristics were significantly measured via seven predicted parameters, lending support to the conceptual model (Fig. 5.1). In addition to this, we were able to understand the future needs of the users with regard to ADAS by conducting these interviews and gaining their feedback.

Throughout the course of the study, appropriate measures were taken to educate drivers on the capabilities of ADAS as well as its potential drawbacks. It is especially important to keep this in mind when narrating the hypothesized characteristics of the drivers. In the event that this does not occur, it will in-

crease the likelihood of unfavorable consequences for knowledge of ADAS, which will ultimately result in a risk to the safety of drivers and passengers.

5.5.1 Users' experience with current ADAS

Not only do the experiences of users shed light on the quality of the product, but they also reveal how much enjoyment users derived from using the product (Parkinson, 1982; Veryzer and Brigitte, 2005; Lindgren et al., 2020). This will also pave the way for a field of brand loyalty, which will result in repeated purchases of the same product (Selinka et al., 2020; Hoyos et al., 2018). Additionally, it validates the concerns that users have regarding their own safety. As a result, by the time it is implemented, it will improve drivers' comprehension of how to use ADAS-based functions within the vehicle. This will ultimately result in an increased acceptance of ADAS-based functions among users and encourage them to purchase vehicles with advanced functionality (Joshi et al., 2009).

a) *Drivers' technical sophistication:* It is necessary to know the perspective of drivers regarding how they feel when using the various ADAS functionalities that are available in their vehicle in order to increase the level of trust that exists between humans and vehicles in the ecosystem (Lubkowski et al., 2021; Hartwich et al., 2021; Dixon et al., 2019; Clement et al., 2022). One of the key criteria and a parameter itself to measure not only safety, but also joyful ride is since how long you have been driven ADAS-based functionality vehicle (Choy et al., 2022; Masello et al., 2022; Carsten and Leena, 2001; Pradhan et al., 2018). According to the current research, only 15.79% of respondents had driven a vehicle for more than 20 hours per week. This is due to the fact that they typically utilised shared transportation for their work in the context of daily mobilisation.

b) *Brand point of view:* In the course of their work, a number of researchers have observed that a person's "brand" is what defines their charismatic character in the eyes of society. The vehicle model that you have used demonstrates, either directly or indirectly, the inherent loyalty you have toward it (Moosa and Zubair, 2015; Wellbrock et al., 2020; Wuestefeld et al., 2012). According to the current research, consumers have a higher level of trust or loyalty in the Maruti brand (with 28.9 %) in comparison to other brands, while Tata Motors has secured the position of second place (with 18.4 %). This analysis is being done for a variety of reasons, including the following: First, Maruti is one of the first original equipment manufacturers (OEMs) to be established in India. Second, Tata Motors have a more aesthetically pleasing look and a variety of features that are ADAS-based. Third, the resale value of both of the company cars is comparable to that of economically viable vehicles. At the time of the purchase, the choice of a particular vehicle model was influenced by all three of these factors, each of which in turn was influenced by the

others.

c) *Perceived ease of use:* There are two primary approaches to consider when thinking about the safety of motor vehicles: the first is passive, and the second is active. As a result of improvements in science and technology, nearly all of today's automobiles come equipped with both passive and active safety features. Examples of the former include airbags and seat-belt reminders, while examples of the latter include ACC, LKA, LC, AEB, and other similar systems (Morris et al., 2010). These features, when integrated into a vehicle, lessen the amount of work required of the driver while they are behind the wheel (Auckland et al., 2008; Kuo et al., 2019; Tanaka et al., 2000). On the other hand, a number of studies have indicated that because ADAS features are included, driver workload will increase (Paxion et al., 2014; Davidse et al., 2009). According to the findings of the current study, the AEB (with a significance level of *SS=2.030, df=2, MS=1.015, F=7.344, p=.002*) and LC (with a significance level of *SS=.466, df=2, MS=.233, F=5.711, p=.007*) have results that are more significant than those of the other similar related parameters.

d) *Personal innovativeness:* It is not enough to simply install ADAS-based safety technology in a vehicle in this age of rapid technological advancement; rather, we need to investigate the experiences that users have had while using the technology. We found that almost half (47.37%) of the people who participated in the survey were content with the current functions of ADAS and felt relaxed in regard to the technological sphere. To some extent, yes, technology can be a source of confusion, in particular regarding the question of whether or not one should make use of it in order to maximise one's enjoyment of driving alone (Eckoldt et al., 2012). Concerns about passenger safety, faith in the efficacy of intelligent technologies, and the discovery in recent years of aesthetically pleasing and technologically advanced design solutions in the cockpit are additional reasons why existing technology is preferred (Hooft van Huysduynen et al., 2016).

e) *Safety concerns and holistic parametric view:* In the present time, ensuring passenger safety is the utmost priority with regard to the automation of vehicles. It is important to investigate ADAS technology from both a design standpoint and a technical viewpoint, looking at how users experienced the technology (Lu et al., 2005; Meng et al., 2004). The findings of the current study add further credence to these established facts; specifically, 36.8 percent of participants strongly agree with the concern that ADAS will increase their level of personal safety, and 28.9 percent of participants strongly believe that their interaction with ADAS is straightforward and easy to comprehend. This gives the OEMs the support they need to implement new features in the ADAS because there has been a tremendous response from users themselves (Nagai and Hidehisa, 2020).

5.5.2 Users' expectations towards future ADAS

ADAS are intended to improve both the security and the convenience of the overall driving experience. Users can anticipate that ADAS systems will become increasingly individualised and customised to meet their specific requirements and preferences in the not-too-distant future. Users can anticipate that ADAS systems will come equipped with features such as climate control, seat adjustments, and lighting that can be managed via voice commands or touchscreens. They might also come with cutting-edge sound systems and various in-car entertainment options, both of which are designed to make the ride more pleasant (Bilac et al., 2022; Lin et al., 2018; Eichhorn et al., 2010; Shelly, 2016). Over time, ADAS systems will acquire the capability to learn and adjust to the preferences of the driver. This could include things like preferred routes, music, and air conditioning settings, among other things (Park et al., 2007; Borodinov et al., 2020). Users can anticipate ADAS systems to become more tailored to their individual needs, with options like voice-recognition and reminders for important personal items (Sarala et al., 2018a). The drivers will have more confidence in their driving thanks to technological advancements like dust removers, which can be used both during and before the trip. Driving is also made more enjoyable and relaxing as a result of this, which is especially noticeable in arid regions.

a) Preferences as the vantage point: It is essential for the design, development, and marketing of these systems to have a solid understanding of the preferences of ADAS users with regard to the functions of the system. It helps to ensure that the systems satisfy the needs and expectations of the users, thereby increasing the likelihood that they will be adopted and used effectively (Zhang et al., 2019; Koppel et al., 2019). As evidence that this study is a useful one, we note that after having someone else drive their car, 39.5% of users adjust their side mirrors (*t=20.032, df=37, p=0.000, MD=3.789*) and that 36.8% of users adjust their seating position (*t=22.483, df=37, p=0.000, MD=3.921*). Moreover, the p-value of 0.000 for all the discussed parameters is extremely statistically significant, suggesting that the results of the *t-tests* are reliable. This is critical for two reasons: first, to identify what features users value most, and second, to rethink the design, if necessary, for potential future improvements.

b) ADAS usefulness: The value of ADAS lies in its ability to provide at least some degree of cognitive functionality. There is a huge amount of variety in terms of preferences and ADAS when considered from the user's point of view (Paiva et al., 2021; Abraham et al., 2018; Driel and Bart, 2005; Lilis et al., 2019; Weiss et al., 2018). The increased use of technology and automation may be welcomed by some users and seen as a time saver by others, while still others may find it to be intrusive and annoying. In this study, users have a lot of faith in the car's ability to learn and adapt to the preferences of each individual driver (t=27.699, df=37, p=0.000, MD=3.842) and in the car's memory function in the event of frequent

changes in the vehicle's drivers (t=24.643, df=37, p=0.000, MD=3.816), with each feature receiving 21.1% acceptance in the strongly agree range. This strongly suggests that users have a strong preference for preference-based systems, and that fleets of the future will incorporate ADAS capabilities with cognitive abilities (Patel et al., 2021; Heide and Henning, 2006; Li et al., 2012).

c) Future ADAS: Through the investigation of the present study, we have found that users have tendency towards accept and adopt cognitively-enabled functional ADAS as a part of their future fleets. It is also noted that in face-to-face meetings they were little knowledge about such kind of technologies, yet, they were open to embedded these technologies in future. The *t-test* results (refer Table 5.16) were proven these beliefs in which all the ADAS-based functionalities have very high statistical significance. To be more specific, the top two needs of the users were to have mirrors that can be adjusted according to the needs of driving (*t=36.891, df=37, p=0.000, MD=4.211*) and to have dust removed from windows before starting a vehicle (*t=31.857, df=37, p=0.000, MD=4.237*). The following explanations help put this into context: (a) In countries like India, where many people know each other and share rides, it is normal for drivers to expect their mirrors to adjust automatically to their preferences. (b) Due to the country's consistently high temperatures, dust is a common natural occurrence in India. Therefore, it was expected by drivers that the windows would be dusted off before each trip. Furthermore, if the machine can meet human requirements, that will go a long way toward fostering mutual trust (Hooft van Huysduynen et al., 2016; Woods, 1985; Cai and Yingzi, 2012; Noor, 2015).

5.5.3 Moving ahead with human-centered ADAS design

In the process of developing human-centered ADAS design, it has been found that the user-focused research will provide a vital direction (Patel et al., 2021; Nirschl, 2007; Blackett, 2021; Tomar et al., 2021). This is owing to the fact that the study itself offered a one-of-a-kind safety experience with users, particularly with regard to AEB (*F(2,35)=7.344, p=.002*) and LC (*F(2,35)=5.711, p=.007*), which will compel us to develop ADAS technology that is user-friendly for future fleets. A further point to consider is that the feature "ADAS increase my safety" (*t=43.272, p=.000*) acts as a catalyst and will enhance efforts to strive towards human-centered ADAS design. It was discovered that "I like the car to adjust itself to my preferences when I use it" (*t=27.699, p=.000*) is another factor that pushes us to construct future ADAS designs that are concentrated on the comfort and convenience of the user. The majority of the characteristics, as shown in Table 5.16, point in a positive direction for the development of human-centered advancements in ADAS in the future.

Furthermore, it is essential for designers to develop detailed user personas and realistic usage sce-

narios based on the findings of research conducted on user engagement (Lindgren et al., 2007). For the purpose of ensuring that the ADAS interfaces, features, and interactions are tailored to match the specific requirements, aims, and situations of a variety of user groups, these will serve as additional recommendations for the actual design process.

5.5.4 Users' feedback

We'd like to share a great piece of discussion we had with a user during an interview about a promising new area of research for the community's benefit. Concern about vehicle-human interaction was expressed by Respondent 9's worry that:

"You should also consider some features like how effective vehicle cooperates with drivers in the sense of critical situations" (P9, Male, 26).

The interaction between humans and machines is the focus of this worry. In order to foresee the nature of human-vehicle cooperation, we asked our respondents to share their hopes, fears, and opinions. How would they be able to keep things running smoothly, even in the direst of circumstances? Following that, etc. Participant 11 discussed with regard to data and awareness context in his expression as:

"All ADAS data should be accessible through a mobile phone's interactive and analytical experience. Enthusiastic users will engage with it, raising the system's profile and benefiting others in the long run" (P11, Male, 40).

Data security and accessibility in a format that users can grasp have been identified as two of the most pressing issues participants have brought up. And because of this, ADAS systems will be built to be user-friendly even for those who aren't particularly tech-savvy. One of the female participants (P16) came up with wide variety of concerns as:

"I do not believe ADAS is beneficial for countries like India, where vehicles approach from all directions. Features such as automatic emergency braking are essential. However, I find myself clinging to manual car control, which inspires confidence. Even with the use of cruise control, I feel somewhat less in control of the vehicle. In contrast, I would love to see seats and mirrors that automatically adjust to the driver's height. Blind spot detection is an extremely useful feature. Additionally, emergency auto-braking is essential. I would choose safety and comfort features over features that emphasise vehicle control, such as lane-keep assist" (P16, Female, 37).

Initially, it was Participant 16 who emphasised the importance of AEB, saying that it is needed whenever

there is unpredicted traffic flow on the road. While she could have given the car's controls to vehicle, she much preferred driving it herself. Alternatively, she had to appreciate the cognitively enabled features that were crucial to her safety and comfort while piloting. Participant 18 was more inclined towards phone-call management services and stated that:

"When driver get phone call while driving the car should be slow down automatically or hazard lights should be automatically on so other car drivers can easily maintain distance from the car and the risk of accident can be less" (P18, Male, 45).

In particular, respondent 18 was worried about how we would deal with phone calls and how we would prevent any mishaps. A phone call should trigger the ADAS to immediately go into alert mode and begin providing solutions. Taken as a whole, Participant 30's comments on a more advanced level can be summarised as:

"Human aware driver assistance systems is much needed in present times" (P30, Male, 40).

A 30^{th} participant argues that ADAS systems should be smart but still require human oversight and control. That means that in the context of the future of automation, he discussed human-centered ADAS. For the future cockpit to be truly effective, it will need to be fitted with cognitively-enabled features while also being able to accommodate the users' preferences, comforts, personalised things, and many more under human control. Member 36 brought up the topic of common occurrences involving the installation of ADAS systems in the vehicle with the following statement:

"Different nations, traffic, driving patterns, road conditions, and levels of citizen compliance with traffic laws. There are no questions that can infer a respondent's location. Can the results be generalised to all global ADAS-assisted driving experiences?" (P36, Female, 31).

There are many reasons why participant 36 is correct in her assessment. It is important to note the role of the federal government and various agencies, as well as how OEMs will approach this, in order to implement common fitting standards.

5.5.5 Limitations of the study

The scope of our investigation is not without its caveats. First, the study relies on a limited sample of focused-group interviews, which may not be representative of the general population's interactions with ADAS. Due to statistical power limitations, a small sample may not be representative of users' experiences with ADAS systems and may not accurately reflect the population as a whole. Second, it's possible that the

study's results don't apply across the board to all ADAS setups and all users. There is a possibility that the study's findings do not apply to all ADAS systems or all users because they are based on a small sample. Third, because this research was based on interviews with small groups of people, there is a possibility that some people in the groups were more outspoken or influential than others, which could introduce bias into the findings. Finally, it is possible that the researcher's own preconceptions will affect how they analyse the results. Finally, as drivers gain more and more familiarity with ADAS technology, they may develop new expectations and standards for convenience and ease of use. It is important to note that only 10.5% of respondents have had more than five years of experience with ADAS-based vehicle functionality.

5.6 Learning experience

We draw the conclusion that OEMs will be motivated to rethink their approach to design in light of what they've learned about ADAS and to offer more user-friendly products in the future. When users have more experience on ADAS-based functions in their fleets, they will generally feel safer in the context of the human-technology ecosystem. This is because of the interplay between humans and technology. In addition, the satisfaction of the users' current needs as well as their future expectations will increase the pleasure of driving while also making the road safer than it is today. It should come as no surprise that this will result in an increase in trust between the two of them (humans and vehicle). Moreover, from a comfort, preference, and personalization standpoint, ADAS-based novel solutions offer an opportunity to enhance in-vehicle and e-HMI capacity while also relieving stress for the driver. This is because the presented results corroborate these hypotheses.

Multiple promising new lines of inquiry have been sparked by these findings. In the first place, over half of our respondents (55.3% to be exact) have less than 10 hours of weekly driving experience and less than 2 years of experience driving an ADAS-based vehicle. This means that more people with experience operating ADAS-equipped vehicles will be needed to participate in future studies. Second, additional research via simulator-based verification is the optimal option for the first potential direction of future work. In which we can not only make full use of ADAS in order to gauge user interest, but also provide a more illuminating visual driving experience with respect to ADAS functions. In addition to the first two points, a group trip to the nearest OEMs to learn more about the ADAS embedded in the vehicle is also possible. These might be useful for them in getting a firm grasp on the features, and they might pique their interest in modern and future in-car systems. Fourth, increasing users' confidence in technology can be accomplished by displaying its security measures at production facilities.

CHAPTER 6

Discussion and Conclusions

We are at the verge of final chapter where there is a discussion about various things including the following: (a) users' attitude towards cognitive vehicles? (b) what are the key factors which plays a vital role to make a vehicle more personalized? (c) what about users' experience with current ADAS? (d) what kind of limitations en-route to the current results? and (e) what will be the users' expectations for their future fleets' features? The solutions of all such kind of questions are available in the current chapter.

6.1 What are the general attitudes towards human driver availability in AVs and people's perception towards AD?

It is crucial to have a grasp of how people think about autonomous cars in this day and age, considering the tremendous pace of digitisation and technical innovation that is currently taking place. However, if we are to look beyond the limitations of innovation, it is crucial to investigate the significance of the "human" user in the context of future cars, where the impression is formed that there is no need for "human" interventions, at least in the context of the driving task. Furthermore, it is of the utmost importance to have an understanding of the existing "human" user's perspective about automated driving. More specifically, in the context of lowering the stress levels of drivers, technical benefits and other such factors will be among the many others. Researchers will have a difficult problem in determining the community-wide

benefits of autonomous driving; our study aims to touch on one of the foundations of this question.

A positive response was received from the participants (N=2080 from 146 countries) when they were questioned about their thoughts on the presence of human drivers in AVs and what they believe about automated driving features (Refer Chapter 3 for more details). As a whole, it has been observed that 84% of respondents have expressed their belief that automated driving is beneficial to the mankind. In response to the question about the presence of a "human" driver, 46% of respondents said that "yes" it is necessary, while 27% of them were unsure as to whether or not it is required, and the same number of respondents stated that "human" drivers are not required in AVs.

6.2 Why personalization is a key enabler for future vehicle users?

We are now living in an era where everyone demands each and every item be more personalised. Personalization is completely intact in our day-to-day lives, serving as an essential component in each and every facet. In light of the fact that the same principle applies to automobiles as well, a commuter need everything to be personalised for the services. They want services that are not only quicker and more streamlined for the goal of booking, but also for the purpose of customising their routines and preferences. We made an effort to catch up with some research among users in order to bring the topic to the forefront of attention and promote awareness.

For the purpose of conducting research on human-centered personalisation in vehicle characteristics, we have received a total of 657 (out of 977) relevant replies from 93 different countries. In instance, over 70% of those who participated in the survey agreed with the concept that the car would learn user habits and, based on those habits, alter the position of the seat and mirrors before the user enters the vehicle. Additionally, it will adjust other pertinent user settings according to the user's needs and preferences. Moreover, participants were in agreement (nearly 65%) that the car should learn user habits and, depending on those routines, defrost the windows and windscreen when it is necessary to do so (Refer Chapter 4 for more details).

6.3 What's about users experience and expectations in the context of ADAS?

When we, as human beings, go through experiences and then, based on those experiences, move on to buy new products with bigger expectations, it is natural for us to do so. It is possible to apply the same kind of philosophy to automobiles as well. In order to have a better understanding of how consumers feel about the present ADAS features, it is essential to conduct an analysis of their experiences while driving their own vehicles. In the same vein, it is taken into consideration what kinds of ADAS features they have used while behind the wheel. When they made use of the ADAS capabilities, what emotions would they experience? What are their future expectations with regard to the incorporation of new ADAS technologies into the vehicle, taking into consideration their previous experiences? This is one of the most important topics that comes up at the moment. That is what we are concentrating on, and we have made an effort to learn more about the opinions of people on the issue.

An ADAS is essential not only for automobiles but also for human passengers who are travelling in vehicles. This is due to the fact that it gives the driver essential information on the vehicle that they are operating in order to ensure that there will be almost no accidents on the road. For the purpose of increasing awareness and enhancing the solutions, we have conducted user-focused interviews in the state of Gujarat, India, with a total of 38 participants from a variety of backgrounds (for more information, refer to Chapter 5). A number of distinct characteristics, such as the driver's level of technological expertise, the brand's point of view, and the perceived ease of use for various ADAS settings, were each subjected to statistical analysis. In order to investigate the users' experiences with ADAS functionalities (see Table 5.13), a *t-test* analysis was carried out. Additionally, the users' expectations for their future fleets were thoroughly investigated (see Table 5.16).

6.4 Limitations and directions for further research

A variety of constraints must be taken into consideration when interpreting the data that were collected for the thesis. These limits, in turn, give useful paths for more study to be conducted in the future. It is possible to consider the constraints in connection to the achievements that the thesis has achieved. In accordance with the information presented in Chapter 3, it has been noticed that the survey about the nexus of AD as a good or bad and a "human" driver availability in AVs was conducted online with a total of N=2080 participants from 146 countries across the globe. Even after we made ourselves accessible

online to provide any type of assistance participants needed in order to complete the survey, it was still likely that some of the participants were unable to comprehend the significance of the questions that were to be asked. This is because of, there were a total of 3139 people who took part in the survey; however, after screening through the survey, only 2080 people were qualified to engage in the data analysis. When it comes to the overall number of participants, the question of how many of them have had experience with AVs as either drivers or passengers was not yet to clear. Additionally, it is likely that all of the participants did not have enough understanding of LoA, despite the fact that it was offered in the survey; nonetheless, it is also feasible that they encounter difficulties in comprehending the technical words. Moreover, the people who took part in the study do not in any way reflect the whole population of the country. The future scope includes with three different avenues including, (a) there is the possibility of conducting simulator research in which the participants are required to have a minimum level of technical knowledge and practical expertise in order to offer constructive feedback on a variety of aspects pertaining to AD and AVs, (b) interviews conducted in person with individuals from a particular geographic region who have had experience with AVs either as a passenger or as a driver, and (c) As a part of the research project, we conducted an online survey, a simulator study, and an in-person interview with the same participants to learn more about what they have encountered in a variety of modes and techniques of engagement. This led to the discovery of new parameters.

Second, the research that is described in Chapter 4 was conducted via the use of an online survey rather than in-person or simulator-based settings. The study presented 657 useful participants out of 977 from 93 nations worldwide to explore parameters on user routines and their preferences in cognitive vehicles. It has been observed that the percentage of participants who were acquainted with human-vehicle interaction (HVI) was only around 25%; thus, this will have an effect on the findings of the survey that was carried out. In addition, only around 18% of the participants had shared a vehicle with someone who was not a member of their family. This indicates that there is a lack of knowledge of the many aspects of cognitively-enabled experience. It is important to note that the participants did not have any interest in being reminded about who would be their daily or frequent passengers, which is somewhere in the region of 23 to 24 percentage points. Even though there are certain restrictions associated with online surveys, there is a significant amount of room for further study, which includes, (a) an investigation need to be carried out among the participants provided that they possess a sufficient level of information about HVI, (b) there are further characteristics that need to be investigated with a wide range of candidates in order to develop the cognitively-enabled cars that will be a part of future fleets, (c) to build a vehicle prototype that is cognitively enabled within the context of a university-industry partnership in order to increase the

amount of personalisation possible for users.

Third, there have been limitations in relation to the study work that is provided in Chapter 5, which encompasses user-focused interviews. An interview was conducted with a small number of participants, all of whom were situated in the Indian state of Gujarat. On the other hand, we had made an effort to get individuals from a wide range of backgrounds and ethnicities for the in-person interviews. In addition, there was a possibility that the users had not comprehended the significance of the ADAS capabilities, or that they were not yet prepared to investigate the next-generation ADAS features. The findings, on the other hand, opens up a wide variety of potential directions for further exploration, including, (a) To investigate more perspectives towards user's personal opinions of their experience with present ADAS features as well as what they believe about the extra features that will be a part of future ADAS systems, mixed research which includes interviews with experienced drivers and simulators would be an excellent chance, (b) it is emphasised that the diverse demands and preferences of users across a broad variety of geographical perspectives will be used to develop more effective solutions for future ADAS, (c) For the purpose of developing cognitively-enabled ADAS features, it would be promising and thrilling to explore additional features of forthcoming ADAS that will be obtained from an online survey. After that, it would be good to check with different user groups via an interview and/or simulator study, and (d) in order to check that users in a certain geographic region are thinking about new features of ADAS, it is fascinating to participate in the study with a varied number of research groups from all over the world. In addition, this is straining the capabilities of collaborative research groups in academic and industry environments.

6.5 Final conclusions

In conclusion, this thesis has made significant contributions to the understanding of the various features of cognitive vehicles and, consequently need of human aware ADAS. The research addressed three main research questions: (RQ1) In the context of automated driving and autonomous vehicles, how do consumers perceive the concept of "human presence"? (RQ2) Where do human-centered ADAS stand in terms of user attitude, needs, and requirements? and (RQ3) How do users feel about the ADAS features they are using now, and what do they expect in the future? What are the basics of human-centered ADAS design, and what features should it include? The *first research question* was addressed via a worldwide online poll that included participants from 146 different countries. The results of the survey indicated that a "human" driver is, in fact, required even if the vehicle is autonomous. On the other side, they are adamant about using automated driving and the many different driving options that are available. In order to investigate

the attitude, needs, and preferences of users in relation to cognitive vehicles, the *second research question* was answered via the use of an online survey that was used in 94 different countries. It is fascinating to argue that the users are genuinely searching for human-centered ADAS for their next cognitive cars, and the findings appear to support this. Within the sphere of human-centered ADAS, experience and expectation were brought about as a result of the *third research question*. By conducting user-focused interviews and exploring numerous lines of research via the input of users, we were able to get the answer we were looking for.

1. The exploratory research, conducted via an online poll, revealed a vital question: whether the "human" driver is essential in AVs or not. We have received a substantial amount of proof from all around the world (that is, from 146 different countries) that the human driver is, in fact, a prerequisite for the fleets of the future. Customers, on the other hand, needed AD and its features in order to improve the quality of their experience when riding in a car. This is one of the unique works anywhere in the world in which the "human" aspect is a "centre" component of both AVs and AD working together.

2. The expansion of personalisation has resulted in the creation of several paths in the world of automobile, where the preferences, needs, and requirements of users are of the utmost importance. In order to learn what users need about their everyday journey, we were able to conduct an online survey that included 93 different countries. The findings that we obtained were helpful in that they demonstrated that the modern user is more concerned with "personalised" than with their items and needs, and that they are also looking forward to new user-centred ADAS capabilities when they buy their new fleet.

3. With regard to the experience that users have had and the expectations that they have for future ADAS, this thesis pushes for a change in that approach. Through conducting interviews with a wide range of personalities, we were able to arrive at the conclusion that a user-focused strategy was the best way to proceed. The purpose of conducting interviews with a total of 38 participants was to get a deeper understanding of their present experience with ADAS and to gather information about what they are looking forward to in terms of expecting future ADAS capabilities. We are certain that this is one of the most exceptional opportunities for us and for the other researchers working in this sector to obtain exciting findings, and we are optimistic about this possibility. As a consequence of the findings, the users expressed their want to purchase ADAS features in the near future and their desire to have them installed in their vehicles.

In summary, this research has significantly advanced the understanding of human centered driver assistance systems for cognitive vehicles. By providing a comprehensive surveys and user-focused interviews, this work equips practitioners with a valuable approach to understanding the features of cognitive vehicles in the realm of ADAS in the context of human-centered perspective.

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