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From Innovation to Social Integration: Evaluating Social Sustainability in ADAS through Key Performance Indicators

MASTER'S DEGREE THESIS IN
MECHANICAL ENGINEERING

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Abstract

The social sustainability of Advanced Driver Assistance Systems (ADAS) is a critical aspect to consider in the automotive industry's pursuit of sustainable development. As ADAS technologies continue to advance and become the future of automotive technology, it is essential to evaluate their impact on society and ensure they contribute positively to social well-being. Key Performance Indicators (KPIs) play a vital role in assessing, measuring, and monitoring the social sustainability of ADAS.

This paper aims to investigate, enumerate, and explore the utilization of various KPIs in evaluating the social sustainability of ADAS through a comprehensive literature review and insights from industry experts. The findings will be utilized to develop a robust framework that identifies the main KPIs and their functions in assessing the social impact of ADAS. Furthermore, the study will propose future research directions to further enhance the understanding and evaluation of the social sustainability of ADAS.

The literature review encompasses various aspects of social sustainability, including but not limited to employment opportunities, skill enhancement programs, workforce development initiatives, technological skills acquisition, collaboration with educational institutions, and community engagement activities. These KPIs provide valuable insights into the social impact of ADAS and the extent to which they contribute to societal well-being, ensuring that ADAS technologies align with social sustainability objectives.

The framework developed in this study serves as a valuable tool for practitioners and stakeholders, enabling them to understand and evaluate the main functions and contributions provided by ADAS technologies in addressing social sustainability challenges. However, it is important to continue conducting further research to expand the knowledge base in this area, exploring additional KPIs and refining the understanding of the social impact of ADAS technologies for a comprehensive evaluation of their social sustainability.

Key words: Advanced Driver Assistance Systems (ADAS), social sustainability, Key Performance Indicators (KPIs), Autonomous Driving.

Abstract in italiano

La sostenibilità sociale dei sistemi di assistenza avanzata alla guida (ADAS) è un aspetto critico da considerare nel perseguimento dello sviluppo sostenibile dell'industria automobilistica. Man mano che le tecnologie ADAS continuano a progredire e diventano il futuro della tecnologia automobilistica, è essenziale valutarne l'impatto sulla società e garantire che contribuiscano positivamente al benessere sociale. Gli indicatori chiave di performance (KPI) svolgono un ruolo fondamentale nella valutazione, misurazione e monitoraggio della sostenibilità sociale delle ADAS.

Questo articolo si propone di indagare, enumerare ed esplorare l'utilizzo di vari KPI nella valutazione della sostenibilità sociale delle ADAS attraverso una revisione esaustiva della letteratura e i contributi di esperti del settore. I risultati saranno utilizzati per sviluppare un solido quadro che identifica i principali KPI e le loro funzioni nella valutazione dell'impatto sociale delle ADAS. Inoltre, lo studio proporrà future direzioni di ricerca per migliorare ulteriormente la comprensione e la valutazione della sostenibilità sociale delle ADAS.

La revisione della letteratura comprende vari aspetti della sostenibilità sociale, tra cui opportunità di impiego, programmi di miglioramento delle competenze, iniziative di sviluppo della forza lavoro, acquisizione di competenze tecnologiche, collaborazione con istituti educativi e attività di coinvolgimento della comunità. Questi KPI forniscono preziose informazioni sull'impatto sociale delle ADAS e sulla misura in cui contribuiscono al benessere della società, garantendo che le tecnologie ADAS siano allineate agli obiettivi di sostenibilità sociale.

Il quadro sviluppato in questo studio serve come strumento prezioso per operatori e stakeholder, consentendo loro di comprendere e valutare le principali funzioni e contributi forniti dalle tecnologie ADAS nel affrontare le sfide della sostenibilità sociale. Tuttavia, è importante continuare a condurre ulteriori ricerche per ampliare la base di conoscenza in questo settore, esplorando ulteriori KPI e perfezionando la comprensione dell'impatto sociale delle tecnologie ADAS per una valutazione completa della loro sostenibilità sociale.

Parole chiave: Sistemi Avanzati di Assistenza alla Guida (ADAS), sostenibilità sociale, Indicatori Chiave di Performance (KPI), , guida autonoma.

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1 Introduction

Smart mobility deals both the means of transport for goods and people, with our focus being on the transport of people and, in particular, the role that Advanced Driver Assistance Systems (ADAS) will play in vehicles in the future, to assist drivers, helping to achieve the maximum level of automation in vehicles.[1]

Given the projected role of ADAS in the future, it is crucial to critically examine the potential benefits and risks of driving automation from an ethical standpoint. Understanding the challenges ahead is vital for guiding transportation innovation towards ethically favourable directions. As such, this thesis offers a detailed exploration of the emerging field of the ethics of driving automation, contributing to raising awareness about the central issues that need to be addressed. It aims to provide valuable knowledge on the ethical problems to be tackled, not only to philosophers, social scientists, and legal scholars but also to engineers, computer scientists, manufacturers, policymakers, and the public.

Moreover, the investigation of the case of ADAS to gain insights into the broader relationship between artificial agency and ethical values. Artificial agents, including automated vehicles, act on behalf of humans and may replace human agents in certain tasks. However, driving, as if many other activities delegated to artificial agents, requires moral judgment for responsible execution. Furthermore, driving is intertwined with important human values such as autonomy, self-determination, safety, privacy, environmental sustainability, and individual pleasure. It can also serve as a means of demonstrating affection, care, or kindness. [2]

As a moral activity, the delegation of driving to artificial agents raises significant philosophical questions. What happens to the ethical dimension of driving when it is entrusted to artificial agents? Can they exhibit moral behaviour affiliated to humans? Should their relationship to ethical values be modelled on human moral experience? Can we delegate the full spectrum of human morality to them? Can they fulfil ethical objectives on our behalf and make moral decisions in our place?

Different road safety mechanisms, also known as advanced driver assistance systems, have been incorporated over the years in the development of the automotive industry to provide a higher level of road safety to traditional transport systems. Data from the World Health Organization estimate that during the period 2011 to 2020, 1.1 million people died due to traffic accidents, and between 20 and 50 million were injured in road accidents. More than 40 million individuals get harmed in road accidents each year around the globe. The evaluated cost of mishaps to governments overall is $518 bn every year Study shows human blunder are included in over 93% of car crashes.

94% of these traffic mishaps can be stayed away from by capacities given by cutting-edge driving help frameworks, such as impact notice, programmed controlling frameworks, blind spot detection notice, and so on. [3]

Nevertheless, ADAS involves automating a morally significant human action using artificial agents, providing a valuable opportunity to examine the ethical implications of artificial agency more closely. Here, it is likely to shed light on contentious issues that are essential for a comprehensive philosophical approach to the topic. Revealing the ethical profile and relationship of artificial agents to human agents is a necessary step towards their conscious and responsible societal deployment. A philosophy of artificial agency can be highly useful in this regard. The examination of the connection between driving automation and ethical values has the potential to provide valuable insights into what needs to be done in this regard.[4]

To mitigate the impact of transportation, adopting a holistic approach that encompasses principles of mobility, energy efficiency, and climate change is vital. Such an approach facilitates the development of sustainable transportation practices that foster cleaner and healthier living environments. The United Nations Sustainable Development Goals (SDGs) for 2030 delineate a roadmap for achieving sustainable transport systems, emphasizing universal accessibility, affordability, reliability, and resilience in urban areas.

Figure 1.1 General Parameters of Sustainability [5]

Numerous concepts contribute to sustainable transportation, with an emphasis on Advanced Driver Assistance Systems. ADAS encompasses a range of technologies designed to assist and enhance the driving experience, thereby improving safety and reducing environmental impact. These technologies include features such as adaptive cruise control, lane-keeping assistance, automatic emergency braking, and blind-spot detection. ADAS systems leverage sensor data, cameras, radar, and advanced algorithms to augment the capabilities of drivers and mitigate the risks associated with human error. [6]

Hence, we can conclude that ADAS plays a vital role in promoting sustainable mobility by enhancing road safety, reducing accidents, and optimizing fuel efficiency. These systems aid in minimizing traffic congestion, improving traffic flow, and ultimately reducing greenhouse gas emissions. Furthermore, the integration of ADAS with emerging technologies like artificial intelligence (AI) and machine learning allows for more sophisticated and intelligent transportation systems.

1.1. What is ADAS?

The automotive industry is witnessing a rapid evolution with the integration of advanced technologies aimed at enhancing vehicle safety, efficiency, and overall driving experience. One of the most significant advancements in recent years has been the introduction and proliferation of Advanced Driver Assistance Systems. ADAS includes a range of technologies and features designed to assist drivers in various aspects of vehicle operation, safety, and convenience.

This section explains the role and scope of ADAS in the automotive industry upto a certain extent to understand the , highlighting its benefits, challenges, and potential. Smart mobility is an emerging concept, which will become increasingly relevant in the coming years, and which is aligned with the sustainable objectives defined by the United Nations where sustainability is advocated in the transport network and the emergence of new mobility paradigms. [7]

Below is a visual showing the concept saturation of ADAS and AD.

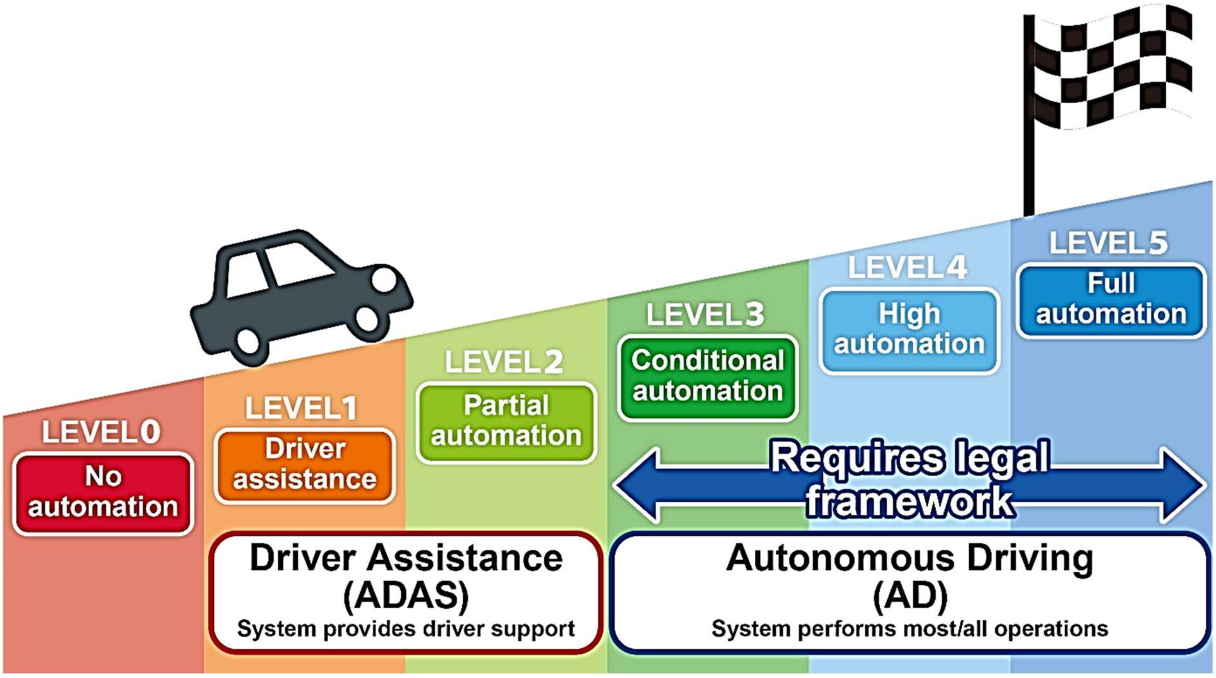

Figure 1.2 The boundary between ADAS and AD lies between Levels 2 and 3. [8]

1.1.1. Forms of Driving Automation

Here we can discuss six levels or forms to describe driving automation. Driving automation involves breaking down driving actions into simpler subtasks and automating them. It assumes human autonomy as the foundation for delegating these subtasks to the automation system. The levels represent different combinations of human autonomy and driving automation, signifying various modes of cooperation between humans and machines.

Levels 0-2 represent lower forms of automation where technology is designed to assist drivers who retain full control. These levels are commonly referred to as Advanced Driver Assistance Systems (ADAS). The distinction between these levels lies in the types and number of ADAS functions that drivers can activate simultaneously. Level 0 (No Driving Automation) includes warning systems and momentary assistance features like automatic emergency braking and lane departure warnings. In Level 1 (Driver Assistance), either steering or acceleration and deceleration can be delegated to the system. Level 2 (Partial Driving Automation) allows for both lateral and longitudinal control functions while the driver closely supervises.

A significant change occurs when comparing levels 2 and 3. From Level 3 onwards, driving is fully delegated to the system, but not with consistent reliability. This variation necessitates different degrees of human supervision and intervention, resulting in diverse forms of human-machine cooperation. At this stage, users can no longer be seen as traditional drivers. They assume a new role that requires further specification.

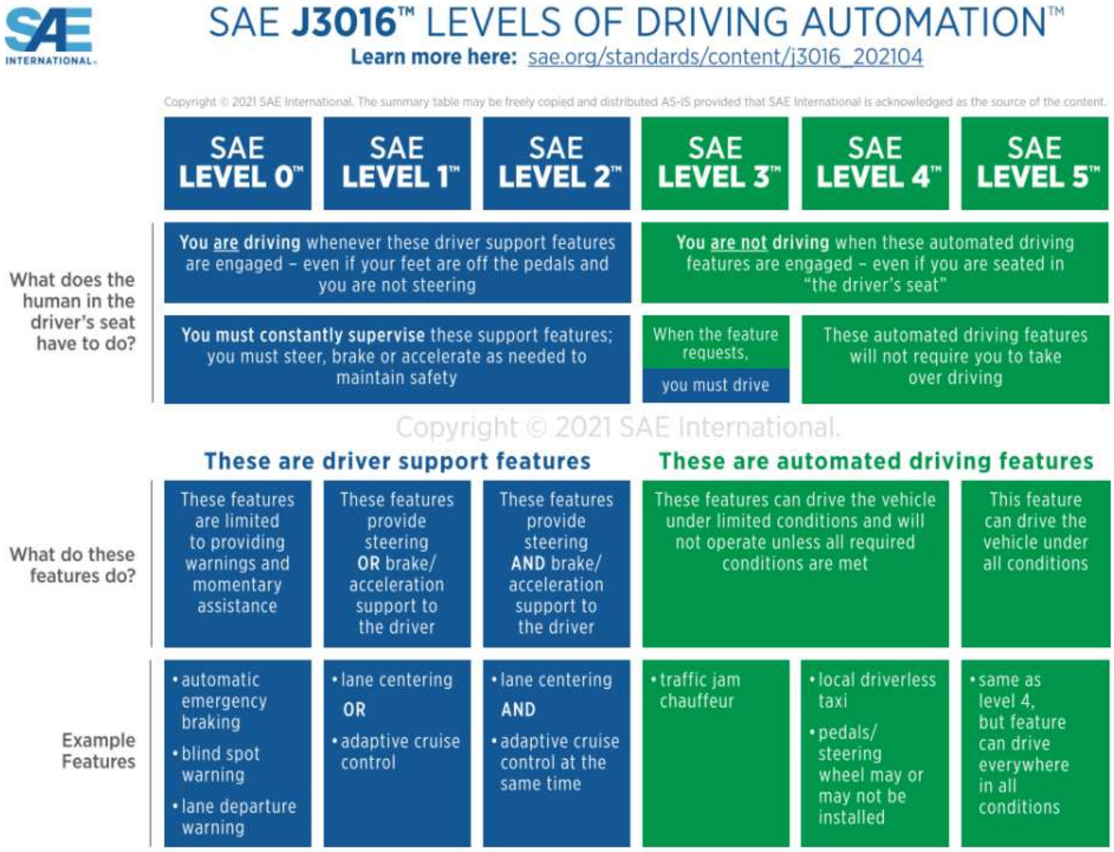

Figure 1.3 SAE J3016 levels of driving automation from SAE International. [9]

Level 3 (Conditional Driving Automation) involves automation within specific Operational Design Domains (ODDs), which define conditions for safe activation of automated driving features based on factors such as weather, temperature, road, and traffic conditions. In Level 3, humans must take over driving when transitioning between different ODDs or when unexpected situations arise within a specific ODD. Handover and takeover maneuvers, the transfer of driving control between humans and systems, are integral to conditional automation. Human intervention is always a possibility, and drivers must remain attentive as the system may or may not prompt them to take over. Handover and takeover maneuvers raise significant safety concerns, presenting a major challenge for this form of driving automation.

Level 4 (High Driving Automation) imagines automation that largely eliminates the need for takeover and handover maneuvers. It describes systems capable of operating vehicles within specific ODDs without requiring user supervision or intervention. In critical situations, Level 4 systems should handle them autonomously or bring the vehicle to a safe stop without involving users. When these automated driving features are activated, users can be considered passengers. If Level 4 automated vehicles were restricted to their ODDs, steering wheels and pedals would no longer be necessary. However, if these vehicles were operated on regular streets, the ODDs would change along the journey, requiring execution of takeover and handover maneuvers.

The extent of human autonomy at Level 4 depends not only on system capabilities but also on infrastructure and environmental factors. This highlights the importance of considering the wider socio-technical context when characterizing the autonomy of a particular driving system. Factors such as deployment context and related infrastructure must be included to provide a comprehensive description of a specific instance of driving automation.

Lastly, Level 5 (Full Driving Automation) encompasses the complete management of all driving subtasks across all possible ODDs, regardless of conditions. Vehicles with Level 5 automation features can handle all traffic situations without user intervention or supervision. Users would only need to set destinations, specify system preferences, and request a vehicle stop through dedicated commands. Like in Level 4, control interfaces might still be required if users have the option to disengage driving automation features and transition to manual driving, reintroducing the issues of takeover and handover. [10]

Now, we can understand some of the basic roles of ADAS in the industry.

1.1.2. Enhanced Safety

ADAS technologies play a crucial role in improving road safety. By utilizing sensors, cameras, and advanced algorithms, ADAS systems can detect potential hazards, alert drivers, and even take corrective actions to prevent or moderate collisions. Features such as forward collision warning, lane departure warning, automatic emergency braking, and blind-spot detection contribute to reducing accidents and saving lives.

1.1.3. Increased Convenience and Comfort

ADAS offers several features that enhance driver convenience and comfort. Adaptive cruise control, for instance, allows the vehicle to maintain a safe distance from the vehicle ahead while automatically adjusting the speed. Parking assistance systems enable automated or semi-automated parking, reducing the stress and effort required in tight parking spaces. Moreover, features like voice recognition, gesture control, and advanced infotainment systems enhance the overall driving experience.

1.1.4. Improved Efficiency and Sustainability

ADAS technologies contribute to improved fuel efficiency and reduced emissions. Systems such as predictive cruise control utilize real-time traffic data to optimize speed and acceleration, leading to more efficient driving patterns. Furthermore, eco-routing systems suggest the most fuel-efficient routes, considering factors such as traffic congestion and road conditions. These technologies help in reducing environmental impact and promoting sustainability.

1.1.5. Transition towards Autonomous Driving

ADAS serves as a crucial stepping-stone towards achieving fully autonomous driving. The technologies and functionalities developed for ADAS systems form the foundation for higher levels of automation. Features like lane-keeping assist, automatic lane change, and traffic jam assist provide semi-autonomous capabilities and pave the way for future self-driving vehicles.

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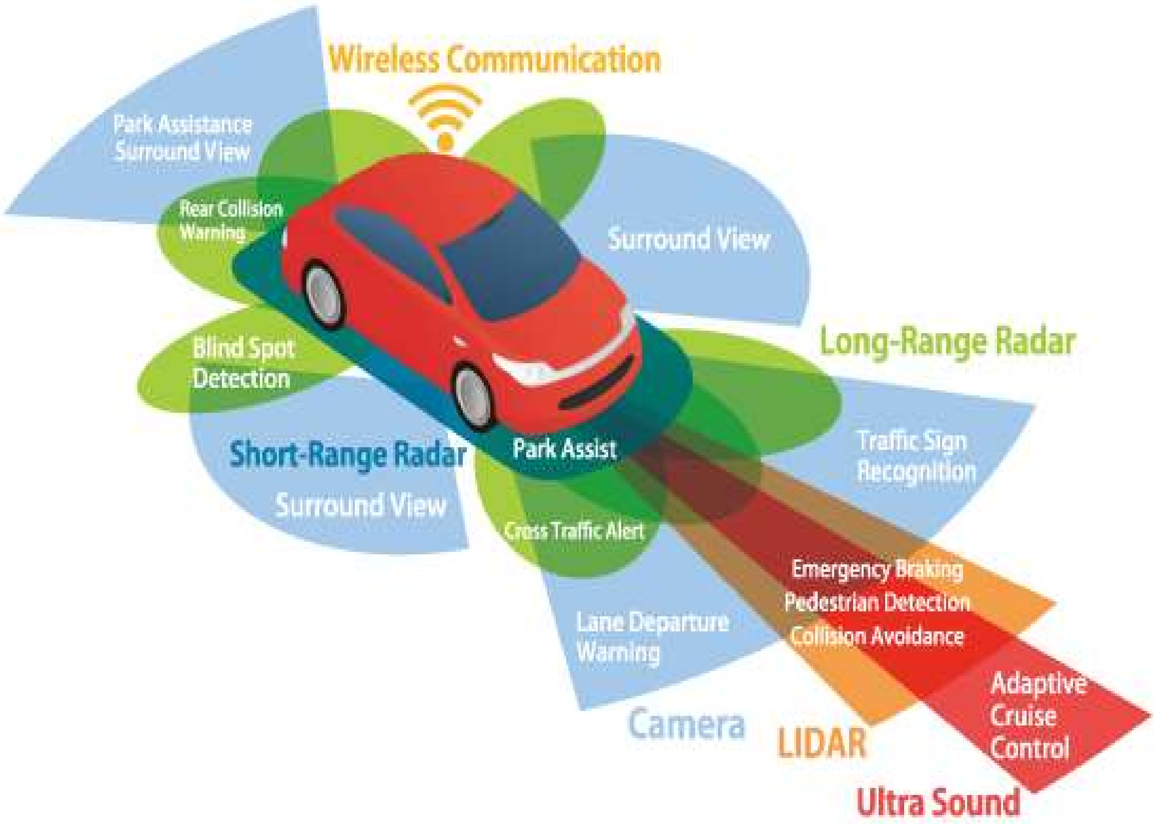

Figure 1.4 Technologies in Self-Driving Car.

1.2. Challenges and Considerations

Although ADAS brings several benefits, it also poses certain challenges. Technical challenges include the need for robust sensor technologies, high processing power, and reliable communication networks. Safety and regulatory challenges involve ensuring system reliability, addressing potential cybersecurity threats, and establishing legal frameworks to govern the deployment and use of ADAS. Additionally, user acceptance and trust, cost considerations, and standardization across manufacturers are essential factors to address.

1.3. Future Outlook

The scope of ADAS in the automotive industry is vast and expanding. Advancements in sensor technologies, artificial intelligence, and connectivity are expected to further enhance the capabilities of ADAS systems. Continued research and development efforts, collaboration among stakeholders, and regulatory support will be crucial in maximizing the potential of ADAS. The future holds the promise of highly autonomous vehicles, where ADAS will play a fundamental role in achieving safer, more efficient, and sustainable transportation.

1.4. The social sustainability of ADAS

1.4.1. Sustainability

Sustainability refers to the practice of meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. It involves managing resources, both natural and human-made, in a way that ensures long-term environmental, economic, and social well-being. Sustainability seeks to balance ecological, economic, and social aspects to create a harmonious and resilient society.

From an environmental perspective, sustainability involves minimizing the use of non-renewable resources, reducing pollution and waste, and promoting the conservation and restoration of ecosystems. Economically, it entails fostering economic growth and development that is equitable, efficient, and does not deplete resources or harm communities. Socially, sustainability encompasses ensuring social equity, promoting social justice, and respecting cultural diversity, while enhancing the well-being and quality of life for all people.

To achieve sustainability, individuals, communities, businesses, and governments need to adopt practices that promote renewable energy, resource efficiency, sustainable agriculture, waste reduction, responsible consumption, and social inclusivity.[11]

1.4.2. Goals for Sustainable Development

The 2030 agenda for sustainable development poses a formidable plan of action encompassing the well-being of people, the planet, and economic prosperity. At its core lies the set of Sustainable Development Goals (SDGs) established in 2015, following years of collaboration between countries and the United Nations (UN) since the Rio conference in 1992, through the Kyoto Protocol in 1997, and culminating in the Paris agreement in 2015. These three pivotal events mark significant milestones in the formation of the SDGs framework.

Containing 17 goals, the SDGs framework aims to safeguard our future by addressing crucial themes. A paramount objective is the ability to sustainably protect a public subjected to road accidents, drive innovation, raise awareness, and foster the integration of ADAS into vehicles and transportation infrastructure. By reducing the human errors and improving situational awareness of drivers, ADAS technologies can play a crucial role in preventing accidents and creating safer road environments, while confronting challenges within the automotive sector, including resource-intensive practices, detrimental environmental impacts, social impact, and the imperative to ensure public security and safety. Recognizing the critical role of ADAS, it has been identified as a key sector in realizing in the coming years.[12]

The list of SDGs can be observed in the image below, sourced from the official UN website:

Figure 1.5 *Sustainable Development Goals (SDGs)* [12]

1.4.3. Social Sustainability

Social sustainability motivations on the well-being, inclusivity, and fairness of individuals and societies within a society. It involves creating conditions that enable all members of society to have their basic needs met, enjoy equal opportunities, and participate in decision-making processes that affect their lives. Social sustainability recognizes that a healthy society is one where people have access to education, healthcare, affordable housing, social services, and meaningful employment.[11]

Key elements of social sustainability include social cohesion, justice, equity, and human rights. It involves reducing social inequalities, addressing poverty, discrimination, and exclusion, and ensuring that vulnerable groups have equal access to resources and opportunities. Social sustainability also encompasses fostering community engagement, participatory governance, and cultural preservation.

To attain social sustainability, it is important to promote social inclusion, gender equality, access to education and healthcare, affordable housing, and fair labor practices. It also requires creating supportive social networks, strong communities, and resilient institutions that can adapt to changing social dynamics and challenges.

What "autonomy" means in the context of ADAS and driving automation needs to be precisely defined. While initially comparing it to human driving autonomy can provide a general understanding, a more focused effort is required to describe what "autonomous" or "self-driving" actually entails. Interestingly, the concept of vehicle autonomy has been articulated by outlining its different forms of dependence on human autonomy. The most commonly used frameworks for driving automation, released by organizations such as the US National Highway Traffic Safety Administration (NHTSA), the German Federal Highway Research Institute, and the Society of Automotive Engineers International (SAE), characterize system autonomy based on what tasks potential users still need to perform.

In the case of ADAS, machine autonomy can only be understood within the broader context of human autonomous agency. Paradoxically, it exists only to serve human autonomy, and the human blueprint plays a different role here. It does not serve as a complete model to be replicated but sets the conditions under which vehicle autonomy becomes meaningful.[9]

With this perspective, driving automation presents a different picture than what terms like "driverless cars," "autonomous vehicles," or "self-driving cars" may suggest. Its goal is not necessarily to completely exclude the human component from the act of driving. On the contrary, driving automation is seen as a form of human-machine cooperation. It aims to automate driving tasks while still considering the broader context of human autonomy, rather than replacing it. Therefore, it would be incorrect to expect vehicle autonomy to match precisely what is expected from human drivers' autonomy. Since driving automation only exists within the framework of human autonomy, it cannot be conceptualized in the same way. Vehicle autonomy must be defined on its own terms, against the background of human autonomy.

The most widely recognized framework that defines machine autonomy in driving automation is outlined in the SAE J3016 document, first published in 2014 and subsequently updated (SAE, 2021). It presents six levels of driving automation, from 0 to 5, which describe different configurations of human-machine driving cooperation. It is important to note that these levels serve a descriptive and informative purpose rather than a normative one, although the progressive numbering may unintentionally convey a hierarchical notion. In other words, the levels aim to define possible forms of human-machine cooperation without implying that one level should be prioritized over others.[9]

It is essential to remember that the complete replacement of human drivers with artificial agents is neither a requirement nor an inevitable outcome. It is merely one possibility among many, if not even a utopian aspiration. Each level of driving automation, blending human autonomy and driving automation in its unique way, has its own legitimacy and should be considered independently, rather than viewed as a step towards the next level. Perhaps, it would be more appropriate to refer to these as different forms of driving automation rather than levels.

Nevertheless, it must always be acknowledged that driving automation only makes sense in relation to human autonomy.

1.5. Literature gaps

As our topic of interest is to assessment of social of impact of ADAS feature in the automotive, I made searches for the relevant articles, which discusses the Key Performance Indicators for the social sustainability of ADAS, but I found a huge gap and could not found much related research material. On the contrary, there are many diversified useful materials are available on the same motivation for the other emerging technologies for example Artificial Intelligence, Machine Learning or Autonomous Driving etc. which will be discussed later in the discussion of literature review.

1.5.1. Research objectives

The research objective of developing a dashboard of Key Performance Indicators (KPIs) to assess the social sustainability of Advanced Driver Assistance Systems (ADAS) is a crucial step in filling the gaps in the existing literature. By achieving this objective, researchers can address the lack of comprehensive evaluation tools and frameworks specifically tailored to assessing the social dimensions of ADAS technologies.

The development of a dashboard of KPIs for the social sustainability of ADAS aims to provide a structured and systematic approach to evaluate the societal impacts of these technologies. Currently, most research on ADAS focuses primarily on technical aspects, safety considerations, and to some extent, environmental implications. The social dimensions, including equity, user experiences, workforce implications, and ethical considerations, have received less attention.

By developing a set of KPIs specifically designed to assess the social sustainability of ADAS, researchers can bridge this gap in the literature. The dashboard of KPIs will provide a standardized framework for evaluating the social impacts of ADAS technologies across various dimensions. It will allow researchers to collect data, measure and analysis the social outcomes of ADAS implementation, and compare the performance of different systems or interventions.

The KPIs included in the dashboard will cover a wide range of social sustainability dimensions. For instance, they might include metrics related to equity, such as the accessibility and affordability of ADAS technologies for different social groups. User experience-related KPIs may assess factors like user satisfaction; trust in technology, and perceived benefits and risks. Workforce-related KPIs can examine the employment implications of ADAS, including job displacement and creation in various sectors. Ethical considerations can be addressed through KPIs that measure aspects such as privacy protection, algorithmic transparency, and accountability.

Achieving the objective of developing a dashboard of KPIs for the social sustainability of ADAS would significantly contribute to the existing literature by providing a comprehensive evaluation tool. It will enable researchers, policymakers, and industry stakeholders to assess the broader societal impacts and consequences of ADAS technologies beyond their technical functionality and safety features.

Moreover, the development of KPIs for social sustainability will highlight the importance of integrating social considerations into the design, development, and deployment of ADAS technologies. It will contribute to raising awareness among stakeholders about the need to address social equity, user experiences, workforce implications, and ethical concerns when implementing ADAS systems.

Generally, fulfilling the research objective of developing a dashboard of KPIs for the social sustainability of ADAS will provide a valuable tool to evaluate and guide the responsible and sustainable integration of these technologies into society. It will enhance the understanding of ADAS impacts from a social perspective and foster informed decision-making to maximize social benefits and minimize potential negative consequences.

2 Methodology

In this chapter, a detailed study has been shown on literature review on Key Performance Indicators for Social Sustainability of Advanced Driver Assistance Systems (ADAS). The methodology employed in this review followed a similar approach as Cicculo et al. (2017) [13], and consisted of three main steps: material collection, descriptive analysis, and presenting the key findings of the thematic analysis.

Theoretical contributions play a crucial role in analyzing the research scope and formulating and addressing research questions. This chapter is divided into two sections: a non-systematic literature review and a systematic literature review. The non-systematic literature review provides the necessary context for Advanced Driver Assistance Systems (ADAS), including key definitions, pro's and con's, and fundamental concepts that are essential for generating research questions. On the other side, the systematic literature review allows for a comprehensive examination of the ADAS process.

The methodology employed in this research follows a mixed-method approach, which typically involves combining different methods, with at least one component being a literature review (usually systematic). This approach offers the potential for a more comprehensive understanding of the research landscape in the specific area of ADAS. [12]

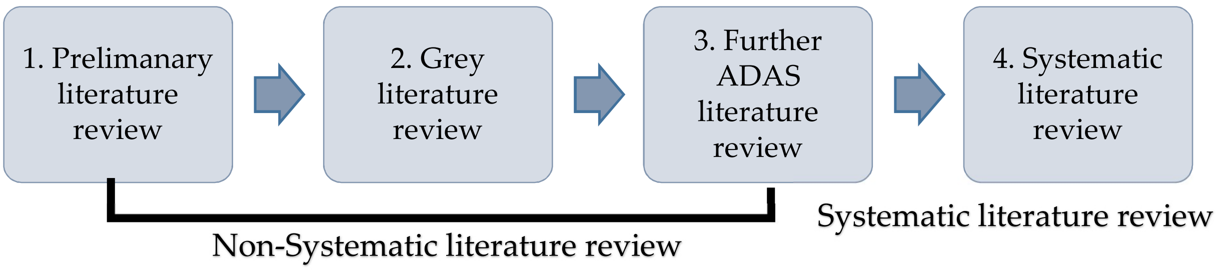

Figure 2.1 Main steps of the theoretical foundations

Above figure, illustrates the main steps involved in establishing the theoretical foundations for this work. These steps will be elaborated upon in next sections, which focuses on the non-systematic literature review, with the systematic literature review.

2.1. Non-Systematic Literature Review

This section contains the methodology and the main contributions stemming from the non-systematic literature review and its main contribution.

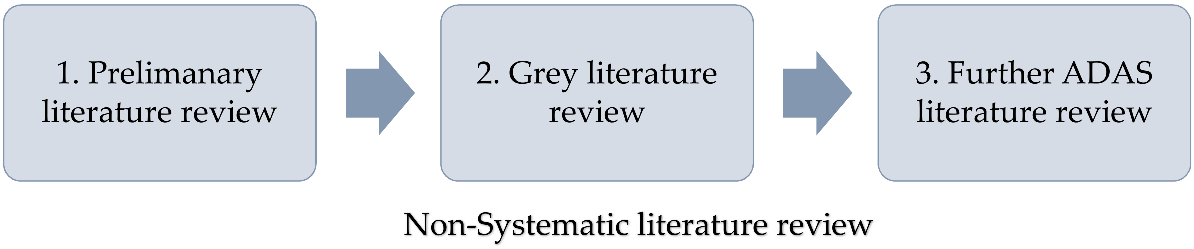

Figure 2.2 Main steps of non-systematic literature review.

A preliminary review was conducted as the first phase to define key definitions and concepts related to Advanced Driver Assistance Systems (ADAS). In order to identify any gaps from a practitioner perspective, this review was supplemented with an examination of the grey literature. The grey literature refers to a diverse and heterogeneous collection of materials that are publicly available but not subjected to traditional academic peer-review processes. Despite its non-academic nature, such material can enhance the relevance and impact of studies (Adams et al., 2017) [14]. The initial search was then expanded through an additional non-systematic literature review, which aided in formulating the research questions and designing the queries for the systematic literature review.

2.1.1. Preliminary literature review

The literature review commenced with an initial set of papers obtained through Scopus by Elsevier, a curated scientific database, using relevant keywords such as "Advanced Driver Assistance Systems," "ADAS," and "Autonomous Driving" The subject areas were limited to "Engineering," "Social Sciences," and "Business, Management and Accounting." From this initial search, a set of articles and papers, chosen based on their citation count (cited highest), was identified and presented in Table below. This step, aligned with the mixed-method approach, helped in understanding and introducing the main concepts related to ADAS. However, two questions arose from this initial review. The first question pertained to the potential gap between academic literature and practitioners' perspectives. To address this, a review of the grey literature was conducted to identify any existing gaps. The second question revolved around the possibility that the initial set of papers might be outdated, as the most recent publication was from not earlier in terms of publishing years. Consequently, a further exploration of ADAS literature from 2011 onwards was carried out.

Is there a gap between academia and practitioners?	Grey literature review
Is the initial set of ADAS related papers outdated?	Further literature review

Table 1- Raised questions during initial of search.

2.1.2. Grey literature review

The grey literature review aimed to examine materials that are publicly available but not subjected to traditional academic peer-review processes. This diverse and heterogeneous body of literature can contribute to the relevance and impact of studies. In the context of Advanced Driver Assistance Systems (ADAS), the grey literature review was conducted to identify any potential gaps between academic literature and the perspectives of practitioners. The search was conducted through the Google search engine, with a "string" composed by two sections as illustrated in Table below.

The search for grey literature involved seeking out sources such as industry reports, technical documents, conference proceedings, government publications, white papers, and other non-peer-reviewed sources. These materials provide valuable insights and perspectives from industry professionals, policymakers, and other stakeholders involved in ADAS.

By conducting a review of the grey literature, researchers aimed to gain a comprehensive understanding of the current state of ADAS research and development, as well as to identify any practical challenges, trends, or innovations that may not be fully captured in academic literature alone. This review can help bridge the gap between academic knowledge and real-world implementation, providing a more holistic view of ADAS and its implications.

First Key Word	AND	Second Key Word
"Social Sustainability" OR "Social Impact"		"ADAS" OR "Autonomous Vehicles" OR "Self-Driving" OR "Autonomous Driving" OR "Machine Learning" OR "Artificial Intelligence" OR "Industry 4.0"

Table 2 – String for the grey literature review.

The queries retrieve and filter and select a number of articles and reports on open platforms like scopus and google, of which around 140 were considered on different types of technologies and directed towards sustainability concepts or similar, relevant to the scope of the dissertation. The main topics covered in the article are

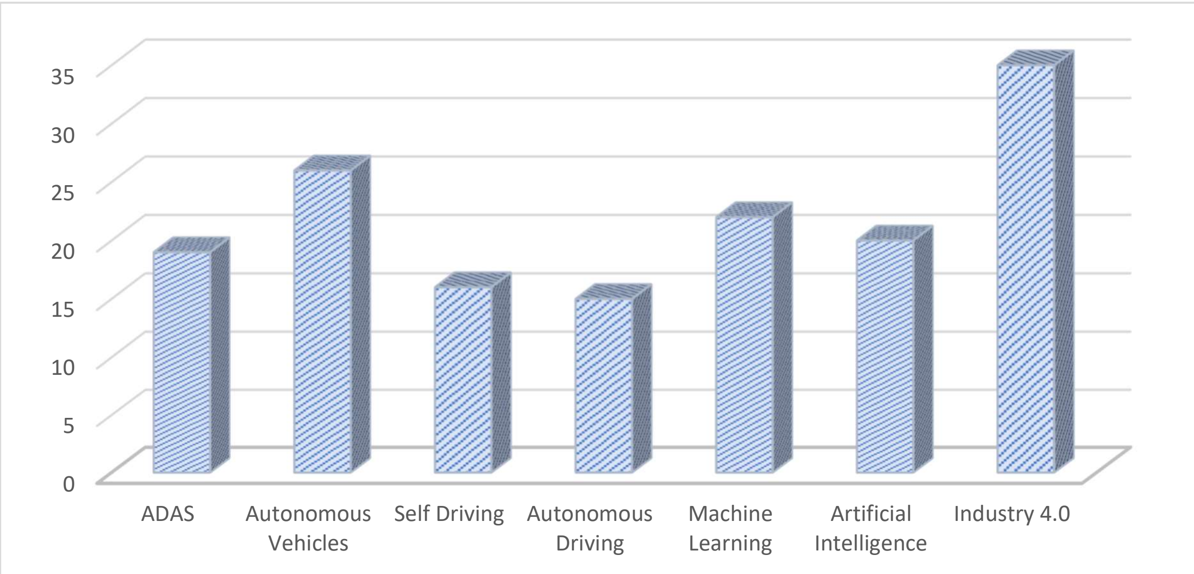

Figure 2.3 – Indication of number of some useful articles.

The analysis of the grey literature for Advanced Driver Assistance Systems (ADAS) uncovered a significant relevance in the ADAS sustainability. It highlighted the growing importance of digital services, particularly in the context of ADAS or AV, where a majority of the articles focused on the development of digital services. However, the investigation did not identify any distinct gaps in relation to the ADAS literature examined during the preliminary review.

2.1.3. Further ADAS literature review

Elsevier and Google Scholar conducted the second step of non-systematic exploration of the literature on both Scopus. The query composition is illustrated in Table#3.

STRING	("Social Sustainability") AND ("ADAS" OR "Autonomous Driving" OR "Self-Driving" OR "Autonomous Driving" OR "Machine Learning" OR "Artificial Intelligence" OR "Industry 4.0" OR "Emerging technologies")
SEARCH WITHIN	Title, abstract, keywords
PUBLICATION YEAR	> 2010
LIMIT TO	Articles

Table 3 - Query for non-systematic literature review.

2.1.4. Key Points from Non-Systematic Literature Review for ADAS deployment:

This subsection examines various concepts related to the widespread deployment of Advanced Driver Assistance Systems (ADAS) as documented in the reviewed studies. Table#4 presents a summary of the benefits, barriers, and concerns associated with ADAS, as well as the opportunities for ADAS deployment discussed in the mentioned studies. The surveys conducted for these studies included questions on the potential advantages of ADAS in terms of safety (reducing accidents), mobility (reducing traffic congestion, travel time, and improving accessibility for elderly and transportation disadvantaged individuals), environmental impact (lower vehicle emissions), cost savings (improved fuel economy), parking convenience (easier and faster parking), emotional well-being (reducing stress during travel), and increased productivity through multitasking with ADAS.

Moreover, the surveys in these studies also inquired about barriers and concerns surrounding the adoption of ADAS, such as equipment and system failures, legal liability, cybersecurity risks (e.g., hacking), privacy concerns related to trip data disclosure, and environmental considerations.

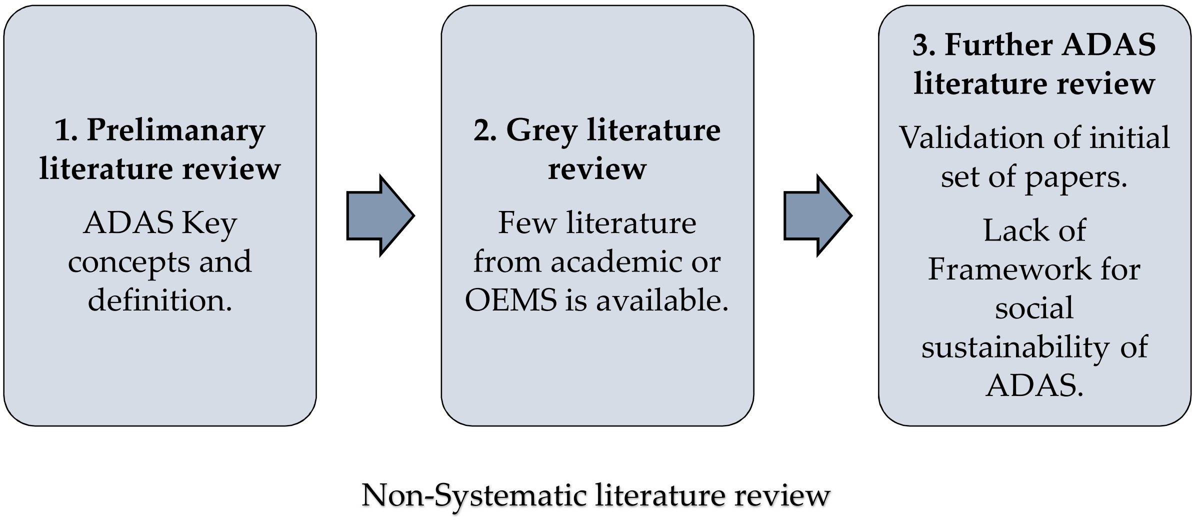

Figure 2.4 Main Results of non-systematic literature review.

Lastly, a few studies identified benefits and opportunities for ADAS deployment and provided policy recommendations are discussed in the table below based on the literature found so far, to show more familiarity towards ADAS and its sustainability.

Study	*Benefits*	*Barriers/Concerns*	*Opportunities*
Casley et al. (2013)	*Increased fuel efficiency*	*Increased cost of the system*	*Increased needs for right-of-way*
	Decreased needs for right-of-way	*Increased safety concerns*	*Reduced travel times leading to social benefits*
	Reduced travel times leading to social benefits	*Legal issues to protect users and civilians*	
Silberg et al. (2013)	*Fewer crashes*	*Data challenges - issues to personal privacy*	*New models for vehicle ownership*
	Reduced needs for new infrastructure		*New business models*
	Shorter travel times		
Begg (2014)	*Reduction of stress levels while traveling*	*Problem of driver 'underload'*	*Improvement of conditions for walking, cycling, and PT*
	Independent mobility for non-drivers	*Liability issues*	*Reduction in parking costs and accidents*
	Reduction in parking costs and accidents	*AVs potentially competing with bus services*	*Energy conservation and emission reductions*
	Energy conservation and emission reductions	*Cybersecurity issues*	
Brown et al. (2014)	*Improvement in safety (reduction in accidents)*	*High cost of the system*	*Lifestyle needs can be met by walking and PT*
	Increased fuel efficiency		
Howard and Dai (2014)	*Increased productivity - multitasking*	*Lack of control*	*Improvement in safety (reduction in accidents)*
	Reduction in time spent finding parking	*Increased ownership or other costs*	*Increased mobility*

	More environmentally friendly	*Issues with equity*	
	Improvement in safety (reduction in accidents)	*Privacy concerns*	
Schoettle and Sivak (2014b)	*Better fuel economy*	*Safety issues due to equipment or system failure*	*Fewer crashes and reduction in severity of crashes*
	Shorter travel times	*Legal liability for drivers/owners*	*Less traffic congestion*
	Fewer crashes and reduction in severity of crashes	*Cybersecurity of vehicles*	*Lower insurance rates*
	Less traffic congestion	*Data privacy (location and destination tracking)*	
Seapine Software (2014)	*Liability issues*	*Cybersecurity*	*Data privacy issues*
Underwood et al. (2014)	*Remove cell restrictions on AVs as an incentive*	*Safety concerns*	*Provide flexibility and incentives of insurance companies*
	Provide incentives to use AVs with automated safety features		*to AV owners*
Abraham et al. (2016)	*Learning strategies for higher adoption rates*		
Bansal et al. (2016)	*Fewer crashes*	*Equipment or system failure*	*Decrease in need for parking in higher rent locations*
	Less traffic congestion	*Legal liability for drivers/owners*	*Lower private vehicle ownership*
	Lower vehicle emissions	*Hacking computer systems of vehicles*	*Better fuel economy*

	Better fuel economy	*Privacy disclosure of travelers*	
Bansal and Kockelman (2016)	*Less traffic congestion*	*Learning curve to use AVs*	*Increased mobility independence*
	Increased mobility independence	*Affordability of AVs*	*Easier*

Table 4 Some basic observations from non-systematic literature review

2.2. Systematic Literature Review:

The non-systematic review of ADAS outlined the key concepts, definitions and significances, including the identification of literature gaps, which led to the formulation of research questions. The following research questions were generated:

Q1 - What are the determining KPI's for social sustainability of ADAS?

Q2 - How can a dashboard can be formed to validate the KPI's for ADAS?

a. How the validation should be carried out?

b. Should we start approaching the experts or conduct surveys or use pre-existing internationally published reports?

c. Which are the pre-requisites, challenges, and barriers?

As the research questions related to the development of dashboard for KPI's of social sustainability, the first approach tried was to define appropriate Social Sustainability keywords and subsequently select technology. We already know that only on the topic, "KPI for social sustainability of ADAS" is very less. Therefore, As the ADAS literature is fragmented in different streams, "Social Sustainability" and "KPI's" were included not to lose any possible valuable contribution, resulting in the following string of keywords:

"Social Sustainability" OR "Key Performance Indicators" OR "Social Impact"

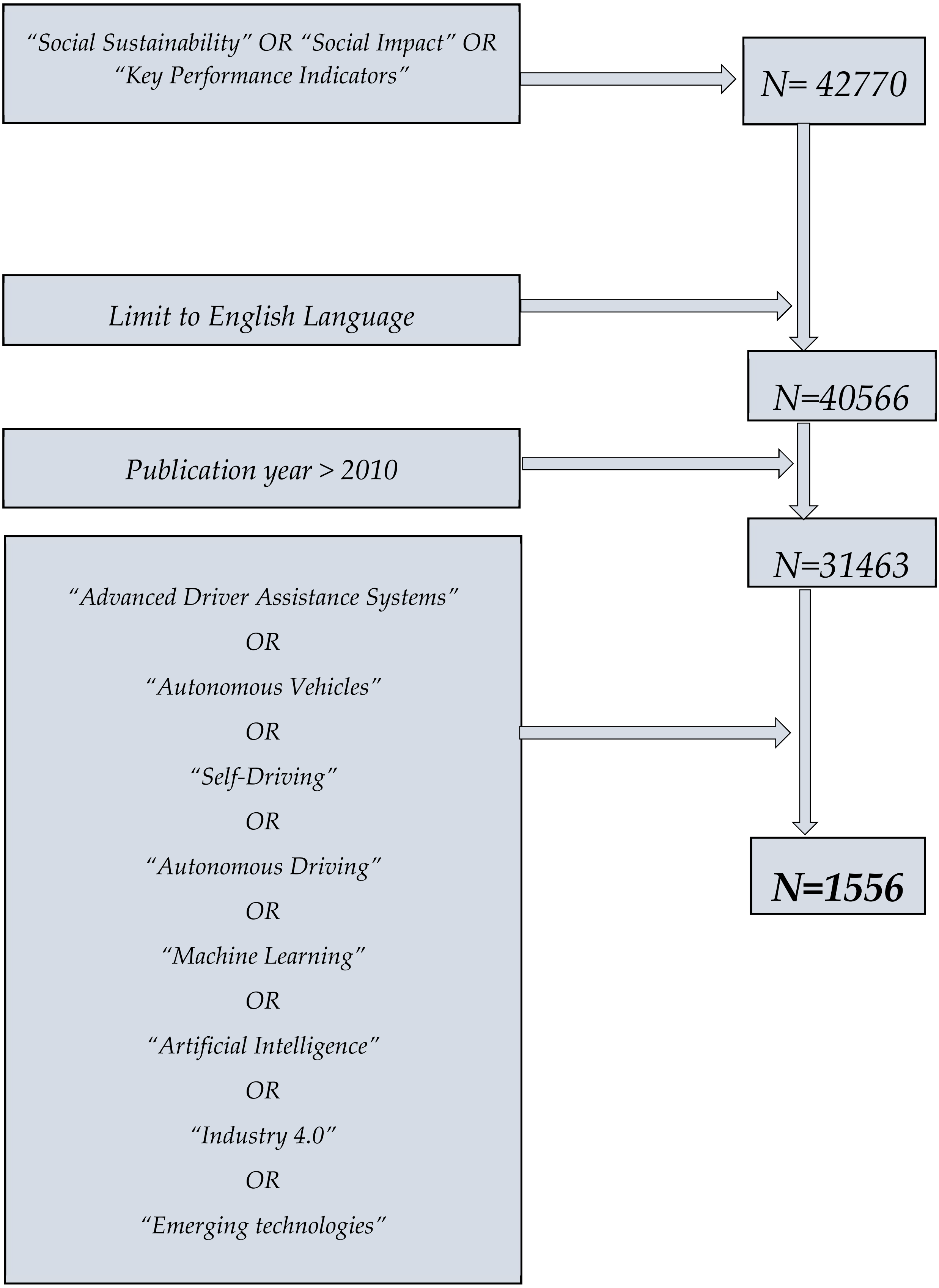

Figure 2.5 First, query for systematic literature review

As shown in Figure#, a preliminary search on Scopus by Elsevier retrieved a very large number of papers, which made unfeasible the manual selection of articles connected to "Social Sustainability". Therefore, the string needed to be complemented with related keywords.

"Social Sustainability" OR "Key Performance Indicators"

Elsevier conducted the search via Scopus on 6 May 2023, and the steps to reach the final set of relevant articles are represented in Figure below.

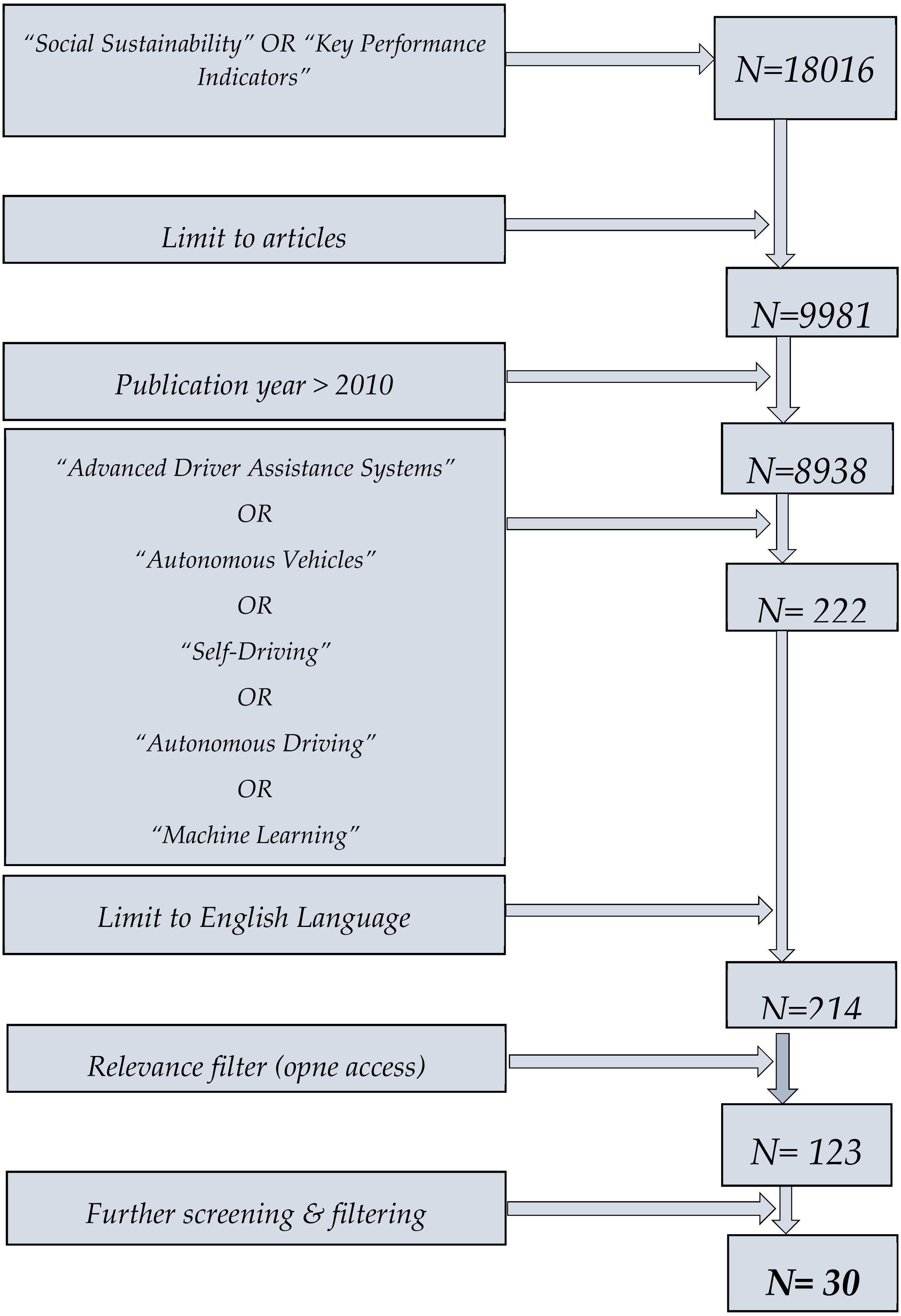

Figure 2.6 Final query for systematic literature review

The search process involved searching for specific keywords in the title, abstract, and keywords of the database. Only articles published from 2011 onwards in the subject areas of "Business, Management and Accounting," "Social Sciences," "Computer Science," and "Engineering," were considered.

After the initial selection, a scan of the title and abstract was performed to exclude articles that were out of scope. The remaining articles underwent a full-text analysis and were further excluded based on specific criteria: if they were deemed out of scope, lacked an English or Italian full-text version, or did not have freely accessible full-text.

The material collection process comprised two steps. Initially, a structured query was used to identify an initial set of papers. The titles and abstracts of these papers were then assessed to determine their relevance to the research area. Subsequently, the full texts of the selected articles were analyzed to further refine the research scope and exclude works that were not closely related to the specific research question. The primary data source for this research was Scopus, an extensive database of peer-reviewed literature.

Formulating an appropriate query was a critical aspect of the first step. The keywords "Social Sustainability", "KPI" and "ADAS" were chosen as they closely aligned with the research topic. Through exploratory research and query experimentation, various keyword variations were identified.

2.3. Literature Review

Here is the list of selected literature after all the filtering and screening processes

S.no	Articles/Papers	ADAS /AV	Social Sustainability	Relevant KPI's
1	*2023 - Fabio Fossa - Ethics of Driving Automation*	*Yes*	*Yes*	*Yes*
2	*Accounting for the Social Dimension of Sustainability Experiences from the Biotechnology Industry*	*No*	*Yes*	*Yes*
3	*Advanced Driver Assistant Systems Focused on Pedestrians' Safety A User Experience Approach*	*Yes*	*Yes*	*No*
4	*Autonomous Driving - Political, Legal, Social, and Sustainability Dimensions*	*Yes*	*Yes*	*Yes*
5	*Country-wise Road Safety Annual Report-2022*	*No*	*Yes*	*Yes*
6	*Impact of Advanced Driver Assistance Systems (ADAS) on Road Safety and Implications for Education, Licensing, Registration, and Enforcement*	*Yes*	*No*	*Yes*
7	*International Road Safety Annual Report*	*No*	*Yes*	*Yes*
8	*KPS-for-Assessing-Impact-CAD_VTT*	*Yes*	*Yes*	*Yes*
9	*National Automated Highway System Consortium Modeling Stakeholder Preferences Project*	*Yes*	*Yes*	*Yes*
10	*Quantifying the Lost Safety Benefits of ADAS Technologies Due to Inadequate Supporting Road Infrastructure*	*Yes*	*Yes*	*No*
11	*Social Sustainability KPIs In Operations Management*	*No*	*Yes*	*Yes*
12	*Sustainability and Industry 4.0 Definition of a Set*	*No*	*Yes*	*Yes*
13	*The development of a basic framework for the sustainability of residential buildings in Pakistan*	*No*	*Yes*	*No*

14	*User Preferences in the Design of Advanced Driver Assistance Systems*	*Yes*	*No*	*Yes*
15	*An empirical investigation on consumers' intentions towards autonomous driving*	*Yes*	*Yes*	*Yes*
16	*Sustainability Prospects for Autonomous Vehicles Environmental Social and Urban*	*Yes*	*Yes*	*Yes*
17	*Attitudes and concerns on automated vehicles*	*Yes*	*Yes*	*Yes*
18	*Development and validation of a questionnaire to assess pedestrian receptivity toward fully autonomous vehicles*	*Yes*	*Yes*	*Yes*
19	*What drives people to accept automated vehicles Findings from a field experiment*	*Yes*	*Yes*	*Yes*
20	*A vision for sustainable mobility through autonomous vehicles in city planning*	*Yes*	*Yes*	*Yes*
21	*What have we learned A review of stated preference and choice studies on autonomous vehicles*	*Yes*	*Yes*	*Yes*
22	*Assessing the Sustainability Implications of Autonomous Vehicles Recommendations for Research Community Practice*	*Yes*	*Yes*	*Yes*
23	*Sustainable Development - 2016 - Strezov - Assessment of the Economic Social and Environmental Dimensions of the*	*No*	*Yes*	*Yes*
24	*A framework to promote social sustainability in industry 4.0*	*No*	*Yes*	*Yes*
25	*Life cycle sustainability assessment A systematic literature review*	*No*	*Yes*	*Yes*
26	*An integrated model for sustainable performance measurement in supply chain*	*No*	*Yes*	*Yes*
27	*Factors influencing the integration of sustainability indicators into a company's performance management system*	*No*	*Yes*	*Yes*

28	*Performance measurement of sustainable supply chains a review and research questions*	*No*	*Yes*	*Yes*
29	*Modelling Of Social Key Performance Indicators Of Corporate Sustainability Performance*	*No*	*Yes*	*Yes*
30	*Eco innovation measurement A review of firm performance indicators*	*No*	*Yes*	*Yes*
31	*Indicators Of Sustainable Development For Industry*	*No*	*Yes*	*Yes*
32	*Insertion of sustainability performance indicators in an industry 4.0 virtual learning environment*	*No*	*Yes*	*Yes*
34	*Underwriting, legal and ethics protocols for future ADAS development (initial version)*	*Yes*	*No*	*Yes*
35	*Autonomous automobilities The social impacts of driverless vehicles*	*No*	*Yes*	*Yes*

Table 5 Literature Review

3 Model Development

The prime objective of this section is to develop and validate a questionnaire for understanding of social sustainability of Advanced Driver Assistance Systems (ADAS). The questions are specifically designed to identify the factors that influence the most in acceptance of ADAS, particularly in context of social sustainability. The safety subscale included survey items that assessed participants' perception of whether the presence of ADAS contributes to a safer traffic environment and the necessary conditions for effective integration of ADAS into the existing traffic environment. I have tried to sum up the complete procedure under separate headings for better understanding.

3.1. The Objectives:

Clearly established the objectives of the survey and determined the specific information to gather and analyze regarding the social sustainability of ADAS.

3.2. The Questionnaires:

Used the list of 50 *Yes or No* questions as a starting point and customized the questionnaire to include additional demographic questions such as the interviewee's name, job title, department, and years of experience, added open-ended questions to allow participants to provide detailed comments and insights.

3.3. Identification of Participants:

Compilation of a list of ADAS experts and professionals within the company who possessed the relevant knowledge and experience, reaching out to individuals.

3.4. Scheduling the Interviews:

Contacting the identified participants and scheduled one-on-one interviews to discuss the social sustainability of ADAS, informing them about the purpose of the survey, the estimated time required for the interview, and the mode of the interview (in-person, video call, or phone call).

3.5. The Interviews:

Conducted the interviews and started by introducing explaining the survey's purpose. Asked each *Yes or No* question and recorded the experts' response. Encouraged them to provide detailed explanations, examples in details.

3.6. Maintained Anonymity and Confidentiality:

Assured the participants that their responses would remain confidential and their identities would be anonymized in the final analysis. Created a safe and open environment for participants to express their opinions freely.

3.7. Analyzed the Data:

After completing the interviews, transcribed the recorded responses and organized the data for analysis. Grouped the responses based on each *Yes or No* question based on open-ended comments.

3.8. The Findings:

Summarized the findings of the survey in a comprehensive report. Included an executive summary, an overview of the survey objectives, a description of the methodology, a presentation of the data analysis, and key conclusions. Provided an interpretation of the findings and any recommendations based on the results.

3.9. List of Questions:

Here are the developed questions for the expert interviews based on social factors such as health, safety, employment diversity, social inclusion, traffic etc.

S.No.	Questions
1	*Does the implementation of ADAS contribute to improved road safety?*
2	*Can the widespread adoption of ADAS technology lead to enhanced social benefits?*
3	*Does ADAS technology promote inclusivity and accessibility in transportation?*
4	*Does the use of ADAS contribute to a more efficient and smoother traffic flow?*
5	*Are there measures in place to prevent overreliance or complacency among drivers using ADAS?*
6	*Does ADAS technology affect the required skills and training for drivers?*
7	*Are there potential ethical concerns associated with the use of ADAS in social settings?*
8	*Does the availability of ADAS create a social divide based on affordability?*
9	*Can ADAS contribute to reducing traffic congestion and improving urban mobility?*
10	*Are there potential job opportunities created by the widespread adoption of ADAS technology?*
11	*Does the introduction of ADAS affect the role and responsibilities of professional drivers?*
12	*Are there privacy concerns related to the collection and use of data by ADAS systems?*
13	*Does ADAS technology influence social perception and acceptance of autonomous vehicles?*
14	*Do ADAS systems have potential implications for energy consumption and environmental sustainability?*
15	*Does the use of ADAS affect the safety of vulnerable road users such as pedestrians and cyclists?*

16	*Are there cultural or social barriers that could hinder the adoption of ADAS in certain regions or communities?*
17	*Does ADAS technology cater to the needs and preferences of different demographic groups?*
18	*Are there measures in place to ensure the safety and reliability of ADAS systems?*
19	*Can ADAS contribute to reducing stress and fatigue for drivers, thus improving overall well-being?*
20	*Are there potential negative social consequences associated with heavy reliance on ADAS technology?*
21	*Does ADAS technology effectively adapt to different driving behaviors and styles?*
22	*Do insurance policies and premiums reflect the social implications of ADAS?*
23	*Does the availability of ADAS affect the affordability and accessibility of vehicle ownership?*
24	*Are there legal or regulatory challenges related to the use of ADAS affecting social sustainability?*
25	*Does ADAS technology promote responsible driving behavior and help reduce aggressive driving?*
26	*Can widespread adoption of ADAS have potential economic impacts in various sectors?*
27	*Does ADAS technology contribute to reducing the carbon footprint and environmental impact of transportation?*
28	*Are there social concerns related to the cybersecurity of ADAS systems?*
29	*Does the use of ADAS technology enhance driver comfort and satisfaction?*
30	*Are there measures in place to ensure that ADAS systems do not discriminate against certain individuals or groups?*
31	*Does the integration of ADAS in public transportation systems promote social equity and accessibility?*
32	*Is there a need for increased education and awareness about ADAS technology among the public?*

33	*Can ADAS technology contribute to reducing traffic*
34	*Is there a need for increased education and awareness about ADAS technology among the public?*
35	*Can ADAS technology contribute to reducing traffic-related injuries and fatalities?*
36	*Do ADAS systems have potential implications for emergency response and rescue operations?*
37	*Does the use of ADAS technology improve the overall efficiency and productivity of transportation systems?*
38	*Are there potential social implications of transitioning from traditional vehicles to ADAS-equipped vehicles?*
39	*Does ADAS technology address the unique needs and challenges of different geographical areas, such as rural and urban environments?*
40	*Can ADAS technology affect job opportunities in the transportation industry?*
41	*Does the availability of ADAS affect the behavior and attitudes of other road users?*
42	*Are there potential cultural or social biases embedded in ADAS algorithms or decision-making processes?*
43	*Can ADAS technology contribute to reducing the social costs associated with traffic congestion, such as air and noise pollution?*
44	*Are there potential social implications of sharing ADAS-equipped vehicles or participating in car-sharing programs?*
45	*Does the use of ADAS technology affect social dynamics within communities, such as changes in commuting patterns or travel behaviors?*
46	*Are there social concerns regarding the ownership and control of ADAS technology by specific companies or organizations?*
47	*Does ADAS technology improve transportation options and accessibility for underserved communities?*
48	*Are there measures in place to ensure that ADAS systems are resistant to hacking or malicious attacks?*

49	*Does the use of ADAS technology influence social norms and behaviors related to driving, such as courtesy and respect on the road?*
50	*Are there potential social challenges in integrating ADAS technology with existing transportation infrastructure?*

Table 6 List of questions for the expert interviews

4 Key Performance Indicators (KPI) Analysis: Measuring Success and Progress

4.1. Overview

Key Performance Indicators (KPIs) are essential tools for measuring and evaluating the performance and effectiveness of various systems and initiatives. In the context of ADAS (Advanced Driver Assistance Systems), KPIs provide valuable insights into the impact of these technologies on road safety, operational efficiency, and overall system performance. By setting quantifiable benchmarks and metrics, KPIs enable stakeholders to assess progress, identify areas for improvement, and make data-driven decisions.

However, in addition to technical measurements, it is equally important to consider the social impact of ADAS technologies. Social KPIs provide a broader perspective by assessing the social implications, benefits, and challenges associated with the implementation of ADAS. These indicators help evaluate the impact of ADAS on social sustainability, inclusivity, equity, public perception, and community well-being. [15]

The integration of social KPIs alongside traditional performance metrics enhances the evaluation framework for ADAS technologies. It allows stakeholders to understand the societal consequences of ADAS implementation, ensuring that the advancements in technology align with broader social objectives and aspirations. By considering social KPIs, policymakers, industry experts, and researchers gain valuable insights into the social dimensions of ADAS, enabling them to make informed decisions and shape policies that promote social well-being.[16]

In this section of the report, we delve into the discussion of KPIs and social KPIs for ADAS. We explore the various aspects that can be evaluated through KPIs, including technical performance, road safety, operational efficiency, as well as the social dimensions, such as accessibility, equity, community engagement, and public perception. By examining both traditional KPIs and social KPIs, we gain a comprehensive understanding of the impact of ADAS technologies on multiple levels.

Through a thorough analysis of KPIs and social KPIs, this report aims to contribute to the ongoing dialogue surrounding the responsible and sustainable integration of ADAS into transportation systems. By considering not only the technical performance but also the social implications, we strive for a holistic approach that ensures all members of society realize the benefits of ADAS.

4.2. Selected dimensions for the social sustainability of ADAS

Before delving into the list of Advanced Driver Assistance Systems (ADAS) dimensions and Key Performance Indicators (KPIs), it is important to understand their significance in the automotive industry. ADAS refers to a wide range of technologies designed to enhance vehicle safety, improve driving comfort, and assist drivers in various situations.

These systems employ sensors, cameras, and artificial intelligence algorithms to provide features such as adaptive cruise control, lane keeping assistance, automatic emergency braking, and blind-spot detection. Assessing the effectiveness and performance of ADAS requires the use of specific dimensions and KPIs. These metrics enable manufacturers, regulators, and consumers to evaluate the capabilities, reliability, and overall impact of ADAS technologies. [17]

By analyzing these dimensions and KPIs, stakeholders can make informed decisions about vehicle safety, understand the limitations of these systems, and drive continuous improvements in the development and implementation of ADAS across the automotive industry

4.2.1. Health and Safety

ADAS technologies such as collision warning, autonomous emergency braking, lane departure warning, and blind-spot detection can significantly enhance road safety. By alerting drivers to potential hazards and assisting in avoiding collisions, ADAS can reduce the number of accidents, injuries, and fatalities on the roads. This leads to safer communities and less societal impact from accidents, such as medical costs and emotional trauma. [18]

4.2.2. Traffic Congestion

It is the evaluate the system's impact on reducing traffic congestion and measures the average travel time, average speed, or reduction in traffic incidents during peak hours in areas where a significant number of vehicles are equipped with ADAS.[19]

4.2.3. Driver Comfort and Convenience

It assess user satisfaction with ADAS features related to comfort and convenience, such as automated parking assistance, voice commands, or traffic sign recognition. It is possible to measure customer feedback through surveys or ratings.[20]

4.2.4. Enhanced Accessibility and Inclusion

ADAS features can make driving more accessible and inclusive for individuals with disabilities or limited mobility. Technologies like adaptive cruise control, automated parking assistance, and voice-activated controls can enable a wider range of people to operate vehicles comfortably and independently, promoting mobility and social inclusion. [21]

4.2.5. Job Creation and Skills Development

It assess the impact of ADAS on job creation and skills development within the automotive and related industries. This can be measured by tracking employment rates, skill enhancement programs, and the development of a skilled workforce in the ADAS sector. [21]

4.3. Selected KPIs for the social sustainability of ADAS

Evaluating the social impact of ADAS involves assessing various aspects, such as the reduction of road accidents, the mitigation of injuries and fatalities, the improvement of traffic flow, and the enhancement of overall road user experience. These social KPIs provide valuable insights into the effectiveness of ADAS in achieving their intended goals, fostering positive societal outcomes, and shaping the future of mobility.

4.3.1. Health and Safety

4.3.1.1. Driver Safety

Driver Safety is a Key Performance Indicator (KPI) that measures the effectiveness of Advanced Driver Assistance Systems (ADAS) in ensuring the safety of the driver. The KPI focuses on reducing the risk of accidents, providing real-time alerts, and assisting the driver in avoiding hazardous situations.[19]

4.3.1.2. Personal Data and Information Security

Security is a Key Performance Indicator (KPI) that measures the level of protection provided by ADAS against unauthorized access, theft, and malicious activities. It assesses factors such as the robustness of the ADAS system's cybersecurity measures, encryption techniques, and secure communication protocols. The KPI aims to ensure the integrity and confidentiality of data transmitted within the ADAS system and protect against potential security vulnerabilities.[22]

4.3.1.3. Reduction in Road Accidental Deaths

Reduction in Road Accidental Deaths is a Key Performance Indicator (KPI) that measures the impact of ADAS in reducing the number of fatalities resulting from road accidents. It assesses the decrease in the total number of deaths caused by accidents after the implementation of ADAS technologies. The KPI aims to monitor the effectiveness of ADAS features, such as emergency braking or pedestrian detection, in preventing fatal accidents and promoting road safety.[23]

4.3.2. Traffic Congestion

4.3.2.1. Travel Time Index (TTI)

The Travel Time Index (TTI) is a KPI that measures the average travel time compared to the ideal or free-flow travel time for a specific route or road segment. It provides an indication of the level of congestion and delays experienced by drivers on a particular road.[24]

4.3.2.2. Congestion Duration

Congestion Duration is a KPI that measures the amount of time that traffic flow is significantly impeded due to congestion on a particular road or within a specific area. It provides insights into the duration and severity of congestion events.[25]

4.3.2.3. Congestion Cost Reduction

It focuses on quantifying the reduction in congestion costs associated with the implementation of Advanced Driver Assistance Systems. Congestion costs refer to the economic losses incurred due to traffic congestion, such as increased travel time, fuel consumption, and productivity losses.[25]

4.3.3. Driver Comfort and Convenience

4.3.3.1. User Satisfaction/Quality of Driving

User satisfaction is a key performance indicator (KPI) that measures the level of contentment or fulfillment experienced by users of an Advanced Driver Assistance System (ADAS). It gauges the overall satisfaction of users with the system's performance, features, ease of use, and effectiveness in enhancing their driving experience and safety.[15]

4.3.3.2. Reduction in Human Error

This KPI measures the extent to which ADAS effectively minimizes or eliminates human errors while driving. It quantifies the reduction in errors such as improper lane changes, failure to maintain a safe following distance, overlooking traffic signs, or other common mistakes that can lead to accidents. A lower value indicates a more successful reduction in human errors.[26]

4.3.3.3. Driver Workload Reduction

This KPI evaluates the degree to which the ADAS effectively reduces the cognitive and physical workload on the driver. It measures factors such as the system's ability to automate certain driving tasks, provide real-time alerts and warnings, and assist in managing complex driving situations. A higher value indicates a greater reduction in driver workload, enabling them to focus on other critical aspects of driving.[27]

4.3.4. Enhanced Accessibility and Inclusion

4.3.4.1. Driver Assistance System Utilization

This KPI tracks the extent to which drivers engage and utilize the features and functions of the ADAS. It measures the frequency and duration of system activation, usage of specific assistance features (e.g., adaptive cruise control, lane keeping assist), and the overall adoption of the ADAS technology by drivers. A higher utilization rate indicates greater acceptance and reliance on the system.[28]

4.3.4.2. Independent Mobility

This KPI evaluates the degree to which accessible vehicle design and transportation solutions enable individuals with disabilities to achieve independent mobility. It measures the ability of individuals with disabilities to travel, commute, and participate in various activities without relying heavily on assistance or support from others. A higher value indicates increased independence and autonomy in mobility for individuals with disabilities.[29]

4.3.4.3. Diversity and Community engagement

This KPI assesses the level of engagement and involvement of diverse communities. It measures the degree of inclusivity, representation, and active participation of diverse stakeholders in shaping policies, programs, and initiatives related to accessible transportation. A higher value indicates a more inclusive and community-centered approach to accessible transportation design and implementation.

4.3.5. Job Creation and Skills Development

4.3.5.1. Employment Rate

The employment rate KPI measures the percentage of individuals employed in the design, development, manufacturing, installation, maintenance, and support of ADAS technology and related systems. It reflects the level of job opportunities and workforce engagement specifically in the ADAS industry. A higher employment rate indicates a growing industry with increased demand for skilled professionals in various ADAS-related roles.[11]

4.3.5.2. Collaboration with Educational Institutions

This KPI evaluates the level of collaboration and partnership between ADAS industry stakeholders and educational institutions, such as universities, colleges, technical schools. A higher value indicates a strong partnership that enhances the alignment of educational offerings with the skills and knowledge needed in the ADAS industry, fostering a pipeline of skilled professionals.[16]

4.3.5.3. Technological Skills Acquisition

This KPI measures the acquisition and proficiency of technological skills specifically relevant to ADAS among professionals in the industry. It assesses the level of expertise and competence in utilizing ADAS technologies, understanding their underlying principles, and adapting to advancements in the field. A higher value indicates a workforce equipped with the necessary technical skills to effectively develop, implement, and maintain ADAS systems and components.[30]

Here is a table describing the measurement method and unit of measurement for selected KPI.

KPI	Measurement Method/Formulae	Unit of Measurement
Driver Safety	*Number of accidents per million miles driven* [31]	*(accidents/million miles)*
Personal Data and Information Security	*Compliance rate with data protection regulations*[32]	*(percentage)*
Reduction in Road Accidental Deaths	*Number of road accident fatalities per year* [33]	*(number of fatalities)*
Travel Time Index (TTI)	*Average travel time during peak hours (TT_peak) / Average travel time during free-flow conditions (TT_free)* [34]	*(dimensionless)*
Congestion Duration	*Total time spent in congestion per unit of time* [34]	*(time units)*
Congestion Cost Reduction	*Reduction in economic costs due to congestion* [35]	*(currency units)*
User Satisfaction/Quality of Driving	*User satisfaction rating* [36]	*(rating scale)*
Reduction in Human Error	*Number of incidents attributable to human error* [37]	*(number of incidents)*
Driver Workload Reduction	*Reduction in driver workload* [38]	*(dimensionless)*
Driver Assistance System Utilization	*Percentage of time or distance covered with the assistance system engaged* [39]	*(percentage)*
Independent Mobility	*Percentage of population with access to independent mobility* [40]	*(percentage)*
Diversity and Community Engagement	*Number of community engagement activities conducted* [41]	*(number of activities)*

Employment Rate	*Employment rate percentage* [42]	*(percentage)*
Collaboration with Educational Institutions	*Number of collaborations with educational institutions* [43]	*(number of collaborations)*
Technological Skills Acquisition	*Number of employees trained in technological skills* [42]	*(number of employees)*

4.4. Performance Measurement Framework for Social KPI's of ADAS:

Now, we shall adapt an approach from "Designing Performance Measures: A Structured Approach" which is a book written by Andy Neely, a prominent scholar and expert in the field of performance measurement and management. The book offers a structured and systematic approach to designing performance measures that align with organizational goals and strategies.

Neely's approach emphasizes the importance of developing a comprehensive performance measurement framework that takes into account the various aspects of an organization, including its objectives, stakeholders, and performance drivers. The book guides readers through a systematic process of defining performance measures, selecting appropriate metrics, and establishing targets and benchmarks.

One of the key strengths of Neely's approach is its focus on the link between performance measures and organizational strategy. The approach highlights the need for performance measures to be directly aligned with strategic objectives, ensuring that they provide meaningful insights and drive performance improvement.[44]

Furthermore, it emphasizes the importance of a balanced set of performance measures, encompassing financial and non-financial aspects, as well as leading and lagging indicators. Neely provides practical guidance on selecting and designing measures that capture both short-term operational performance and long-term strategic outcomes.

Throughout the book, Neely's draws on real-world examples and case studies to illustrate the application of his structured approach. He also addresses common challenges and pitfalls in performance measurement design and provides recommendations for overcoming them.

"Designing Performance Measures: A Structured Approach" is a valuable resource for professionals involved in performance measurement and management, including managers, executives, consultants, and researchers. It offers a systematic and practical framework for designing performance measures that enable organizations to monitor progress, make informed decisions, and drive continuous improvement.

There are many characteristics displayed in the literature by the various performance measures but we manage to shorten the list and select only the important and relevant for the ADAS KPI's. Four of them listed below:

4.4.1. Comprehensibility:

Ease of understanding the indicator by those who need to use it or by those who are evaluated on that performance dimension.

4.4.2. Measurability:

Ease and cost of obtaining and processing data for measurement.

4.4.3. Significance:

Impact on the critical success factors of the process.

4.4.4. Structuring:

Degree of discretion (objectivity) in the measurement

The reference for this performance measuring tools is **"Laboratori'/o di Analisi e Modellizzazione dei Processi",** which is a simplified version of the world renowned framework by **Neely et al. (1997)** [44]

While considering the importance of this approach, I came across some interview of experts and engineers in the company I am performing my internship, which is a well known and leader in the automobile manufacturing company for heavy medium vehicles. I asked them some questions regarding the KPI dashboard for the evaluation of their effectiveness.

DIMENSIONS	KPI	Measurability	Significance	Comprehensibility	Structuring
Health and Safety	Driver Safety	X	X	X	
	Personal Data and Information Security	X		X	
	Reduction in Road Accidental Deaths	X	X	X	
Traffic Congestion	Travel Time Index (TTI)		X		X
	Congestion Duration	X	X	X	
	Congestion Cost Reduction	X	X	X	
Driver Comfort and Convenience	Reduction in Human Error	X	X		X
	Driver Workload Reduction		X	X	
	User Satisfaction/Quality of Driving	X		X	

DIMENSIONS	KPI	Measurability	Significance	Comprehensibility	Structuring
Enhanced Accessibility and Inclusion	Driver Assistance System Utilization	X		X	X
	Independent Mobility	X	X	X	
	Diversity and Community engagement		X		X
Job Creation and Skills Development	Employment Rate	X	X	X	
	Collaboration with Educational Institutions	X		X	X
	Technological Skills Acquisition	X	X		X

Table 7 Performance measurement analysis for selected Dimensions and KPIs

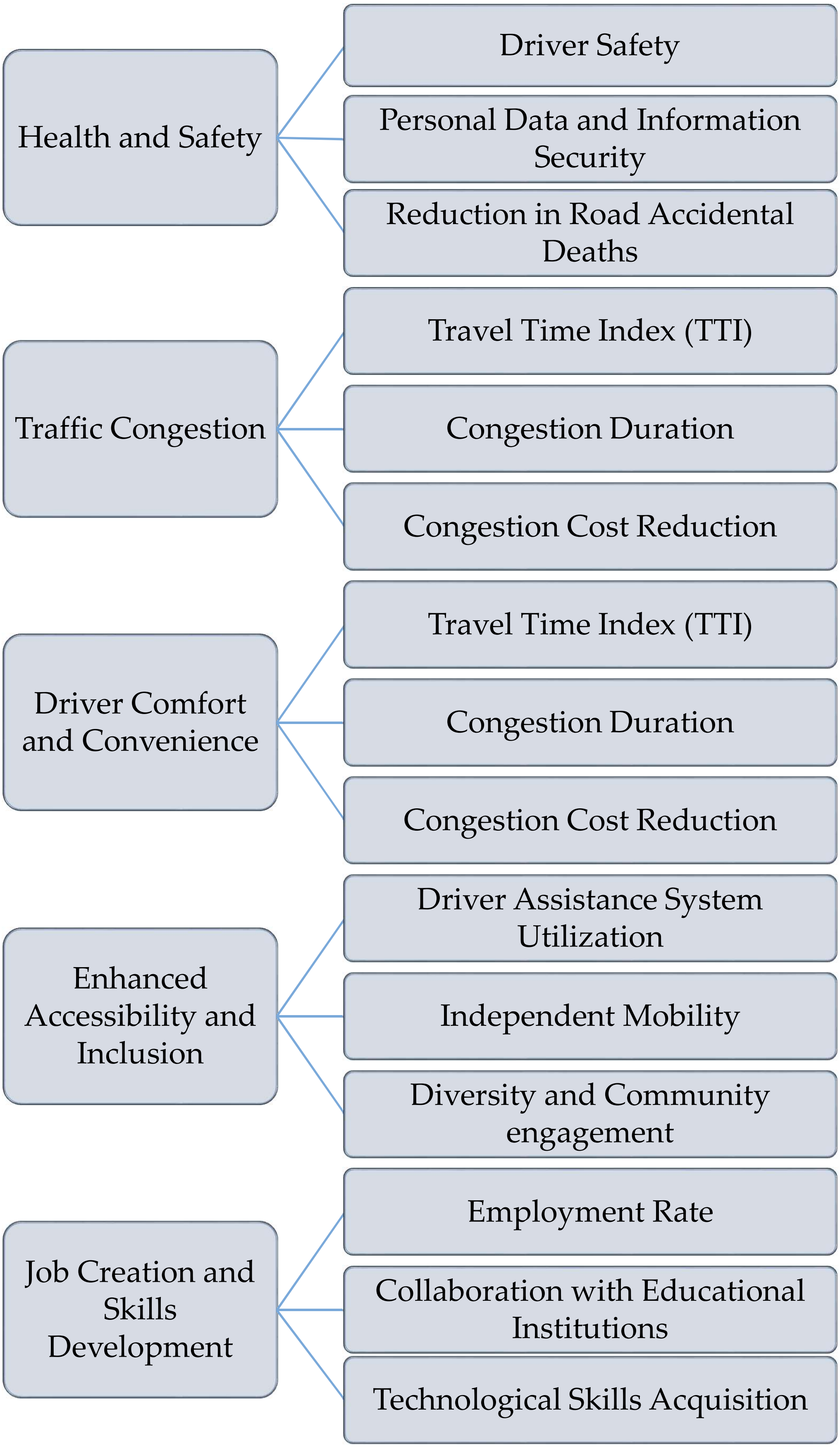

Figure 4.1 Classification of chosen KPIs

5 Exploring Insights: Questionnaires and Experts' Views

As discussed before, in order to gain comprehensive insights into the key performance indicators (KPIs) of Advanced Driver Assistance Systems (ADAS), as well as understand the viewpoints of industry experts, a combination of questionnaires and expert interviews was conducted. This section delves into the methodology employed to explore the KPIs of ADAS and presents the valuable perspectives shared by experts in the field.

Through a meticulously designed questionnaire, participants were invited to share their knowledge and experiences regarding the evaluation and assessment of ADAS technologies. The questionnaire aimed to capture a broad range of viewpoints, covering aspects such as the importance of KPIs, specific metrics used in ADAS evaluation, and challenges faced in measuring the performance of these systems.

To further enrich our understanding, expert interviews from my internship company which is one the biggest name among Medium and Heavy vehicles manufacturer in the world, were conducted with renowned professionals who possess extensive expertise in ADAS development, safety regulations, and related fields. These interviews provided an opportunity to delve deeper into the intricacies of ADAS KPIs, drawing upon the practical experiences and valuable insights of industry leaders.

By employing both questionnaires and expert interviews, this study ensures a holistic approach towards exploring the KPIs of ADAS. The combined perspectives obtained from industry professionals and the broader participant pool offer a comprehensive and well-rounded understanding of the evaluation criteria that shape the development and assessment of ADAS technologies.

In the following sections, we will present and analyze the findings from the questionnaires and expert interviews, highlighting the key KPIs identified and the expert viewpoints that shed light on their significance. The insights gained from this research endeavor contribute to the broader understanding of ADAS technology and pave the way for advancements in safety, reliability, and functionality in the automotive industry.

Overall, this section serves as a vital resource for researchers, automotive manufacturers, regulatory bodies, and anyone interested in the evaluation and optimization of ADAS technologies. Through the collective expertise and perspectives shared, it offers valuable guidance in shaping the future of ADAS and driving innovation towards safer and more efficient transportation systems.

5.1. Responds to the Quesionaires

Here, I want to discuss the answers to developed questionaires recorded from some expert interviews:

S.No.	**Questions**	**Expert 1**	**Expert 2**	**Expert 3**
1	*Does the implementation of ADAS contribute to improved road safety?*	*Y*	*Y*	*Y*
2	*Can the widespread adoption of ADAS technology lead to enhanced social benefits?*	*Y*	*Y*	*Y*
3	*Does ADAS technology promote inclusivity and accessibility in transportation?*	*N*	*N*	*N*
4	*Does the use of ADAS contribute to a more efficient and smoother traffic flow?*	*N*	*N*	*Y*
5	*Are there measures in place to prevent overreliance or complacency among drivers using ADAS?*	*Y*	*N*	*Y*
6	*Does ADAS technology affect the required skills and training for drivers?*	*N*	*Y*	*Y*
7	*Are there potential ethical concerns associated with the use of ADAS in social settings?*	*Y*	*Y*	*Y*
8	*Does the availability of ADAS create a social divide based on affordability?*	*N*	*N*	*N*
9	*Can ADAS contribute to reducing traffic congestion and improving urban mobility?*	*N*	*N*	*Y*
10	*Are there potential job opportunities created by the widespread adoption of ADAS technology?*	*Y*	*Y*	*Y*
11	*Does the introduction of ADAS affect the role and responsibilities of professional drivers?*	*N*	*N*	*N*
12	*Are there privacy concerns related to the collection and use of data by ADAS systems?*	*Y*	*Y*	*N*
13	*Does ADAS technology influence social perception and acceptance of autonomous vehicles?*	*Y*	*Y*	*Y*

14	*Do ADAS systems have potential implications for energy consumption and environmental sustainability?*	*Y*	*N*	*Y*
15	*Does the use of ADAS affect the safety of vulnerable road users such as pedestrians and cyclists?*	*Y*	*N*	*Y*
16	*Are there cultural or social barriers that could hinder the adoption of ADAS in certain regions or communities?*	*Y*	*Y*	*Y*
17	*Does ADAS technology cater to the needs and preferences of different demographic groups?*	*Y*	*Y*	*Y*
18	*Are there measures in place to ensure the safety and reliability of ADAS systems?*	*Y*	*Y*	*Y*
19	*Can ADAS contribute to reducing stress and fatigue for drivers, thus improving overall well-being?*	*Y*	*Y*	*Y*
20	*Are there potential negative social consequences associated with heavy reliance on ADAS technology?*	*Y*	*Y*	*N*
21	*Does ADAS technology effectively adapt to different driving behaviors and styles?*	*N*	*Y*	*N*
22	*Do insurance policies and premiums reflect the social implications of ADAS?*	*Y*	*Y*	*Y*
23	*Does the availability of ADAS affect the affordability and accessibility of vehicle ownership?*	*Y*	*Y*	*Y*
24	*Are there legal or regulatory challenges related to the use of ADAS affecting social sustainability?*	*Y*	*Y*	*Y*
25	*Does ADAS technology promote responsible driving behavior and help reduce aggressive driving?*	*Y*	*N*	*Y*
26	*Can widespread adoption of ADAS have potential economic impacts in various sectors?*	*Y*	*Y*	*Y*
27	*Does ADAS technology contribute to reducing the carbon footprint and environmental impact of transportation?*	*N*	*Y*	*N*

28	*Are there social concerns related to the cybersecurity of ADAS systems?*	*Y*	*Y*	*Y*
29	*Does the use of ADAS technology enhance driver comfort and satisfaction?*	*Y*	*Y*	*Y*
30	*Are there measures in place to ensure that ADAS systems do not discriminate against certain individuals or groups?*	*N*	*N*	*N*
31	*Does the integration of ADAS in public transportation systems promote social equity and accessibility?*	*N*	*N*	*N*
32	*Is there a need for increased education and awareness about ADAS technology among the public?*	*N*	*N*	*N*
33	*Can ADAS technology contribute to reducing traffic*	*N*	*N*	*N*
34	*Is there a need for increased education and awareness about ADAS technology among the public?*	*Y*	*Y*	*Y*
35	*Can ADAS technology contribute to reducing traffic-related injuries and fatalities?*	*Y*	*Y*	*N*
36	*Do ADAS systems have potential implications for emergency response and rescue operations?*	*Y*	*Y*	*Y*
37	*Does the use of ADAS technology improve the overall efficiency and productivity of transportation systems?*	*N*	*N*	*N*
38	*Are there potential social implications of transitioning from traditional vehicles to ADAS-equipped vehicles?*	*N*	*N*	*N*
39	*Does ADAS technology address the unique needs and challenges of different geographical areas, such as rural and urban environments?*	*N*	*Y*	*N*
40	*Can ADAS technology affect job opportunities in the transportation industry?*	*Y*	*Y*	*Y*
41	*Does the availability of ADAS affect the behavior and attitudes of other road users?*	*N*	*N*	*N*

42	*Are there potential cultural or social biases embedded in ADAS algorithms or decision-making processes?*	*Y*	*Y*	*Y*
43	*Can ADAS technology contribute to reducing the social costs associated with traffic congestion, such as air and noise pollution?*	*N*	*N*	*N*
44	*Are there potential social implications of sharing ADAS-equipped vehicles or participating in car-sharing programs?*	*Y*	*Y*	*Y*
45	*Does the use of ADAS technology affect social dynamics within communities, such as changes in commuting patterns or travel behaviors?*	*N*	*N*	*N*
46	*Are there social concerns regarding the ownership and control of ADAS technology by specific companies or organizations?*	*Y*	*Y*	*Y*
47	*Does ADAS technology improve transportation options and accessibility for underserved communities?*	*Y*	*Y*	*N*
48	*Are there measures in place to ensure that ADAS systems are resistant to hacking or malicious attacks?*	*Y*	*Y*	*Y*
49	*Does the use of ADAS technology influence social norms and behaviors related to driving, such as courtesy and respect on the road?*	*Y*	*N*	*Y*
50	*Are there potential social challenges in integrating ADAS technology with existing transportation infrastructure?*	*Y*	*Y*	*Y*

Table 8 Questionaires with reponses

5.2. Empirical Validation

In this section, a powerful tool for empirical validation of the selected dimensions, named the Analytic Hierarchy Process (AHP) is taken into account to evaluate and prioritize Advanced Driver Assistance Systems (ADAS) effectively. AHP is a theory of measurement through pairwise comparisons and relies on the judgements of experts to derive priority scales. It is these scales that measure intangibles in relative terms, which enables decision-makers to systematically assess various criteria and alternatives, associated with ADAS implementation. Firstly, the decision problem is defined, which could involve selecting the most suitable ADAS technology or prioritizing criteria for ADAS integration.

Next, a hierarchy is established, consisting of the main goal, such as enhancing road safety, criteria such as effectiveness, usability, and compatibility, and alternative ADAS options. Pairwise comparisons are then conducted to determine the relative importance of each criterion, considering factors like performance, user experience, and system compatibility. The judgments are quantified using a numerical scale, and the relative weights of the criteria are calculated based on these comparisons. By aggregating the weighted scores, decision-makers can make informed choices regarding the adoption and implementation of ADAS technologies, considering the overall performance and importance of each criterion. The AHP methodology facilitates a structured and systematic decision-making process, enhancing the evaluation and prioritization of ADAS alternatives for improved road safety and transportation efficiency. [45]

Here are the AHP matrices attempted by our technology experts for the selected dimensions.

5.2.1. From Expert Interview # 1

Input matrix

VS	Health and Safety	Traffic Congestion	Driver Comfort and Convenience	Enhanced Accessibility and Inclusion	Job Creation and Skills Development
Health and Safety	1.00	2.00	3.00	4.00	2.00
Traffic Congestion	0.50	1.00	2.00	3.00	2.00
Driver Comfort and Convenience	0.33	0.50	1.00	3.00	3.00
Enhanced Accessibility and Inclusion	0.25	0.33	0.33	1.00	2.00
Job Creation and Skills Development	0.50	0.50	0.33	0.50	1.00
Totals	2.58	4.33	6.67	11.50	10.00

Normalized matrix

VS	Health and Safety	Traffic Congestion	Driver Comfort and Convenience	Enhanced Accessibility and Inclusion	Job Creation and Skills Development
Health and Safety	0.39	0.46	0.45	0.35	0.20
Traffic Congestion	0.19	0.23	0.30	0.26	0.20
Driver Comfort and Convenience	0.13	0.12	0.15	0.26	0.30
Enhanced Accessibility and Inclusion	0.10	0.08	0.05	0.09	0.20
Job Creation and Skills Development	0.19	0.12	0.05	0.04	0.10
Totals	1.00	1.00	1.00	1.00	1.00

CI	0.09
RI	1.12
CR	0.08

5.2.2. From Expert Interview # 2

Input matrix

VS	Health and Safety	Traffic Congestion	Driver Comfort and Convenience	Enhanced Accessibility and Inclusion	Job Creation and Skills Development
Health and Safety	1.00	2.00	2.00	3.00	2.00
Traffic Congestion	0.50	1.00	2.00	3.00	4.00
Driver Comfort and Convenience	0.50	0.50	1.00	2.00	2.00
Enhanced Accessibility and Inclusion	0.33	0.33	0.50	1.00	3.00
Job Creation and Skills Development	0.50	0.25	0.50	0.33	1.00
Totals	2.83	4.08	6.00	9.33	12.00

Normalized matrix

VS	Health and Safety	Traffic Congestion	Driver Comfort and Convenience	Enhanced Accessibility and Inclusion	Job Creation and Skills Development
Health and Safety	0.35	0.49	0.33	0.32	0.17
Traffic Congestion	0.18	0.24	0.33	0.32	0.33
Driver Comfort and Convenience	0.18	0.12	0.17	0.21	0.17
Enhanced Accessibility and Inclusion	0.12	0.08	0.08	0.11	0.25
Job Creation and Skills Development	0.18	0.06	0.08	0.04	0.08
Totals	1.00	1.00	1.00	1.00	1.00

CI	0.08
RI	1.12
CR	0.07

5.2.3. From Expert Interview # 3

Input matrix

VS	Health and Safety	Traffic Congestion	Driver Comfort and Convenience	Enhanced Accessibility and Inclusion	Job Creation and Skills Development
Health and Safety	1.00	3.00	2.00	3.00	3.00
Traffic Congestion	0.33	1.00	2.00	2.00	2.00
Driver Comfort and Convenience	0.50	0.50	1.00	3.00	2.00
Enhanced Accessibility and Inclusion	0.33	0.50	0.33	1.00	2.00
Job Creation and Skills Development	0.33	0.50	0.50	0.50	1.00
Totals	2.50	5.50	5.83	9.50	10.00

Normalized matrix

VS	Health and Safety	Traffic Congestion	Driver Comfort and Convenience	Enhanced Accessibility and Inclusion	Job Creation and Skills Development
Health and Safety	0.40	0.55	0.34	0.32	0.30
Traffic Congestion	0.13	0.18	0.34	0.21	0.20
Driver Comfort and Convenience	0.20	0.09	0.17	0.32	0.20
Enhanced Accessibility and Inclusion	0.13	0.09	0.06	0.11	0.20
Job Creation and Skills Development	0.13	0.09	0.09	0.05	0.10
Totals	1.00	1.00	1.00	1.00	1.00

CI	0.07
RI	1.12
CR	0.06

6 Discussion

The aim of this project was to create holistic KPIs for social sustainable ADAS systems adapted to automotive industry. Theses KPIs aim to measure and quantify sustainability from social perspective. This study is a consists of my experience of internship with the best known Medium and Heavy vehicles manufacturer on sustainable ADAS systems. The aim of the project is to define a development of methodology as well as creating a data driven study towards sustainability, in which the KPI presented in this study potentially could be integrated. The overall discussion can be summed up under two points; theoretical implications and practical implications.

6.1. Theoretical implications

The literature highlights various dimensions of social sustainability in the context of ADAS, each with its own significance that may vary depending on the specific context. It is essential to consider these dimensions comprehensively to gain a holistic understanding of the social impact of ADAS technologies. Here's a detailed comparison of the different Key Performance Indicators (KPIs) related to Advanced Driver Assistance Systems (ADAS), along with their pros and cons and the appropriate contexts for their use:

6.1.1. Driver Safety

Pro: Measures the effectiveness of ADAS in enhancing driver safety and reducing accidents.

Con: May not capture other aspects of social sustainability beyond safety.

Use: When evaluating the primary goal of improving driver safety and reducing accidents.

6.1.2. Personal Data and Information Security

Pro: Addresses concerns regarding data privacy and security in ADAS systems.

Con: May not directly reflect social sustainability impacts.

Use: When assessing the protection of personal data and addressing privacy concerns.

6.1.3. Reduction in Road Accidental Deaths

Pro: Provides a clear and quantifiable measure of the impact on saving lives.

Con: Focuses primarily on fatal accidents and may overlook non-fatal injuries.

Use: When assessing the success of ADAS in reducing fatalities on the roads.

6.1.4. Travel Time Index (TTI)

Pro: Measures the efficiency of traffic flow and travel times.

Con: Does not capture other aspects of social sustainability beyond congestion.

Use: When evaluating the effectiveness of ADAS in reducing traffic congestion and improving travel times.

6.1.5. Congestion Duration

Pro: Quantifies the duration of traffic congestion and its impact on mobility.

Con: Focuses solely on congestion and may not reflect other social sustainability factors.

Use: When assessing the reduction in congestion duration and its benefits for road users.

6.1.6. Congestion Cost Reduction

Pro: Captures the economic impact of reducing traffic congestion.

Con: Does not consider other social sustainability dimensions beyond economic factors.

Use: When evaluating the economic benefits of ADAS in reducing congestion costs.

6.1.7. Reduction in Human Error

Pro: Addresses a significant cause of accidents and injuries on the roads.

Con: May not account for external factors and system limitations.

Use: When assessing the effectiveness of ADAS in mitigating human error and improving road safety.

6.1.8. Driver Workload Reduction

Pro: Focuses on improving driver comfort and reducindg fatigue.

Con: May not capture other aspects of social sustainability beyond driver workload.

Use: When evaluating the impact of ADAS on reducing driver workload and improving driving experience.

6.1.9. User Satisfaction/Quality of Driving

Pro: Reflects user acceptance and the overall quality of driving experience.

Con: Subjective and may vary across different user groups.

Use: When assessing the user satisfaction and market viability of ADAS technologies.

6.1.10. Driver Assistance System Utilization

Pro: Measures the adoption and utilization of driver assistance systems.

Con: Does not directly reflect social sustainability impacts.

Use: When evaluating the effectiveness of ADAS technologies and their integration into driving practices.

6.1.11. Independent Mobility

Pro: Measures the extent to which ADAS enables individuals to have independent mobility, particularly for those with mobility limitations.

Con: May not be directly applicable to all contexts and populations.

Use: When evaluating the impact of ADAS on promoting independent mobility and accessibility for all individuals.

6.1.12. Diversity and Community Engagement

Pro: Assesses the extent to which ADAS technologies consider diverse user needs and engage with local communities.

Con: May be challenging to quantify and measure objectively.

Use: When evaluating the inclusivity and community-centric approach of ADAS implementation.

6.1.13. Employment Rate

Pro: Measures the impact of ADAS on job creation and employment opportunities.

Con: May not capture other dimensions of social sustainability beyond employment.

Use: When assessing the contribution of ADAS technologies to local economies and job markets.

6.1.14. Collaboration with Educational Institutions

Pro: Evaluates the extent of collaboration between ADAS industry stakeholders and educational institutions to promote research, training, and skill development.

Con: May not directly reflect the social sustainability impact but supports future workforce development.

Use: When assessing the efforts of the ADAS industry in fostering educational partnerships and skill acquisition.

6.1.15. Technological Skills Acquisition

Pro: Measures the acquisition and development of technological skills by individuals through ADAS usage.

Con: May require subjective self-assessment or surveys for measurement.

Use: When evaluating the impact of ADAS on enhancing technological literacy and skill acquisition.

6.2. Practical implications

To compare the comments provided with practical and expert opinions, it would be necessary to conduct further research and consult relevant studies, reports, and expert opinions in the field of ADAS and social sustainability. However, based on the information provided, we can make some general observations:

6.2.1. Driver Safety

Expert remarks reflect the common understanding that driver safety is a crucial aspect of ADAS evaluation. Practical studies and expert opinions also emphasize the importance of measuring the effectiveness of ADAS in enhancing safety and reducing accidents.

6.2.2. Personal Data and Information Security

Expert remarks highlight the growing concern regarding data privacy and security in ADAS systems. Practical considerations and expert opinions often emphasize the need to address data security issues to build trust and ensure social sustainability in ADAS implementation.

6.2.3. Reduction in Road Accidental Death

Their comments emphasize the significance of measuring the reduction in fatal accidents as a key indicator of ADAS effectiveness. This aligns with expert opinions and studies that often focus on reducing fatalities as a primary goal of ADAS technologies.

6.2.4. Travel Time Index (TTI)

The interviews recognize that TTI provides a measure of traffic flow efficiency but may not capture broader social sustainability aspects. Practical evaluations often include TTI as a performance indicator to assess the impact of ADAS on reducing traffic congestion and improving travel times.

6.2.5. Congestion Duration

Expert remarks acknowledge that congestion duration is an important metric for understanding the impact of ADAS on mobility. Practical studies also consider congestion duration as a key factor in assessing the benefits of ADAS technologies in reducing traffic congestion.

6.2.6. Congestion Cost Reduction

The comment highlights the economic perspective of ADAS in reducing congestion costs. Practical evaluations often incorporate the economic benefits of ADAS in terms of reduced fuel consumption, lower maintenance costs, and improved productivity due to reduced congestion.

6.2.7. Reduction in Human Error

Expert remarks acknowledges the significance of addressing human error as a leading cause of accidents. Practical evaluations often emphasize the importance of ADAS in mitigating human error through features like lane departure warning, forward collision warning, and automatic emergency braking.

6.2.8. Driver Workload Reduction

The comment recognizes the importance of improving driver comfort and reducing fatigue. Practical studies highlight that ADAS technologies can alleviate driver workload by assisting with tasks such as lane-keeping, adaptive cruise control, and parking assistance.

6.2.9. User Satisfaction/Quality of Driving

Expert remarks highlights the subjective nature of user satisfaction and the varying perceptions across different user groups. Practical evaluations often incorporate user surveys, feedback, and user experience studies to assess the overall acceptance and perceived quality of driving with ADAS technologies.

6.2.10. Driver Assistance System Utilization

The comment acknowledges the significance of measuring the adoption and utilization of ADAS systems. Practical evaluations often focus on monitoring the extent to which drivers engage and effectively use the available ADAS features, ensuring that the technology is being utilized as intended.

6.2.11. Independent Mobility

The comment recognizes the importance of assessing the impact of ADAS on promoting independent mobility, especially for individuals with mobility limitations. Practical considerations often include evaluating the accessibility and inclusivity aspects of ADAS technologies to ensure they cater to diverse user needs.

6.2.12. Diversity and Community Engagement

The interviews emphasizes the need for ADAS technologies to consider diverse user needs and engage with local communities. Practical evaluations often consider stakeholder engagement, inclusivity in design and development, and community-based pilot projects to ensure ADAS technologies align with social sustainability goals.

6.2.13. Employment Rate

The comment highlights the impact of ADAS on job creation and employment opportunities. Practical evaluations often assess the direct and indirect employment effects of ADAS technologies, including the manufacturing, installation, maintenance, and support services associated with these systems.

6.2.14. Collaboration with Educational Institutions

The comment recognizes the importance of collaboration between ADAS industry stakeholders and educational institutions. Practical considerations often involve partnerships with universities and vocational training centers to promote research, develop relevant curriculum, and provide training programs that enhance technological skills in the field of ADAS.

6.2.15. Technological Skills Acquisition

The interviews acknowledges the significance of measuring the acquisition and development of technological skills through ADAS usage. Practical evaluations may involve assessments of training programs, skill enhancement initiatives, and surveys to understand the impact of ADAS on improving technological literacy and skill acquisition.

7 Conclusions

7.1. Key Findings: Assessing the Social Sustainability of ADAS through KPIs

The primary barriers to widespread adoption of ADAS may not be technological but psychological and societal, as highlighted by the experts and assessment of developed KPIs. It is important to understand the factors influencing people's interest and benefits of ADAS. However, relying solely on online or paper-based surveys with participants who have little or no experience with ADAS has been criticized as limited. To address this gap, a field study was conducted with experts who directly involved in the industry to examine the impact of direct experience with ADAS at social level.

For this study, a methodology has been developed to create and assess the KPIs for social sustainability based on experts remarks. A number of attempts for the search of useful literature have been made which results in systematic and non-systematic literature reviews. From non-systematic approach helps in to acquire useful definitions and significances related to ADAS while systematic literature review gives strong foundation for the development of required methodology and consequently the KPIs for social sustainability. These findings provide valuable insights for the design and promotion of socially sustainable ADAS technologies. They emphasize the importance of direct experience in shaping individuals' trust, safety and benefits, ultimately influencing their acceptance and intention to use ADAS. By understanding and addressing these factors, stakeholders can effectively design ADAS systems and strategies that enhance social sustainability and foster wider acceptance and adoption of these technologies.

It is clear from our research that we are entering another age of great creativity and innovation for the automotive industry. A time when fundamental change seems possible, even likely. What is less clear is whether this incredible technology will change the world as decisively in the 21st century as did the automobile in the 20th century. But, we are highly optimistic.

7.2. Limitations and Future Research Directions

The assessment of social sustainability in Advanced Driver Assistance Systems (ADAS) through Key Performance Indicators (KPIs) has several limitations and requires further research to provide a more comprehensive understanding of ADAS social sustainability. Critical examination of these limitations can help identify areas for improvement and guide future research in this field.

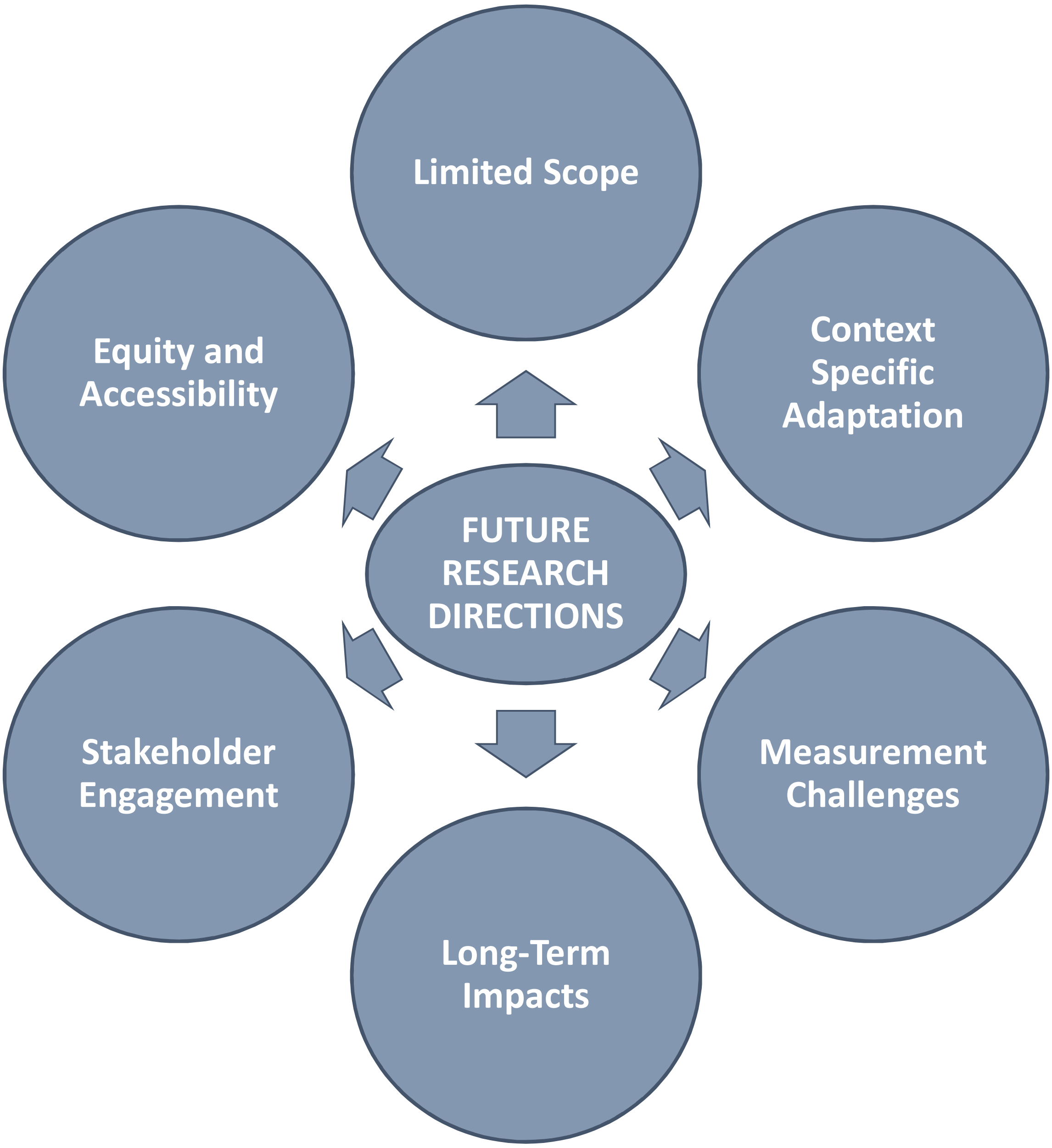

Figure 7.1 Future Research Directions for social sustainability of ADAS

7.2.1. Limited Scope:

The identified KPIs primarily focus on driver safety, congestion reduction, user satisfaction, and employment opportunities, overlooking other crucial dimensions of social sustainability such as environmental impact, social equity, and community resilience. Neglecting these aspects can result in an incomplete assessment of ADAS social sustainability and limit our ability to address broader societal concerns.

7.2.2. Specific Adaptation:

The effectiveness and relevance of KPIs may vary across different regions, cultural contexts, and user groups. Failure to adapt KPIs to specific contexts may lead to skewed assessments and hinder the accurate evaluation of ADAS social sustainability outcomes. Future research should emphasize context-specific adaptations to ensure the applicability and reliability of KPIs in diverse settings.

7.2.3. Measurement Challenges:

Some KPIs, such as user satisfaction or diversity and community engagement, rely on subjective assessments or qualitative data, introducing measurement biases and limitations. Subjective measures can be influenced by individual perceptions and preferences, hindering the objectivity of social sustainability assessments. Future research should develop robust and objective measurement methodologies to overcome these challenges and enhance the accuracy of ADAS social sustainability evaluations.

7.2.4. Long-Term Impacts:

The long-term effects of ADAS on social sustainability remain understudied. While initial deployment may show positive outcomes, the durability and sustained impact of ADAS technologies over time are not well understood. Future research should investigate the long-term implications of ADAS, considering factors such as system maintenance, technological advancements, and changes in user behavior.

7.2.5. Equity and Accessibility:

ADAS deployment should address social equity concerns and ensure accessibility for all individuals, including those from marginalized communities or with mobility limitations. Failure to prioritize equity and accessibility can exacerbate existing inequalities in transportation systems.

Future research should explore how ADAS can be implemented in a way that reduces disparities and promotes equal access to benefits.

7.2.6. Stakeholder Engagement:

Involving relevant stakeholders, such as policymakers, industry representatives, and user communities, is critical for assessing and improving the social sustainability of ADAS. Neglecting stakeholder engagement can result in a limited understanding of societal needs and preferences, hindering the development of effective ADAS strategies. Future research should prioritize participatory approaches that incorporate stakeholder perspectives into the evaluation and decision-making processes.

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A Appendix A

7.3. Road fatalities in the EU and EFTA countries

Here is the list of countries with number of road fatalities [46]

							% change 2021 in relation to		*Updated April 2023*
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2020**	**2019**	**Average 2017-19**
EU-27	**23 800**	**23 400**	**23 300**	**22 800**	**18 800**	**19 900**	6%	-13%	-14%
Belgium	670	609	604	646	499	516	3%	-20%	-17%
Bulgaria	708	682	610	628	463	561	21%	-11%	-12%
Czech Republic	611	577	656	618	518	532	3%	-14%	-14%
Denmark	211	175	171	199	163	130	-20%	-35%	-28%
Germany	3 206	3 180	3 275	3 046	2 719	2 562	-6%	-16%	-19%
Estonia	71	48	67	52	59	55	-7%	6%	-1%
Ireland	182	154	135	140	147	137	-7%	-2%	-4%
Greece	824	731	700	688	584	624	7%	-9%	-12%
Spain	1 810	1 830	1 806	1 755	1 370	1 533	12%	-13%	-15%
France	3 471	3 444	3 246	3 237	2 538	2 931	15%	-9%	-11%
Croatia	307	331	317	297	237	292	23%	-2%	-7%
Italy	3 283	3 378	3 334	3 173	2 395	2 875	20%	-9%	-13%
Cyprus	46	53	49	52	48	45	-6%	-13%	-12%
Latvia	158	136	148	132	139	147	6%	11%	6%
Lithuania	192	191	173	186	175	148	-15%	-20%	-19%
Luxembourg	32	25	36	22	26	24	-8%	9%	-13%
Hungary	607	625	633	602	460	544	18%	-10%	-12%
Malta	23	19	18	16	11	9	-18%	-44%	-49%
Netherlands	533	535	598	586	515	509	-1%	-13%	-11%
Austria	432	414	409	416	344	362	5%	-13%	-12%

Poland	3 026	2 831	2 862	2 909	2 491	2 245	-10%	-23%	-22%
Portugal	563	602	700	688	536	561	5%	-18%	-15%
Romania	1 915	1 951	1 867	1 864	1 644	1 779	8%	-5%	-6%
Slovenia	130	104	91	102	80	114	43%	12%	15%
Slovakia	275	276	260	270	247	247	0%	-9%	-8%
Finland	258	238	239	211	223	225	1%	7%	-2%
Sweden	270	253	324	221	204	210	3%	-5%	-21%
Switzerland	216	230	233	187	227	200	-12%	7%	-8%
Norway	135	106	108	108	93	80	-14%	-26%	-25%
Iceland	18	16	18	6	8	9	13%	50%	-33%
Liechtenstein	0	2	0	0	1	0	n/a	n/a	n/a

Table 9 Number of road fatalities in the EU and EFTA countries [33]

B Appendix B

Here, we have some statistical data regarding the road traffic fatalities in EU in 2021 to understand importance of the public health and safety at societal level.[47]

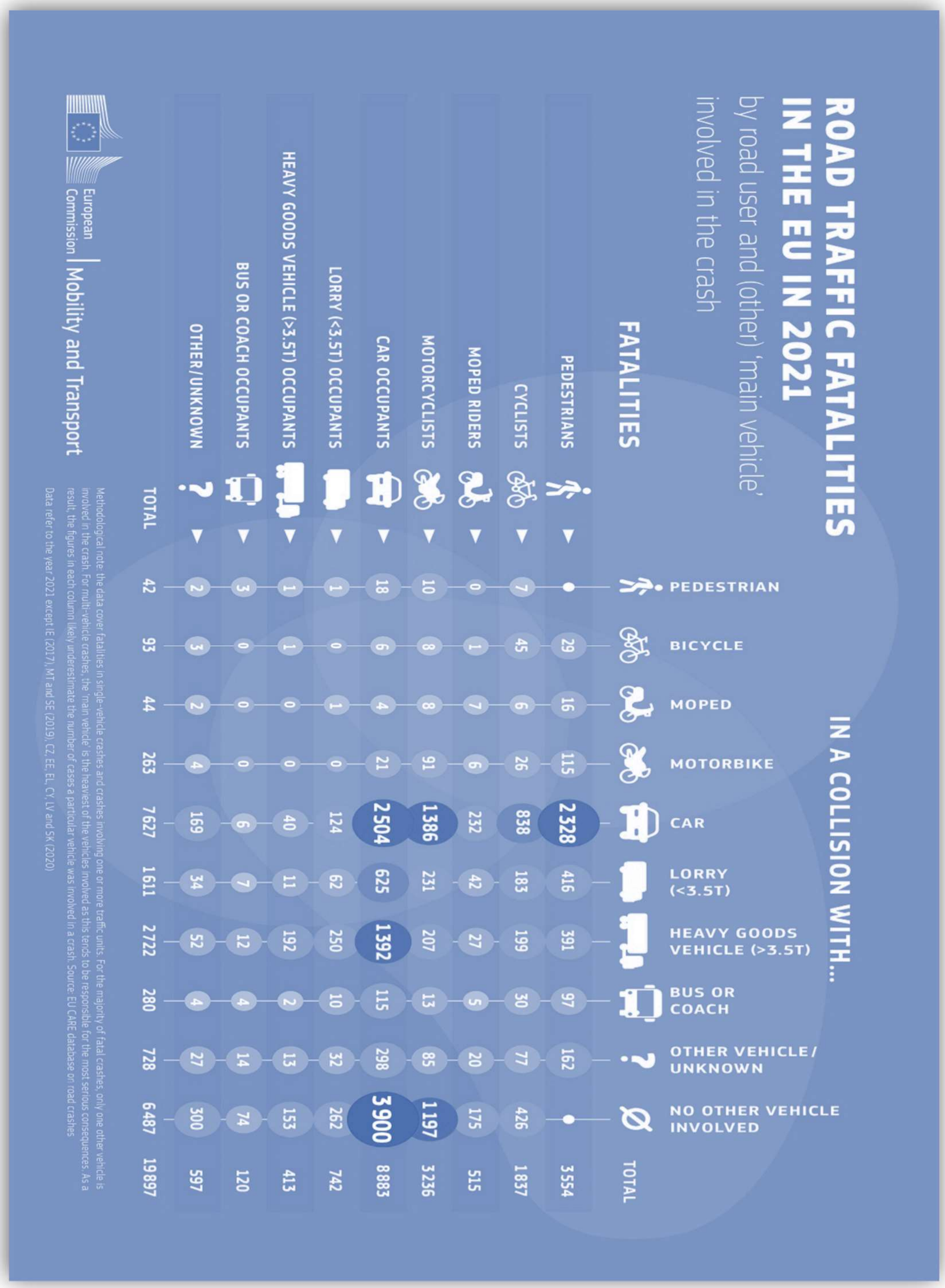

Figure B.1 Collision matrix (all roads)

C Appendix C

Here I would like to enlist ADAS technology names with their uses for the readers so that they can have better understanding of this technology, its uses and impact on our society.

ADAS Technology Name	***What it does***
Adaptive Cruise Control	*Controls acceleration and/or braking to maintain a prescribed distance between the vehicle and the one in front. Can come to a stop and continue.*
Adaptive Headlights	*Adapts to changing roadway conditions, such as curves, to better illuminate the road along the driver's path.*
Anti-lock Braking Systems	*Helps prevent wheels from locking up, allowing the driver to steer to safety.*
Automatic Crash Notification	*Detects airbag deployment or sudden deceleration and connects to an emergency operator, providing basic information and location without driver input.*
Automatic Emergency Braking	*Senses slow or stopped traffic ahead and applies the brakes urgently if the driver fails to respond.*
Automatic Emergency Steering	*Detects potential collisions and automatically controls steering to avoid or lessen the severity of impact.*
Automatic High Beams	*Automatically activates or deactivates headlamp beams based on lighting, surroundings, and traffic conditions.*
Automatic Parallel Parking	*Assists in guiding the vehicle into a parallel parking spot after identifying a viable option. Does not monitor surroundings or apply brakes.*
Back Up Warning	*Alerts the driver to objects behind the vehicle while reversing, such as when backing out of driveways or parking spots.*

Back Up Camera	*Displays a wide view behind the vehicle while in reverse, including at night.*
Bicycle Detection	*Alerts the driver of a potential collision with a bicyclist ahead.*
Blind Spot Warning	*Detects vehicles in rear adjacent lanes and alerts the driver to their presence.*
Brake Assist	*Detects aggressive braking and applies maximum force to the brakes to help stop the vehicle as quickly as possible.*
Cruise Control	*Maintains a constant vehicle speed without the need to keep foot on the accelerator pedal.*
Curve Speed Warning	*Uses GPS to warn the driver when approaching a curve or exit on the road too quickly.*
Driver Drowsiness Monitoring Systems	*Alerts the driver if signs of drowsiness are detected and suggests taking a break when safe to do so.*
Driver Monitoring Systems	*Alerts the driver when signs of drowsiness or distraction are detected.*
Dynamic Brake Support and Crash Imminent Braking	*Supplements the driver's braking to avoid a crash. If no action is taken, the system automatically applies the vehicle's brakes to reduce the severity of the crash.*
Dynamic Driving Assistance	*Controls vehicle acceleration, braking, and steering within the SAE standard definition of L2 Autonomous systems.*
Electronic Stability Control	*Helps prevent loss of control and reduces the risk of rollover in spin-out or plow-out situations.*
Forward Automatic Emergency Braking	*Detects potential collisions while traveling forward and automatically applies brakes to avoid or reduce impact severity.*
Forward Collision Warning	*Detects impending collisions while traveling forward and alerts the driver.*

Fully Automated Parking Assistance	*Controls acceleration, braking, steering, and shifting during parking, potentially capable of parallel and/or perpendicular parking.*
High Speed Alert	*Alerts drivers if they are exceeding the speed limit by coordinating the car's position with a GPS database of speed limits.*
Highway Pilot	*Maintains the vehicle's lane position and following distance by automatically braking and accelerating as needed.*
Hill Descent Control or Assist	*Helps maintain a steady speed when driving down a hill or decline.*
Hill Start Assist	*Prevents rollback when starting up from a stopped position on an incline.*
Intersection Assistant	*Warns drivers of vehicles approaching from the sides at intersections, highway exits, or car parks and applies brakes if the driver does not respond in time.*
Lane Centering Assist	*Gently steers the vehicle back into the lane if it begins to drift out of it.*
Lane Departure Warning	*Monitors the vehicle's position within the driving lane and alerts the driver as it approaches or crosses lane markers.*
Lane Keeping Assist	*Controls steering to keep the vehicle within the driving lane, preventing it from departing the lane or continuously centering the vehicle.*
Night Vision	*Enhances driver vision at night by projecting enhanced images on the instrument cluster or heads-up display.*
Obstacle Detection	*Uses sensors in the front and/or rear bumpers to determine the distance between the car and nearby objects, with automatic braking in some versions. Does not work in low visibility weather conditions.*

Parking Obstruction Warning	*Detects obstructions in close proximity to the vehicle during parking maneuvers.*
Parking Sensors	*Alerts the driver to the position of objects around the car while parking.*
Pedestrian Automatic Emergency Braking	*Provides automatic braking for vehicles when pedestrians are in front and the driver has not acted to avoid a crash.*
Pedestrian Detection	*Detects pedestrians in front of the vehicle and alerts the driver to their presence.*
Push Start Button	*Simplifies turning the car on and off using a unique key fob.*
Rain Sensor	*Detects rainfall and activates the windshield wipers.*
Rear Cross Traffic Warning	*Detects vehicles approaching from the side and rear while reversing and alerts the driver.*
Remote Parking System	*Parks the vehicle without the driver being physically present inside. Automatically controls acceleration, braking, steering, and shifting.*
Reverse Automatic Emergency Braking	*Detects potential collisions while reversing and automatically applies the brakes to avoid or reduce impact severity.*
Semi-Automated Parking Assistance	*Controls steering during parking, but does not accelerate, brake, or change gear position. Capable of parallel and/or perpendicular parking.*
Side view Camera	*Provides an expanded view of the lane beside the vehicle when the turn signal is used or manually activated.*
Surround View Camera	*Uses cameras located around the vehicle to present a view of the surroundings.*
Temperature Warnings	*Alerts the driver when the outside temperature is at or below freezing, which can impact road conditions.*

Tire Pressure Monitoring	*Warns the driver if the tires are under- or over-inflated, helping increase fuel economy and prevent tire blowouts. May not specify which tire needs attention.*
Traction Control System	*Helps the wheels gain traction on slippery surfaces.*
Traffic Jam Assist	*Automatically accelerates and brakes the vehicle with the flow of traffic, keeping it between lane markings, even in curves.*
Trailer Assistance	*Assists the driver during backing maneuvers with a trailer attached.*
Vibrating Seat Warnings	*Vibrates the driver's seat bottom cushion if a crash risk is detected, assisting hearing-impaired drivers.*

Table 10 List of ADAS technologies with their uses[48]

D Appendix D

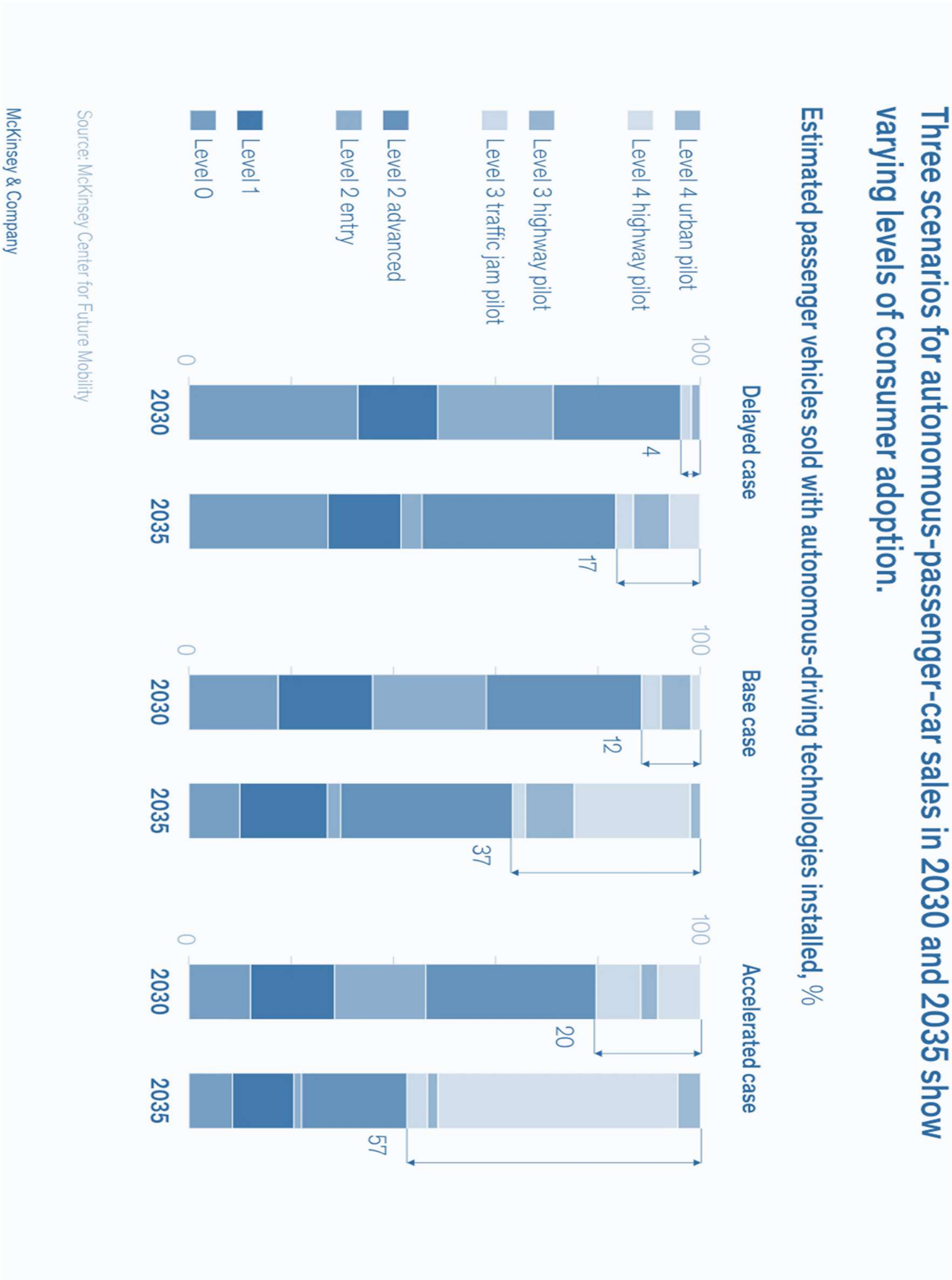

Figure D.1 Estimated passenger vehicles sold with AD technology installed.[49]

E Appendix E

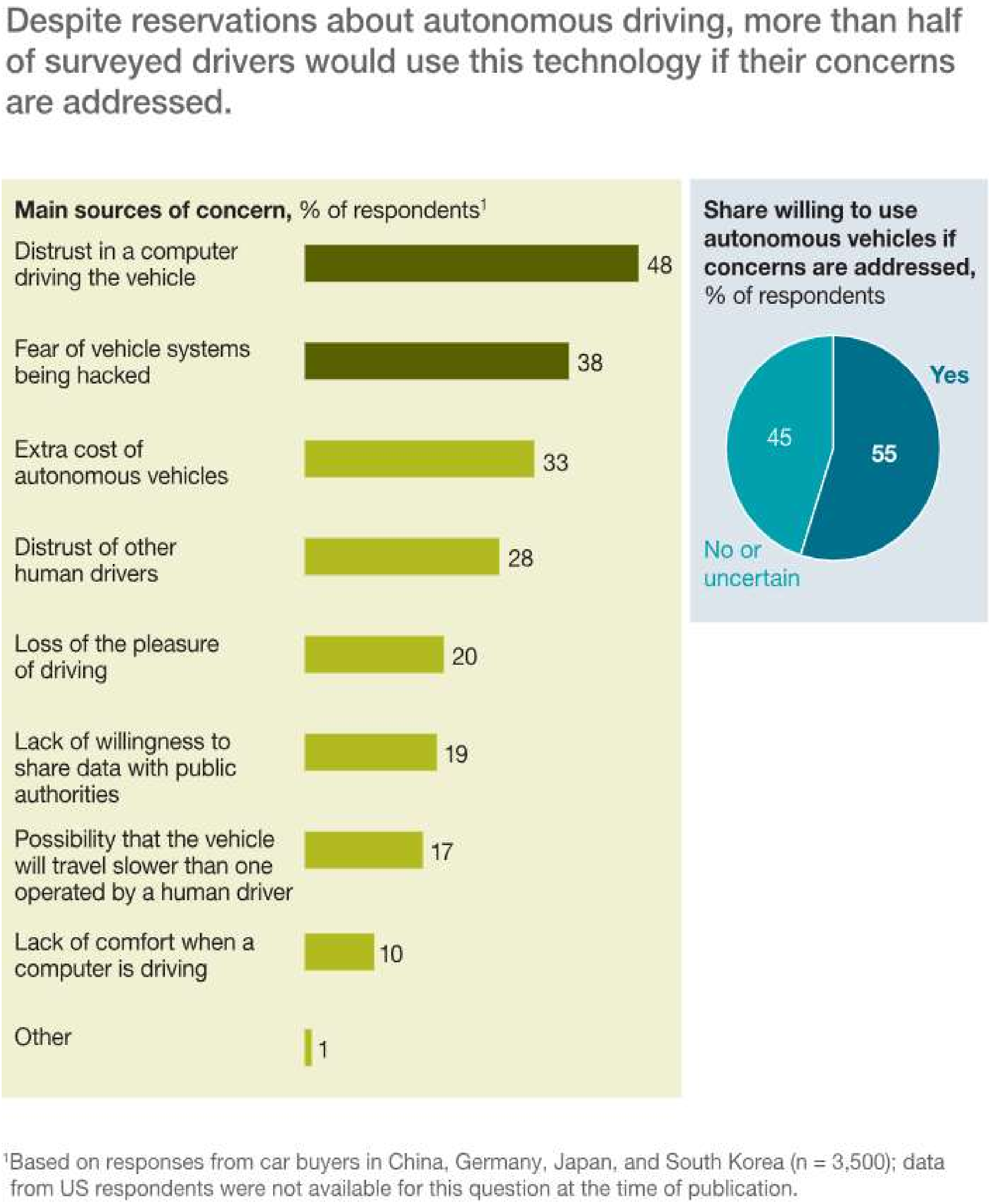

Figure E.1 A useful survey showing interest of users towards AD/ADAS featured vehicles [48]

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