Driverless taxis in Germany – a realistic future scenario?

Investigating factors influencing the acceptance of Level 5 Shared Autonomous Vehicles

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Abstract

Title: Driverless taxis in Germany – a realistic future scenario? The acceptance of Level 5 Shared Autonomous Vehicles in Germany.
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This dissertation investigates the factors that influence the acceptance of Level 5 Shared Autonomous Vehicles (SAVs) in Germany's public transport system. As the automotive industry moves closer to fully autonomous vehicles, it is crucial to understand the complex web of factors that shape potential customers' perceptions and attitudes. A structured mixed-methods research methodology is used to eliminate the complexities of this topic. This includes both quantitative surveys and qualitative in-depth interviews.

The results of the study highlight the central role that several critical factors play in the development of Level 5 SAVs in Germany. Safety and waiting time are key factors, playing an essential role in building user confidence in SAV technology. It is important to consider these factors when promoting SAV technology to potential users. Gender also plays a role, with males showing a higher tendency to use SAV, highlighting gender differences in technology adoption. Further research has also revealed the perceived importance of travel time and cost, although these factors did not significantly affect behavioural intentions towards the use of SAVs.

This study contributes significantly to the ongoing debate about the adoption of self-driving vehicles in the wider context of Germany's fast-changing mobility landscape. The findings offer valuable insights for stakeholders, including lawmakers, industry leaders, and policymakers, to navigate the disruptive digital environment. This dissertation addresses critical factors that impact acceptance and provides stakeholders with tools to enable the seamless integration of Level 5 SAVs into Germany's transport ecosystem.

Keywords: Autonomous Driving, Shared Autonomous Driving, Robotaxis, Future Mobility, Automotive

Resumo

Título: Táxis sem condutor na Alemanha - um cenário futuro realista? A aceitação de Veículos Autónomos Partilhados de nível 5 na Alemanha.
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Esta dissertação investiga os fatores que influenciam a aceitação dos Veículos Autónomos Partilhados (SAV) de nível 5 no sistema de transportes da Alemanha. À medida que a indústria automóvel se aproxima dos veículos totalmente autónomos, é crucial compreender a complexa rede de fatores que moldam as perceções e atitudes dos potenciais utilizadores. Uma metodologia de investigação de métodos mistos será utilizada para eliminar as complexidades deste tópico. Isto inclui inquéritos quantitativos e entrevistas qualitativas aprofundadas.

Os resultados da investigação destacam o papel de vários fatores críticos no desenvolvimento de SAVs de nível 5 na Alemanha. A segurança e o tempo de espera são fatores-chave, desempenhando um papel essencial na confiança dos utilizadores na tecnologia dos SAV. É importante considerar estes fatores ao promover estas tecnologias junto de potenciais utilizadores. O género também desempenha um papel importante, com os homens a mostrarem maior tendência para utilizar SAV, evidenciando diferenças de género na adoção da tecnologia. Outros estudos revelaram também a importância do tempo de viagem e do custo, embora estes fatores não afetem substancialmente intenções relativas à utilização.

Este estudo contribui significativamente para o debate em curso sobre a adoção de veículos autónomos no contexto da mutável mobilidade da Alemanha. Os resultados oferecem informações valiosas para as partes interessadas - incluindo legisladores, líderes da indústria e decisores políticos -, navegarem no ambiente digital disruptivo. Esta tese aborda os fatores que impactam a aceitação e fornece ferramentas para permitir a integração perfeita dos SAV de nível 5 no ecossistema de transportes alemão.

Palavras-chave: Condução autónoma, Condução autónoma partilhada, Robotaxis, Mobilidade futura, Automóvel

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List of Abbreviations

AV	Autonomous Vehicle
DRS	Demand Responsive Services
FCEV	Fuel Cell Electric Vehicle
GPS	Global Positioning System
LiDAR	Light Detection and Ranging
MaaS	Mobility-as-a-Service
MNL	Multinomial Logistic Regression
NL	Nested Logit
SAE	Society of Automotive Engineers
SAV	Shared Autonomous Vehicle
SD	Standard Deviation
SE	Standard Error
TAM	Technology Acceptance Model
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UTAUT	Unified Theory of Acceptance and Use of Technology

1 Introduction

The acceptance of Shared Autonomous Vehicles (SAVs) has emerged as a critical concern in the ever-evolving landscape of modern transportation. A variety of factors influence individuals' attitudes and willingness to embrace this transformative technology, and researchers around the world have diligently investigated these factors in various contexts. From examining user experiences in field tests to uncovering public preferences in developing countries, from exploring the impact of the external environment to understanding the attitudes of new car buyers, these studies have delved deep into the complex dynamics of SAV acceptance.

This dissertation explores the factors that influence the acceptance of shared autonomous driving in Germany, a country known for its strong automotive industry, efficient public transport systems and a careful approach to technological innovation. Building on an extensive body of global research, this study aims to investigate the unique context of "Acceptance of Shared Autonomous Vehicles in Germany". The research conducted to answer this key question is based on a comprehensive survey and consumer interviews involving participants from Germany, allowing a direct assessment of the feelings and preferences of the German public. In addition, expert interviews were conducted to gain deeper insights into the nuances of SAV acceptance. This involved drawing on the knowledge and expertise of individuals who are intimately familiar with the German automotive and transportation landscape particularly in the field of autonomous driving.

Germany's deep-rooted automotive culture, stringent regulations and a penchant for innovation create an intriguing backdrop for the investigation into SAV acceptance. Drawing inspiration from research conducted in China, United States of America, South Korea and various other countries, this study attempts to develop a comprehensive understanding of the factors that influence German consumers' attitudes and preferences towards SAVs.

1.1 Relevance of SAVs

The emergence of Level 5 Shared Autonomous Vehicles marks a pivotal point in the evolution of transportation, that will fundamentally change the automotive industry and reshape urban life (Kaur & Rampersad, 2018; Unsted 2019). This technological revolution not only affects mobility, but also has a profound impact on societal behaviours, economic structures, and urban planning. According to various studies, SAVs can have several positive impacts improving urban areas such as reducing costs and traffic congestion as well as reducing greenhouse gas emissions.

Reduction of private car ownership

Shared Autonomous Vehicles are expected to significantly reduce the number of private vehicles. Estimates suggest that each SAV has the potential to substitute 3-14 conventional cars, as SAVs have the potential to provide low-cost mobility services (Chen et al., 2016; Spieser et al., 2014; Milakis et al., 2017). In addition, the growing role of SAVs in shared mobility could significantly reduce the need for private vehicle ownership, affecting aspects such as urban planning, land use and resource allocation (Clements & Kockelman, 2017). SAVs could decrease the demand of parking by up to 90% and travel costs by up to 85% through increased vehicle utilisation (Zhang et al., 2015; Fagnant & Kockelman, 2015). In addition, switching from private vehicles to fully autonomous vehicles can increase the safety of a vehicle. According to reports, human error causes 90% of all car accidents (Fagnant & Kockelman, 2015). Therefore, autonomous vehicles are expected to significantly reduce accident rates by eliminating human error (Haboucha et al., 2017; Ullah et al., 2019). On the environmental front, researchers suggest that SAVs could produce up to 90% less greenhouse gases than current passenger vehicles (Greenblatt & Shaheen, 2015).

Improvement of urban areas

The introduction of shared autonomous vehicles promises significant improvements in urban areas. Research suggests that SAVs could lead to a 25% reduction in congestion and an increase in road capacity, resulting in significant economic savings (Fagnant & Kockelman, 2015; Jonas et al., 2014). The positive impact of SAVs on traffic flow has been demonstrated in simulations, with cities such as Budapest showing positive changes in traffic performance (Matalqah et al., 2022). SAVs also offer increased availability and flexibility due to their automatic relocation and pick-up capabilities (Pakusch et al., 2018). These developments are expected to change the organisational structure of metropolitan regions, towns and communities (Faisal et al., 2019; Ashkrof et al., 2019). One of the most significant changes will be the demand for urban parking. The use of SAVs could significantly reduce the need for parking in city centres. This decrease would allow current parking spaces to be reused for other economic activity, infrastructural development, and the promotion of active and environmentally friendly transport modes such as cycling, thus making city centres more attractive and sustainable (Wellik et al., 2020). Furthermore, the expected reduction in the need for parking spaces not only alleviates urban congestion, but also opens up new opportunities for urban planning and development (Soteropoulos et al., 2019)

Cost reduction

Cost reduction is a key benefit of shared autonomous vehicles. The operating costs of these vehicles are estimated to be between $0.20 and $0.40 per mile, which is relatively low compared to conventional vehicles (Litman, 2023). The introduction of SAVs is also expected to lead to a 25% reduction in congestion and an increase in road capacity, resulting in significant economic savings. The potential annual savings, which include reductions in property damage, injuries and fatalities, are estimated to be about 447.1 billion USD in the United States and about 5.6 trillion USD globally (Fagnant et al., 2015; Jonas et al., 2014). Another study has estimated the benefits of SAVs, including crash savings, travel time reductions, fuel efficiency and parking benefits, to be close to 2,000 USD per year per vehicle and could reach up to 4,000 USD when total crash expenses are taken into consideration (Fagnant et al., 2015).

The introduction of Level 5 Shared Autonomous Vehicles represents a tremendous step forward in the evolution of transportation and could drastically transform the automotive industry and urban landscapes. These vehicles are expected to significantly reduce private vehicle ownership, resulting in reduced urban congestion and increased road safety. In addition, SAVs are expected to help advance urban planning by repurposing parking spaces and promoting sustainable transport options. Essentially, SAVs offer an economically viable and sustainable solution for the mobility of the future.

2. Industrial Analysis

This section provides a comprehensive overview of the autonomous vehicle (AV) and shared autonomous vehicle markets. The definitions of AV and SAV are outlined, along with a brief introduction to the underlying technology and levels of automation (1-5). This fundamental knowledge is essential for understanding the market analysis that follows. This section is structured in such a way that it examines the market categorisation according to AV levels and regional distinctions. It will also highlight the major players currently leading these markets and provide projections for future market trends.

2.1 Autonomous Vehicles

An autonomous vehicle, also known as a self-driving or driverless car, is a vehicle that is capable of driving without the need for human intervention (Paden et al., 2016). The National Highway Traffic Safety Administration (NHTSA) classifies autonomous or self-driving cars as those that operate without direct human intervention for steering, acceleration, and braking, allowing the driver to disengage from continuous monitoring in self-driving mode (NAIC, 2022).

The Society of Automotive Engineers (SAE) has defined six levels of automotive automation, ranging from fully manual driving at Level 0 to fully automated self-driving cars at Level 5 (SAE, 2021). This classification system highlights the range of technological intervention and the decreasing need for human involvement in vehicle control. These vehicles will use a combination of remote sensing technologies, including radar, GPS (Global Positioning System), cameras and LiDAR (Light Detection and Ranging), to create a comprehensive 3D map of their environment (Ignatious et al., 2021). The potential applications of AVs can be broadly categorised into two different models (Collinwood, 2017): private ownership and SAVs. In the private ownership model, individuals own autonomous vehicles in a similar way to traditional cars. The main advantage of this model is the convenience and personalisation it offers. Owners can customise their vehicles according to their preferences and have them at their disposal at all times. This model significantly increases the comfort and efficiency of personal travel, as AVs can perform all driving tasks (Bösch et al., 2018). Shared Autonomous Vehicles, on the other hand, represent a paradigm shift towards a service-based approach. In this model, AVs are not owned by individuals, but are part of a shared fleet that provides on-demand transport services.

2.1.1 Technology

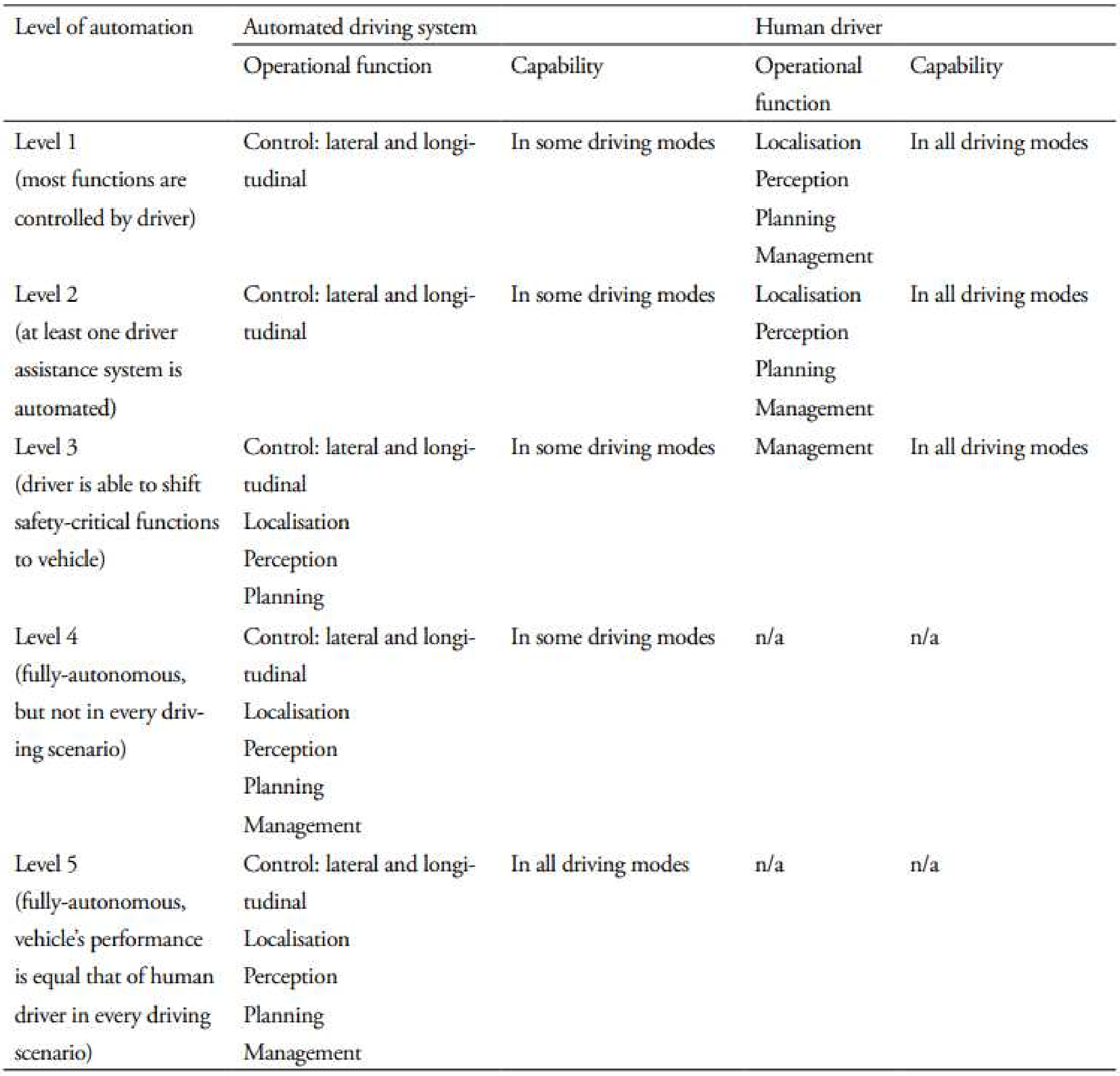
Autonomous vehicles rely on a combination of technologies and sensors to identify the road, other cars, and items on and near the road, and react to the movements of all traffic to provide an advanced safety advantage (Ignatious et al., 2021). Sensing the dynamic and diverse driving environment is a challenge for autonomous vehicles and requires the development of advanced geolocation systems through connectivity with various cameras, radars, and sensors (Bagloee et al., 2016). Technologies used in autonomous vehicles include:

- LiDAR technology uses lasers to create a 3D map of the vehicle's surroundings, allowing it to detect and avoid obstacles (Ignatious, 2021).
- Radar technology uses radio waves to detect the distance, speed, and direction of objects around the vehicle (Ignatious et al., 2021).
- Cameras capture images of the vehicle's surroundings, which are then analysed by computer vision algorithms to identify objects and their movements (Ignatious et al., 2021).
- GPS technology uses satellites to relay information about the vehicle's position (Gao et al., 2022).
- Ultrasonic sensor technology provides short-range information to assist with parking and reverse warning (Ignatious et al., 2021).
- Prebuilt mapping technology relies on specified road maps to limit the possible routes that can be taken (Soorchaei et al., 2022).
- Artificial intelligence algorithms interpret sensor inputs to understand the ever-changing environment around the vehicle (Nascimento et al., 2019).
- Connected vehicle technology enables communication with other vehicles and infrastructure, creating a more complete picture of the environment and leading to a safer environment for drivers, pedestrians, and cyclists (Gao et al., 2022).

Large amounts of data are collected and transmitted to the relevant computer system, where a program generates the necessary recommendations. Operations such as accelerating, braking, lane changing and overtaking can be performed without the involvement of a human (Bagloee et al., 2016). AV technology enables an autonomous driving system to operate synchronously while keeping complete control of the vehicle and detect exterior objects. AVs must be able to make rational judgements, analyse sensory input and make decisions in order to react intelligently to external factors (Ignatious et al., 2021).

2.1.2 Levels of Automation

Autonomous driving is divided into several levels of automation, each of which describes the extent to which a vehicle can operate without human intervention. These levels are standardised by the SAE in standard J3016 (Table 1). The levels range from Level 0, with no automation, to Level 5, with complete automation without human intervention. Starting at Level 4, self-driving cars are those that operate completely on their own without human assistance. In any operational scenario, level 5 specifies full automation, meaning that the human driver is not required to take on any driving responsibilities (Rubin, 2016; Walker & Marchau 2017).



Level of automation	Automated driving system		Human driver	
	Operational function	Capability	Operational function	Capability
Level 1 (most functions are controlled by driver)	Control: lateral and longitudinal	In some driving modes	Localisation Perception Planning Management	In all driving modes
Level 2 (at least one driver assistance system is automated)	Control: lateral and longitudinal	In some driving modes	Localisation Perception Planning Management	In all driving modes
Level 3 (driver is able to shift safety-critical functions to vehicle)	Control: lateral and longitudinal Localisation Perception Planning	In some driving modes	Management	In all driving modes
Level 4 (fully-autonomous, but not in every driving scenario)	Control: lateral and longitudinal Localisation Perception Planning Management	In some driving modes	n/a	n/a
Level 5 (fully-autonomous, vehicle's performance is equal that of human driver in every driving scenario)	Control: lateral and longitudinal Localisation Perception Planning Management	In all driving modes	n/a	n/a

Table 1: 5 Levels of automation (according to Faisal et al., 2019; based on SAEJ3016)

2.1.3 Shared Autonomous Vehicles

Shared autonomous vehicles are an innovative approach to urban transport that uses autonomous driving technology to provide a shared, on-demand mobility service (Mojumder and Jin, 2023). These vehicles are designed to operate without a human driver and are typically managed through a digital platform, allowing users to book rides on demand (Stocker & Shaheen, 2017).

SAVs offer several advantages over traditional transport options. They address the problem of vehicle underutilisation and the shortage of parking spaces in urban areas, which is a major challenge for urban planning and infrastructure (Faisal et al., 2019). By optimising the use of each vehicle, SAVs lower the overall number of cars needed to satisfy transportation demands, leading to less traffic congestion and lower emissions (Fagnant & Kockelman, 2015). In addition, SAVs are an integral part of the Mobility-as-a-Service (MaaS) concept, which integrates different modes of transportation, including driverless taxis (robotaxis) and driverless buses, into a single platform, improving travel efficiency and flexibility for users (Stocker & Shaheen, 2017). Recent studies have further clarified the benefits of SAVs. For example, SAVs can improve accessibility and reduce social exclusion in low-density areas, although they may increase vehicle miles travelled without passengers (Mojumder and Jin, 2023). In certain urban contexts, SAV systems have been shown to have a positive impact on traffic performance (Matalqah et al., 2022). Furthermore, shared autonomous cargo bike fleets could provide a sustainable solution for urban transport, reducing emissions and congestion while enhancing public transport as an integrated last-mile service (Schmidt et al., 2021). In addition, the introduction of SAVs can significantly reduce PM 2.5 (type of particulate matter) emissions and energy consumption under appropriate pricing strategies, especially when combined with vehicle electrification (Zhong et al., 2023).

In summary, SAVs represent a major advance in urban mobility. They offer sustainable, efficient and equitable transport solutions by addressing key challenges in urban environments and aligning with global trends towards smart, connected transportation systems.

2.2 Autonomous Vehicles Market

Autonomous vehicles are a crucial invention in the automotive industry with tremendous growth potential, operating as a driver for automotive technological advancement (Grand View Research, 2021). According to Statista (2023a), the global market for autonomous vehicles will double between 2021 and 2025 (Figure 1). Considering levels 1-4 of autonomous driving, the automotive industry will be able to generate significant revenues from the further development of driver technologies. The market for driver assistance systems and autonomous driving in private cars is expected to grow from around USD 50 billion in January 2023 to USD 300-400 billion in 2035, with an annual growth rate of 15-20% (McKinsey, 2023a). As a result of government regulations to improve road safety, a rising number of autonomous vehicles are being developed with modern technologies embedded in smartphones. (Mordor Intelligence, 2023). This offers market players the potential to attract customers. The ability of cars to drive themselves has improved with recent advances in artificial intelligence, machine learning and other sensors such as GPS, LiDAR, Radar and computer vision (Mordor Intelligence, 2023). The establishment of a beneficial legislative environment, government funding, and investments in digital infrastructure are projected to play a crucial role in positively affecting market development (Grand View Research, 2021). Partnerships and investments to create autonomous cars have grown drastically in the automobile industry. (Mordor Intelligence, 2023). According to the Institute of Electrical and Electronics Engineers, 75% of the world's cars will be driverless by 2040 (NAIC, 2022).

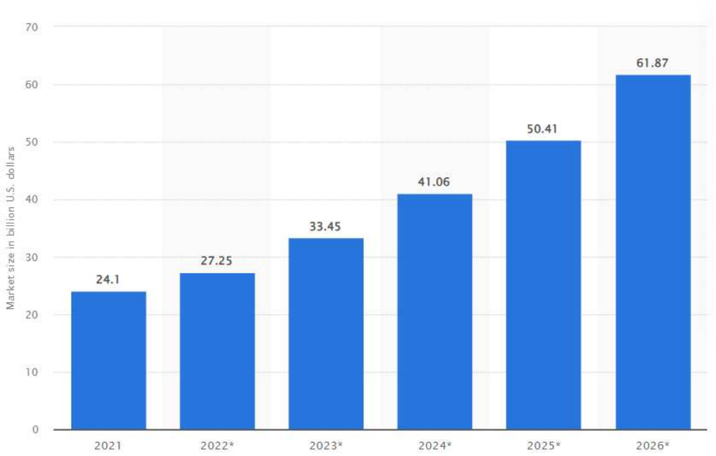


Figure 1: Size of the global autonomous car market from 2021 to 2028 (following Statista 2023)

2.2.1 Autonomous Vehicle Market by Type

The rising need for safer and more efficient transportation technologies is driving the creation and introduction of semi-autonomous (levels 1-3) automobiles. In addition, numerous local governments have adopted strict driving and safety legislation, pushing businesses to provide such technologies in their cars (Mordor Intelligence, 2023). During the pandemic, sales of autonomous vehicles increased, as approximately 11.2 million vehicles with level 2 capabilities were sold in 2020, an increase of 78% compared to 2019 (Mordor Intelligence, 2023). Given these favourable market conditions, car manufacturers around the world are introducing new semi-autonomous car models to attract potential customers. Currently, level 2 and 3 autonomous vehicles are the most prevalent in the market. Consequently, the expansion of these level 2 and 3 vehicles is projected to drive the mobility market until 2028. (Mordor Intelligence, 2023). According to Statista (2023b), the estimated share of newly registered level 2 autonomous cars worldwide in 2025 is 33%, while the share of level 3 cars is expected to be only 1%. 2030 will be the year in which the highest revenues will be generated with level 2, while five years later, in 2035, level 4 will dominate the market with the highest revenue share (McKinsey, 2023b) (Figure 2).

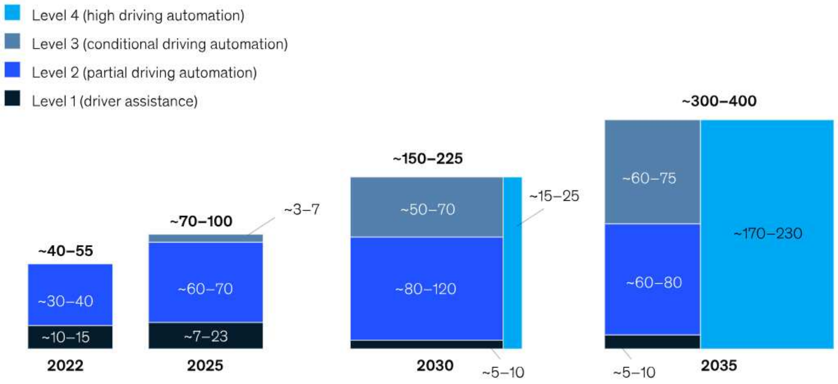


Figure 2: Advanced driver-assistance systems (ADAS) and autonomous-driving (AD) revenues ($ billion) (Following McKinsey 2023b)

2.2.2 Autonomous Vehicle Market by Region

According to the Autonomous Vehicle Readiness Index, the most advanced countries in terms of autonomous vehicles were predicted in 2020 are Singapore, the Netherlands, Norway, the US, Finland, Sweden, South Korea and the United Arab Emirates (KPMG, 2020). However, the autonomous vehicle (AV) market can be divided into three key global regions: North America, Asia Pacific and Europe. Each region has unique characteristics and trends in the development and adoption of AV technology.

North America

North America is predicted to lead the autonomous (driverless) automobile market throughout the forecast period until 2028 (Mordor Intelligence, 2023). The region is a forerunner for autonomous cars because of factors such as strong and experienced automotive industries, as well as the presence of the world's biggest technological corporations, such as Google, Microsoft, and Apple. Autonomous vehicles have already been tested and implemented in California, Texas, Arizona, Washington and Michigan. North America, particularly the United States, is also known for its productivity in scientific research and patent jurisdiction for related technologies such as fuel cell electric vehicles (FCEVs), indicating a robust infrastructure for AV development (Alvarez-Meaza et al., 2020). However, their AV landscape is presently restricted to certain testing locations and driving conditions. The Insurance Institute for Highway Safety predicts that the number of self-driving cars on US roads will reach 3.5 million by 2025 and 4.5 million by 2030. The Institute clarifies that these cars are not intended to be completely driverless, but will have some degree of autonomy (NAIC, 2022).

Asia Pacific

According to Mordor Intelligence (2023), demand for autonomous vehicles is increasing in countries such as China, Japan, India and South Korea, leading to expected growth in the Asia-Pacific region over the forecast period to 2028. The growth is characterised by disproportionate developments and the emergence of new suppliers, particularly in technologies related to 3D printing and printed electronics, which are essential for AV manufacturing (Sommer, 2022). The region is expected to see significant growth in the AV market, driven by increasing technological advancements and investments by major automotive companies. McKinsey (2021) expects that by 2030, 22.5% of shared mobility passenger-kilometres in China's major cities will be driven by robotaxis.

Europe

The automotive industry is of great importance for the economy and employment in Europe. It's a major contributor to the EU's GDP and provides a significant number of jobs. Around 13.8 million people are employed in the automotive sector in Europe, representing 6.1% of total employment in the EU (European Commission, 2023). The evolution of the industry, towards digital components such as networking, entertainment and autonomous systems, is shifting the focus of value creation. Companies outside the traditional automotive sector, especially those specialising in digital technologies, are increasingly becoming key players. This integration of modern technologies, including autonomous driving systems, is changing the differentiators in the automotive market, emphasising aspects such as digital connectivity over traditional elements such as engine performance (Bardt, 2017). Progress towards fully autonomous driving is characterised by different levels, with level 3 vehicles currently representing the highest level of automation available to consumers in Europe. level 4 vehicles are currently being developed and tested. The timeframe for large-scale commercial availability of these vehicles in Europe is expected to be around 2030. Despite technical and regulatory challenges, significant investments and progress are being made in this area (SAE, 2023). In the context of autonomous driving, Europe is making significant progress. The EU has established a regulatory framework for fully automated vehicles, facilitating the testing and deployment of autonomous driving functions up to SAE (Society of Automotive Engineers) level 4 on public roads. This legislative progress puts Europe at the forefront of this technological innovation, with countries such as Germany leading the way in creating a legal framework for fully automated driving. These developments indicate a strong push towards the integration of autonomous driving into mainstream transport systems in Europe (SAE, 2023).

2.3 Shared Autonomous Vehicles Market

As a transition from the broader autonomous vehicle market, the shared autonomous vehicle market represents a more niche but rapidly developing segment. This market is still in its early stages, largely due to the significant investment risks involved. The development and deployment of SAVs requires substantial financial resources, not only for technology development, but also for the establishment of the necessary infrastructure and operational framework. The SAV market also faces significant regulatory and legislative challenges. Many countries still lack clear regulations governing the use of shared autonomous vehicles. In the US, key decisions on robotaxis are made by appointed bodies such as the California Public Utilities Commission, often without widespread public awareness. The existing regulatory framework is particularly inadequate. In California, cities have no regulatory authority over robotaxis operating in their jurisdictions, and police are legally unable to issue citations for moving violations committed by these vehicles (Schneider, 2023).

2.3.1 Main Market Players

The autonomous vehicle market is highly competitive and concentrated, with numerous companies operating in the industry (Smita et al., 2023; Mordor Intelligence, 2023). As discussed in previous sections, multiple players, ranging from car manufacturers to software companies, are part of today's AV landscape. In particular, level 2 and 3 autonomous vehicles are the most prevalent in the market. When it comes to fully autonomous vehicles (level 4-5), there are currently two leading companies, Waymo and Cruise, considering the public use of their SAV service and the amount of funding until April 2022 (Statista, 2022). Both companies are based in the US and offer a fully autonomous taxi service. In August 2023, the California Public Utilities Commission (CPUC) granted Waymo and Cruise permission to transport paying passengers around the city 24 hours a day, even without a safety driver (CPUC, 2023).

Waymo LLC

Waymo, a subsidiary of Alphabet Inc, has established itself as a leader in the autonomous driving industry through a combination of advanced data and technology, systematic safety management, significant investment, open data initiatives, a focus on emerging technologies, and superior tracking system performance. The company's advanced second-generation dataset is notable for its complexity in sensor modalities and expanded scale and diversity, reflecting a deep commitment to developing cutting-edge autonomous driving technology (Chougule et al., 2023). In addition, Waymo has developed a comprehensive risk management framework that emphasises risk prevention, monitoring and mitigation during on-road testing of automated driving system technology, demonstrating its meticulous approach to vehicle safety (Favaro et al., 2023). Financially, Waymo has made significant investments in autonomous driving systems, aligning itself with other industry giants such as Google, Uber, Tesla and Mobileye, further cementing its position as a key innovator in the field. The company also fosters innovation by releasing open datasets from autonomous vehicle tests, encouraging developers to create faster and smarter self-driving algorithms (Anderson, 2020). Furthermore, Waymo's adoption of emerging technologies, particularly in addressing critical safety issues such as the long-tail problem in driving safety, highlights its role as a forward-thinking industry leader (Zhou et al., 2021).

Cruise LLC

Cruise, a subsidiary of General Motors recognised for its innovative approach to the autonomous driving industry, is making significant progress. A key aspect of Cruise's market position is its focus on disrupting urban transport with a fully autonomous, electric, SUV-sized vehicle, the Cruise Origin. As well as being a technological marvel, this vehicle is also cost effective, with production costs expected to be around half those of today's fully electric SUVs. This approach positions Cruise to potentially revolutionise ride-sharing services with fleets of these autonomous vehicles (Perry, 2020). In terms of funding, Cruise has reached a notable milestone. According to statistics from Statista (2022), as of April 2022, Cruise is ranked as the world's number one major autonomous driving startup, with a staggering $8.47 billion in funding. This substantial financial backing underlines Cruise's strong market position and investor confidence in its technology and business model. In 2022, former CEO Kyle Vogt announced a goal of reaching $1 billion in revenue by 2025 (Abuelsamid, 2022).

However, Cruise's journey in the autonomous driving landscape has not been without its challenges. The company has faced issues, including accidents in San Francisco, which have drawn attention to the safety and reliability aspects of autonomous driving technology. As a result, in October 2023, California regulators ordered Cruise to suspend its service in San Francisco. Cruise said it would continue to work on improving the technology. Despite the ban, the company is still allowed to test its autonomous taxis as long as there is a safety driver in the car who can intervene at any time (Shepardson, 2023; Lu & Metz, 2023). These incidents highlight the ongoing challenges that companies like Cruise face in developing and deploying autonomous vehicles in urban environments and meeting regulatory standards.

3 Acceptance

However, several barriers to the adoption of robotaxi services have been identified, including technological constraints, regulatory obstacles (vehicle licencing criteria), and cost (with affordability being a major concern). Previous study has revealed that one of the most important challenges of widespread acceptance of autonomous vehicles is not a technological problem, but a psychological one (Fagnant & Kockelman, 2014; Shariff et al., 2017). Understanding user acceptance is key when introducing new technologies to the public. This chapter will first define what acceptance means in general and then in the context of new technologies. In addition, this section will look specifically at the acceptance of shared autonomous vehicles among different socio-demographic groups. Research shows that people's interest to use autonomous vehicles has increased, especially after the COVID-19 pandemic, regardless of their technical knowledge, gender, or where they live (World Economic Forum, 2021). Drawing on different studies, this section also explores what specific factors influence the acceptance of SAV in different countries.

3.1 Definition

There are many different definitions of the term acceptance in science. According to Cambridge acceptance means “a general agreement that something is satisfactory or right” (Cambridge dictionary). Quoting Gabler, it means “the willingness to accept a situation with approval. Acceptance of an object is seen as a partial aspect of conformity in the spectrum between obedience, adaptation, and internalization. In addition to time-related acceptance, the change over time through learning is also of interest” (Gabler dictionary). Acceptance occurs within the context of social and technological construction processes, meaning it relies on various factors such as individuals' attitudes, expectations, behaviours, and the environment in which they are, along with the values and norms that shape these elements (Friedrich & Lenz, 2016).

3.2 Acceptance of technology

Technology acceptance indicates the user's willingness towards using a technology for the tasks it is meant to support. It is an interdisciplinary subject that uses the fields of psychology and information systems to study the attitudes and perceptions of individuals or organisations towards the adoption and use of a particular technology (Teo, 2011). “The Technology

Acceptance Model (TAM) is an information systems theory that explains how to encourage users to accept and use new technologies" (Davis, 1989). The Technology Acceptance Model has been used extensively by information systems scholars to address the challenge that organisations face in promoting the acceptance of new technologies (Alomary & Woollard, 2015). TAM identifies two critical factors that influence user acceptance: perceived usefulness and perceived ease of use (Davis, 1989). The core idea of TAM is that the more convinced users are that an application will improve their performance and the easier they find it to use, the more likely they are to adopt it. Over time, the model has been expanded to include additional factors that influence adoption. In a previous study of public acceptance of autonomous taxis in China, a new factor called "social influence" was added to the TAM (Liu et al. 2020). In addition to the Technology Acceptance Model for studying user acceptance of technologies, scholars have introduced several other models and frameworks. These include the Theory of Planned Behaviour (TPB) (Ajzen, 1991), the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) and its subsequent iteration, UTAUT2 (Venkatesh, 2012). While the TPB is based on the Theory of Reasoned Action (TRA) to examine different types of behaviour, UTUAUT and UTUAT2 are extended theories based on TAM. In addition to UTUAUT, UTUAT2 requires that participants in the study have already experienced the new technology (Liu et al., 2022).

3.3 Acceptance of (Shared) Autonomous Vehicles

Shared Autonomous Vehicles are a novel concept for overland transport with limited commercial availability. Despite this, SAVs have attracted considerable interest in recent research. Several studies have looked at the potential impact of SAVs, how they operate and how they might enter the market. The research has also explored which modes of transport people in different cultures and economies prefer when SAVs become available.

The current existing research is mostly based on data collected through online surveys, with some using online stated preference (SP) surveys. The data are analysed using a wide variety of methodological approaches, including multinomial logit (MNL), nested logit (NL), logit kernel or mixed logit, and numerous regression models. It is worth noting that the majority of the research was carried out in advanced economies and focused on autonomous cars, car-sharing services, and their integration with SAVs (Wang et al., 2020). Factors influencing SAV adoption include socio-demographic variables (age, education, gender) and transport attributes (travel time, travel cost, waiting time). In addition, the public's desire for SAVs is influenced by factors such as safety and comfort (Haboucha et al., 2017; Paddeua et al., 2020). Other factors, such as having a driving licence and owning a private car, also significantly influence user preferences for AVs and SAVs. Furthermore, a recent study found that young adults and students from low-income homes with limited or no access to a private car rather use shared autonomous vehicles (Etminani-Ghasrodashti et al., 2022).

4 Problem Statement

Shared Autonomous Vehicles represent a transformative innovation in the transport sector, with the potential to reshape mobility patterns and urban landscapes. However, assuming that the technology matures in the near future and a legal framework is in place, the widespread adoption of SAVs will depend on public acceptance of the technology. In Germany, a nation renowned for its automotive heritage and strict regulatory standards, understanding the factors that influence the acceptance of shared autonomous vehicles is of high importance. Despite the promise of improved mobility, challenges to the acceptance of SAVs remain, including concerns about safety, trust in autonomous technology and cultural preferences. These challenges highlight the need for a comprehensive examination of the factors shaping the acceptance landscape in Germany.

While there is a global discourse on shared autonomous vehicles in the current literature, including acceptance in countries such as the US, China and South Korea, the nuances specific to the German context remain underexplored. Thus, the rationale behind this research is to address this gap, as insights from Germany's unique socio-cultural and automotive landscape can significantly contribute to a broader understanding of the acceptance of autonomous vehicles. The primary audience for this research includes policy makers, urban planners, automotive industry stakeholders and researchers seeking to inform strategies for the integration of SAVs into the German transport ecosystem. By identifying and understanding the factors that influence acceptance, this study aims to provide actionable insights that can facilitate a smoother transition to a future where Shared Autonomous Vehicles are an integral part of the German mobility paradigm.

4.1 Research Question

What are the key factors influencing the acceptance of Shared Autonomous Vehicles in Germany?

4.2 Hypotheses

This section presents the hypotheses formulated to explore the key factors influencing the uptake of shared autonomous vehicles. Each hypothesis is based on scientific research as well as results from qualitative consumer interviews, drawing on empirical studies and theoretical frameworks to provide a comprehensive overview of the issues likely to influence individuals' willingness to adopt SAVs. These hypotheses are categorised according to psychological perceptions, time factors, economic considerations and demographic influences, providing insights into the multifaceted nature of SAV acceptance.

Psychological Perceptions

H1: Safety has a positive effect on behavioural intentions to use SAV

Safety concerns have a significant impact on behavioural intentions to use shared autonomous vehicles, as demonstrated by various studies. Individuals concerned about safety are wary of automated vehicle technology, likely due to its unfamiliarity and current unavailability (Nazari et al., 2018). Despite this, the potential for safety improvements and the elimination of human error are expected to improve road safety (Fagnant and Kockelman, 2015). The interviews conducted with industry experts and potential consumers also show that safety is the most critical factor influencing the acceptance of AVs. Concerns about the AV's response to unexpected situations and potential technical failures dominate, with safety emerging as the most desired service attribute (Miller et al., 2022). This is supported by findings that positive safety perceptions are directly linked to willingness to use SAVs, underlining the central role of safety in driving user acceptance and trust in autonomous vehicle technology (Patel et al., 2022; Jabbari et al., 2022).

H2: Comfort has a positive effect on behavioural intentions to use SAV

The positive effect of comfort on behavioural intentions to use shared autonomous vehicles (SAVs) is supported by evidence suggesting that improvements in comfort, alongside cost and time efficiencies, are likely to increase the adoption of pooled autonomous vehicle services (Stoiber et al., 2019). Furthermore, comfort, along with travel time, emerges as a primary influence on the willingness to use SAVs (Maghraoui et al., 2020). A significant relationship between expected comfort and initial trust in AVs highlights the importance of comfort in acceptance, implying that higher comfort can positively influence behavioural intentions to use SAVs (Paddeu et al., 2020). In addition, another study found out that small improvements in comfort could lead to a larger increase in the demand for SAVs, highlighting the need for future SAV modes to offer high comfort levels (Cordera et al., 2022).

H3: Environmental pollution has a negative effect on behavioural intentions to use SAV

Increased environmental awareness has become a significant factor influencing behavioural intentions to use shared autonomous vehicles. A BCG survey highlighted that following the pandemic, there has been a notable increase in concern for environmental issues, with more people willing to change their behaviour to support sustainability (Kachaner et al., 2020). This shift in awareness not only reinforces the positive impact that the perceived benefits of autonomous vehicles (AVs) have on attitudes, but also reinforces the negative perceptions associated with the drawbacks of AVs, thus influencing the intention to use services such as robotaxis (Li et al., 2022). Environmental concerns have emerged as one of the key factors in the decision-making process regarding the use of AVs, highlighting their importance in consumer preferences (Haboucha et al., 2017). Furthermore, personal attributes such as environmental concerns have been shown to significantly influence the intention to adopt SAVs, suggesting that environmental considerations are crucial in shaping consumer attitudes towards these technologies (Si et al., 2023). Emphasis on building environmental factors and promoting eco-friendly travel patterns are also identified as key drivers of public interest in (S)AVs, highlighting the role of sustainability in promoting the adoption of AV technologies. This collective evidence underscores the critical impact of environmental concerns on the acceptance and adoption of SAVs, suggesting that addressing pollution and promoting sustainability could increase behavioural intentions towards SAV use.

Time-Related Factors

H4: Travel time has a negative effect on behavioural intentions to use SAV

Increased travel time is associated with a negative effect on behavioural intentions to use shared autonomous vehicles. Research has consistently shown that generic attributes, including travel time, significantly influence transport choices in different cities, highlighting the importance of efficiency and speed of travel in user preferences (Wang et al., 2021). The desire for improved mobility efficiency, reflected in a preference for shorter journey times combined with comfort and lower costs, suggests that minimising travel time could lead to higher adoption of pooled autonomous vehicle services (Stoiber et al., 2019). Furthermore, travel time has been identified as a critical determinant of the use and acceptance of SAVs and Demand Responsive Services (DRS) along with travel cost and waiting time, further highlighting the need for efficient travel solutions to attract users (Krueger et al., 2016). The significant impact of travel time on SAV acceptance and adoption highlights the need for SAV operators to consider this factor when designing and optimising their services to meet user expectations (Paddeu et al., 2021). The emphasis on travel time as one of the main criteria influencing willingness to use SAVs (Maghraoui et al., 2020) reinforces the critical role of efficient travel in shaping user acceptance and behavioural intentions to adopt new mobility solutions.

H5: Waiting time has a negative effect on behavioural intentions to use SAV

Increasing waiting times are found to have a negative impact on users' willingness to accept and use shared autonomous vehicles as their regular mode of transport. This correlation suggests that potential users of SAVs are those who value the efficiency of their mobility, particularly in terms of reduced travel time, and are therefore likely to be deterred by longer waiting times (Etminani-Ghasrodashti et al., 2022). The importance of waiting time, along with travel time and travel costs, has been recognised in influencing user preferences in different cities, highlighting its universal impact on the decision-making process regarding transport options (Wang et al., 2021). Furthermore, crucial service features such as trip cost, travel duration, and waiting time have been observed as major predictors of the usage and acceptance of SAVs and Demand Responsive Services (DRS), highlighting the importance of these factors in shaping consumer behaviour towards new mobility solutions (Krueger et al., 2016). The findings indicate that service attributes, including waiting time, have a significant impact on the acceptance and adoption of SAVs, highlighting the need for SAV operators to optimise these parameters to improve the user experience and increase adoption rates (Paddeu et al., 2021).

Economic Considerations

H6: Travel cost has a negative effect on behavioural intentions to use SAV

The relationship between travel costs and behavioural intentions to use shared autonomous vehicles is characterised by a negative correlation, suggesting that higher travel costs may deter potential users. This observation is supported by research in different cities where travel cost, along with waiting and travel time, significantly influences transport preferences, highlighting the importance of affordability in user choice (Wang et al., 2021). The influence of cost, in conjunction with comfort and time, on the likelihood of adopting pooled autonomous vehicle services further illustrates the critical role of cost-effectiveness in enhancing the attractiveness of new mobility solutions (Stoiber et al., 2019). Furthermore, travel cost, as part of a set of critical service attributes including travel and waiting time, has been identified as a determinant of the uptake and use of SAVs and demand-responsive services, highlighting the need for SAV operators to address cost concerns in order to promote wider uptake (Krueger et al., 2016). The impact of travel costs on the acceptance and use of SAVs highlights the importance of competitive pricing strategies in promoting the adoption of innovative transport modes (Paddeu et al., 2021).

H7: Owning a private vehicle has a negative effect on behavioural intentions to use SAV

The relationship between private vehicle ownership and behavioural intentions to use shared autonomous vehicles is complex. Evidence indicates that car users may be more inclined to use autonomous vehicles, suggesting a certain openness to new forms of mobility among private vehicle owners (Cordera et al., 2022). However, greater access to a private vehicle correlates with a strong preference for personal car use over ridesharing alternatives, leading to less frequent use of piloted SAVs (Etminani-Ghasrodashti et al., 2022). In addition, car ownership negatively affects the probability of using established app-based on-demand transport services, highlighting the reluctance of car owners to switch to alternative transport modes (Patel et al., 2022). Conversely, in some regions, private car owners have shown greater interest in SAVs, suggesting that the impact of vehicle ownership on SAV usage intentions varies across contexts (Wang et al., 2021).

Demographic Influences

H8: Age has a negative effect on behavioural intentions to use SAV

Age significantly influences behavioural intentions towards the use of shared autonomous vehicles, with younger individuals showing a higher likelihood of adoption and use. Studies have shown different relationships between age, gender and risk taking with attitudes towards autonomous vehicles, with younger adults and males being more accepting (Hulse et al., 2018). Early adopters of AV technology are expected to be predominantly young (Haboucha et al., 2017). Furthermore, young adults, particularly those from low-income households with limited access to private vehicles, have been identified as more likely to use SAVs (Etminani-Ghasrodashti et al., 2022). This trend is further supported by findings that young adults are significantly more likely to use SAV services frequently (Patel et al., 2022). Another study revealed that young travellers rather use SAVs than older travellers, especially if the SAVs include a ride-sharing system (Krueger et al., 2016).

H9: Education has a positive effect on behavioural intentions to use SAV

Education positively influences behavioural intentions to use shared autonomous vehicles. Early adopters of this technology are likely to be individuals with higher levels of education, including students (Haboucha et al., 2017). This trend is supported by findings that students from low-income households, particularly those without access to a private vehicle, more likely to use SAVs (Patel et al., 2022). A study focusing on the demographics of SAV service users found that the majority were young, educated Asians and students from low-income backgrounds, highlighting the link between education and SAV use (Etminani-Ghasrodashti et al., 2022). Furthermore, research in Lahore found that socio-demographic factors such as educational attainment were significantly correlated with increased interest in using SAVs, alongside other variables such as income, frequency of travel and possession of a driving licence (Wang et al., 2021), reinforcing the idea that education increases receptiveness to innovative transport solutions.

H10: Male has a positive effect on behavioural intention to use SAV

Gender significantly influences behavioural intentions towards the use of shared autonomous vehicles (SAVs), with studies suggesting that males have more favourable attitudes towards the technology. Males and younger adults have been shown to be more accepting of autonomous vehicles, suggesting a positive correlation between male gender and willingness to adopt such technologies (Hulse et al., 2018). Further research has shown that men are more likely than women to use AVs and SAVs, particularly for leisure purposes (Cordera et al., 2022). This gender disparity is also evident in findings where women are less likely to use the SAV service frequently than their male counterparts (Patel et al., 2022). In addition, male respondents perceive self-driving cars as safer and place less importance on car ownership compared to females (Jabbari et al., 2022). Positive perceptions of AVs are more common among male respondents, particularly among younger individuals and those more familiar with the technology (Wang et al., 2020).

4.2.1 Conceptual Framework

The developed hypotheses allow the following conceptual model to be proposed, illustrated in Figure 3. These factors influencing the behavioural intention to use SAVs are examined in the quantitative part of this dissertation.

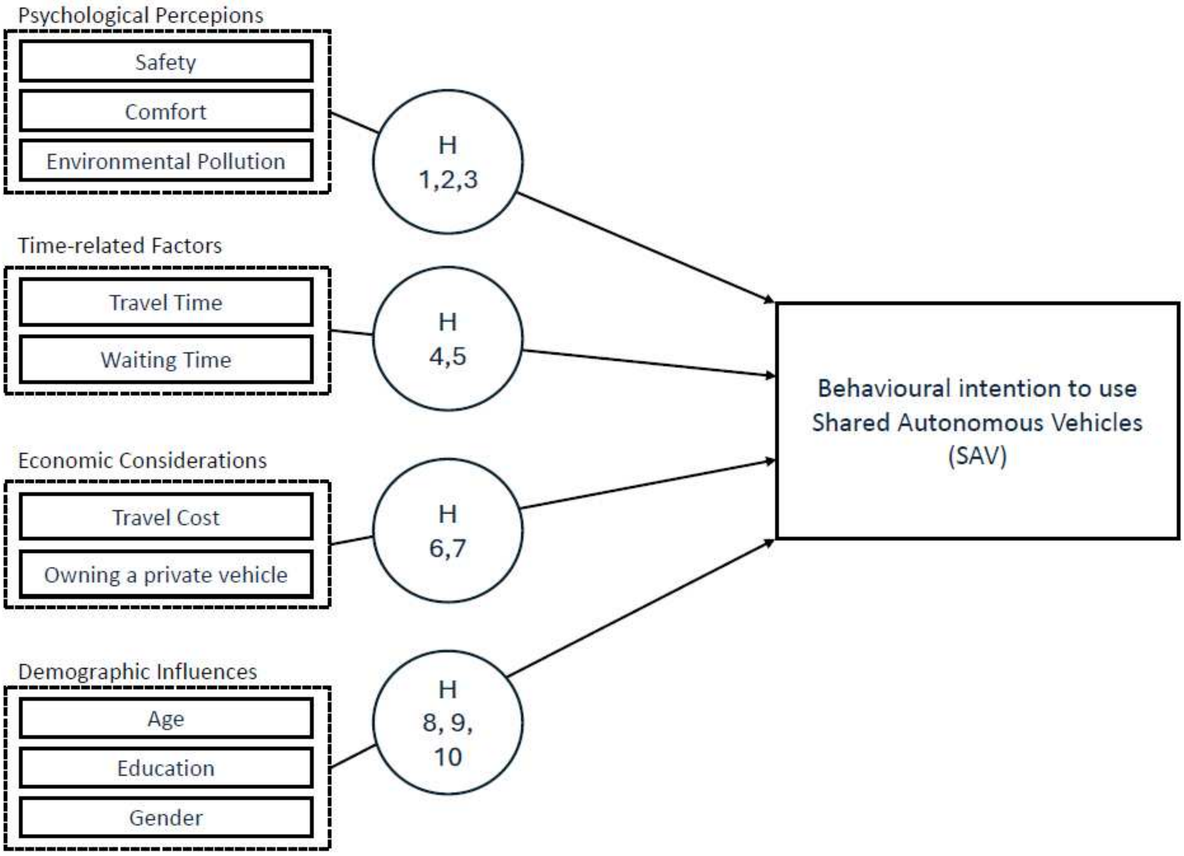


Figure 3: Conceptual Framework

5 Methodology

This study adopts a mixed methods approach, integrating qualitative insights with quantitative analysis to provide a comprehensive understanding of the research questions. The mixed methods approach enriches research findings by combining the depth of qualitative data with the breadth of quantitative data, providing a nuanced understanding of complex phenomena (Kaplan, 2015; Roxburgh & Evenden, 2015). This methodology is advantageous for exploring the acceptance of new technologies as it allows for the examination of complex user attitudes through qualitative data, whilst also allowing for the measurement of acceptance across broader populations through quantitative analysis. This dual approach facilitates a more detailed understanding of the factors that influence technology acceptance and adoption (Kaplan et al., 2014; Roxburgh & Evenden, 2015). There are various mixed methods designs, each characterised by the timing of the integration of qualitative and quantitative research. For this dissertation, the exploratory design was chosen. This particular design is advantageous when the aim is to first collect qualitative data to explore a topic in depth, followed by the application of quantitative data to further investigate the findings (Ivankova & Creswell, 2009). The integration of qualitative research helps to refine hypotheses and identify key factors to be considered in quantitative studies (Jervis & Drake, 2014). The methodological framework of this study is presented in Figure 4.

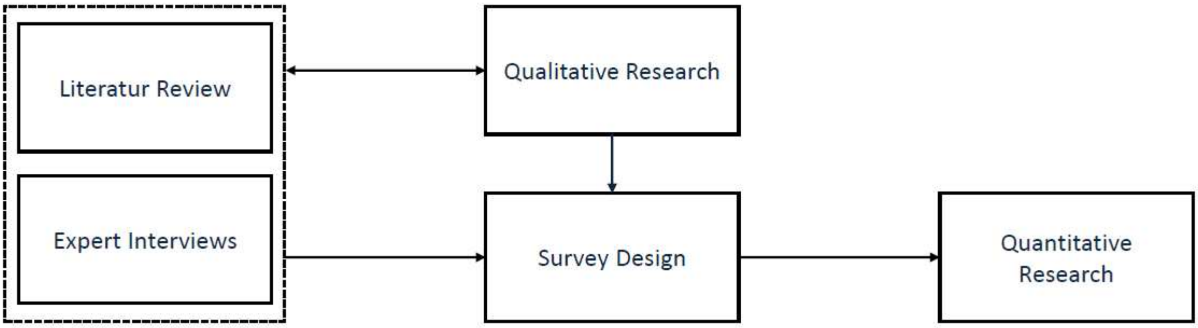


Figure 4: Methodological Framework

5.1 Literature Review

The literature review is an essential part of any research project, serving to map the current state of knowledge and developments within a particular field (Rowley & Slack, 2004). Its core purpose is to collate and synthesise existing studies, providing an important background for new research (Barker et. al, 2014). By identifying key themes and gaps in the literature, it guides the formulation of research questions and situates the study within the wider scholarly discourse. Moreover, by drawing on a wide range of sources, the literature review ensures that the research is grounded in the context of previous findings, thereby avoiding redundancy and highlighting the study's contribution to the field (Rowley & Slack, 2004; Parajuli et al., 2020).

5.2 Expert Interviews

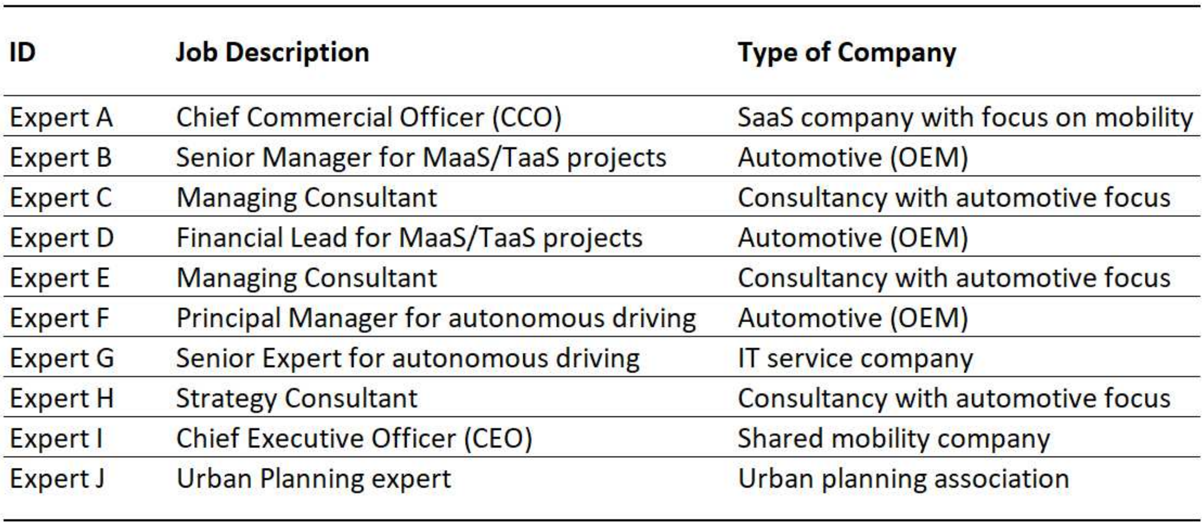
Integrating expert interviews with literature reviews is essential in research, especially when the technology in question is new and there is no direct user experience. Experts bring a wealth of knowledge about the field, as well as theoretical insights and forward-looking predictions about potential impacts and challenges. This unique perspective is invaluable, complementing existing literature by providing depth and context that written sources alone may not capture. Such interviews provide forward-looking analysis, bridging the gap between current knowledge and future possibilities, and enhancing understanding of the implications of the technology in its broader context (von Soest, 2022).

5.2.1 Semi-structured Interviews

The semi-structured interview approach is particularly effective for expert interviews in the context of emerging technologies such as SAVs, as it provides a balance between structured guidance and the freedom to explore insights beyond pre-defined questions. This method allows researchers to capture the depth of expert knowledge and nuanced perspectives on emerging technologies, while the flexibility allows for the discovery of unanticipated insights and the exploration of complex issues in greater detail (Adams, 2015).

5.2.2 Sample

The sample for the expert interviews comprised a diverse group of professionals from the mobility sector, each bringing a unique perspective based on their specific roles and experiences. Participants included high-level executives and senior managers from various areas of the automotive industries and consultancies, as well as experts in urban planning and shared mobility. All experts had extensive experience in their respective fields, with work experience ranging from 4 to 14 years, ensuring both a high level of credibility and a comprehensive insight into the current and future dynamics of mobility. The expert interviewees are listed in Table 2. The interview questions and a summary of the responses are presented in Appendix A.



ID	Job Description	Type of Company
Expert A	Chief Commercial Officer (CCO)	SaaS company with focus on mobility
Expert B	Senior Manager for MaaS/TaaS projects	Automotive (OEM)
Expert C	Managing Consultant	Consultancy with automotive focus
Expert D	Financial Lead for MaaS/TaaS projects	Automotive (OEM)
Expert E	Managing Consultant	Consultancy with automotive focus
Expert F	Principal Manager for autonomous driving	Automotive (OEM)
Expert G	Senior Expert for autonomous driving	IT service company
Expert H	Strategy Consultant	Consultancy with automotive focus
Expert I	Chief Executive Officer (CEO)	Shared mobility company
Expert J	Urban Planning expert	Urban planning association

Table 2: Expert interviewees indicating their job description and industry

5.2.3 Interview Results

There are several significant barriers to the introduction of robotaxi services in Germany. These include a strict legal framework that is more complex than in countries such as China and the US, a conservative and risk-averse attitude on the part of German car manufacturers, and the general challenge of making the business model financially viable due to high initial investment and risk. Technological maturity and the regulatory environment are also mentioned as key barriers, as is the German focus on quality, which can increase time-to-market compared to other countries. Data protection regulations are another major challenge, particularly with regard to the collection and processing of data by autonomous vehicles.

The acceptance of fully autonomous vehicles and robotaxis by the German population is seen as crucial for the successful establishment of these services. Experts underline the importance of building trust and familiarity with the technology to overcome initial concerns. They note that younger generations, tech-savvy individuals, and environmentally conscious people are more likely to be early adopters. However, there is a broad agreement that safety, time efficiency (from order to arrival at destination) and cost are the most important factors in the adoption of this technology. In particular, price is cited as a key driver for using the service, suggesting socio-demographic differences in uptake, with younger people and those in higher income groups likely to be early adopters.

5.3 Qualitative Research

Qualitative research seeks to deeply understand phenomena by capturing participant views in their own words. Hypotheses identified in the literature review can be supported and additional factors influencing the acceptance of SAVs can be explored. Naturally, the small sample size (N=10) makes it difficult to consider any extrapolation of learning as statistically valid, although there are areas for reflection (Marshall, 2015).

5.3.1 Semi-structured Interviews

Semi-structured interviews were conducted to evaluate and refine the hypotheses generated from the literature review. These interviews were conducted individually and included a mixture of open-ended and closed questions, allowing for additional probing questions to be asked (Adams, 2015). These interviews are particularly valued for their flexibility, allowing for exploration beyond structured questionnaires in order to generate and refine hypotheses (Marczyk et al., 2010).

5.3.2 Sample

In order to better understand the opinions of German consumers on autonomous vehicles and robotaxis, a qualitative consumer survey (N=10) was conducted to reflect the diverse opinions and attitudes towards this innovative technology. The survey covered a wide range of ages and occupations, from young students to retirees, to provide a comprehensive picture of public perception. Specifically, participants ranged in age from 19 to 72, and there was an equal representation of men and women to ensure gender balance. Further information on the participants and the interview questions can be found in Appendix B.

5.3.3 Interview Results

The survey results show that the use of public transport is highly variable, while the use of taxi services is rather rare. The majority of respondents had heard of autonomous vehicles, with sources of information including the media, the internet, and reports of trials in other countries. None of the respondents had experience of driverless cars, although some had direct experience of driver assistance systems. Initial reactions to autonomous vehicles and robotaxis range from curiosity and interest to scepticism and safety concerns. Safety is a prevalent theme when considering travelling in a driverless car, with the majority of respondents expressing uncertainty and the need to be able to intervene in dangerous situations. The question of whether autonomous vehicles are safer than conventional vehicles is answered in different ways, with some emphasising technological progress and others seeing mature technology and extensive testing as a prerequisite for greater safety. The perceived benefits of robotaxis include environmental friendliness, efficiency, cost savings, and the ability to perform other activities while driving. Several factors play a role in the decision to use a robotaxi, with the safety of the vehicle being the most important factor, followed by price, availability, and environmental friendliness. Entertainment and comfort are considered less important. Despite the interest in robotaxis, respondents expressed concerns about safety, emergency response, and technical failures. The ability to intervene in the journey, transparent communication about journey times, and additional services such as luggage assistance are cited as desirable features of robotaxis. The survey shows that there is interest and openness towards autonomous vehicles and robotaxis in Germany, but that this is accompanied by a number of concerns. Safety, trust in the technology, and the desire for human control in emergencies are at the forefront. While the benefits, particularly in terms of environmental friendliness and efficiency, are recognised, it is clear that the acceptance and use of robotaxis will depend heavily on further development of the technology, proof of safety, and consideration of the needs and concerns of potential users.

5.4 Quantitative Research

Quantitative research involves the consistent quantification of phenomena through the use of statistical tools to analyse numerical data. Guided by hypotheses formulated from literature review, it seeks to quantify the degree of influence of variables and identify trends within the data. This methodological framework enables an objective evaluation of the factors influencing the acceptance of SAVs in Germany.

5.4.1 Questionnaire Design and Measures

Based on the findings from the literature review and interviews, an online questionnaire was created using Qualtrics. From the literature and interviews, 30 variables were selected for investigation. Due to the limited research on factors influencing the acceptance of shared autonomous vehicles (SAVs), this survey adapted and modified elements from studies on the acceptance of autonomous vehicles (AVs), tailoring them to the shared service context of SAVs. The questionnaire predominantly used a 5-point Likert scale for responses, with options ranging from 'Do not agree at all' to 'Totally agree'. Demographic and socio-demographic information was also collected. Given that German is the native language in Germany, the questionnaire was translated into German and participants were given the option of completing it in either German or English. The questionnaire can be found in Appendix C. In addition, a pre-test was carried out with five people before the survey was distributed. This pre-testing stage is crucial for assessing the potential effectiveness of the questionnaire, allowing for refinement of the design and identification of any issues not apparent to the developers but potentially problematic for the target audience (Reynolds et al., 1993).

5.4.2 Data Collection and Sample

The survey was conducted using the Qualtrics online platform, a tool known for its extensive use in various research fields for data collection and analysis. Its appeal lies in the seamless user experience it provides and its robust analytical capabilities (Barnhoorn et al., 2014), making it a preferred choice among researchers. The survey was made available on 28 February

2024 and remained accessible until 08 March 2024. Distribution channels included a variety of social media platforms, particularly Instagram and WhatsApp, with participants encouraged to further distribute the survey. This approach effectively employed the snowball sampling technique (Scott & Vigar-Ellis, 2014). Throughout the survey period, 226 individuals participated. However, 12 respondents were disqualified at an early stage due to a screening question regarding their residence in Germany. A further 11 people participated but did not complete the survey. The number of respondents who completed the survey in full is therefore 203. The analysis was conducted with a 95% confidence interval, using a z-score (z) of 1.96 and a margin of error (e) of 7%. The standard deviation (SD) applied was 0.5, as generally recommended by Qualtrics, resulting in a calculated sample size requirement (N) of 196 individuals. The formula applied was:

$$required\ N = \frac{z^2 * SD * (1 - SD)}{e^2}$$

5.4.3 Data Analysis

Data analysis was carried out using IBM® SPSS® Statistics software. The data were initially cleaned, resulting in a final sample of 203 participants eligible for further investigation. The specific exclusion criteria applied were outlined in the previous chapter 'Data collection and sample'. To test the hypotheses, multiple regression was used to test the factors influencing the acceptance of SAVs. The two factors related to gender (0 = male, 1 = female) and car ownership (0 = not owning a car, 1 = owning a car) had to be changed to dummy variables for the regression. As the level of education correlates with the Likert scale scores, it is considered as a continuous variable and therefore included in the linear regression analysis (Pasta, 2009).

6 Results

This section systematically presents the results of statistical analysis, translating data into significant insights. It quantifies the relationships between the dependent and independent variables and provides a clear view of the patterns, trends and discrepancies identified.

6.1 Normality Test

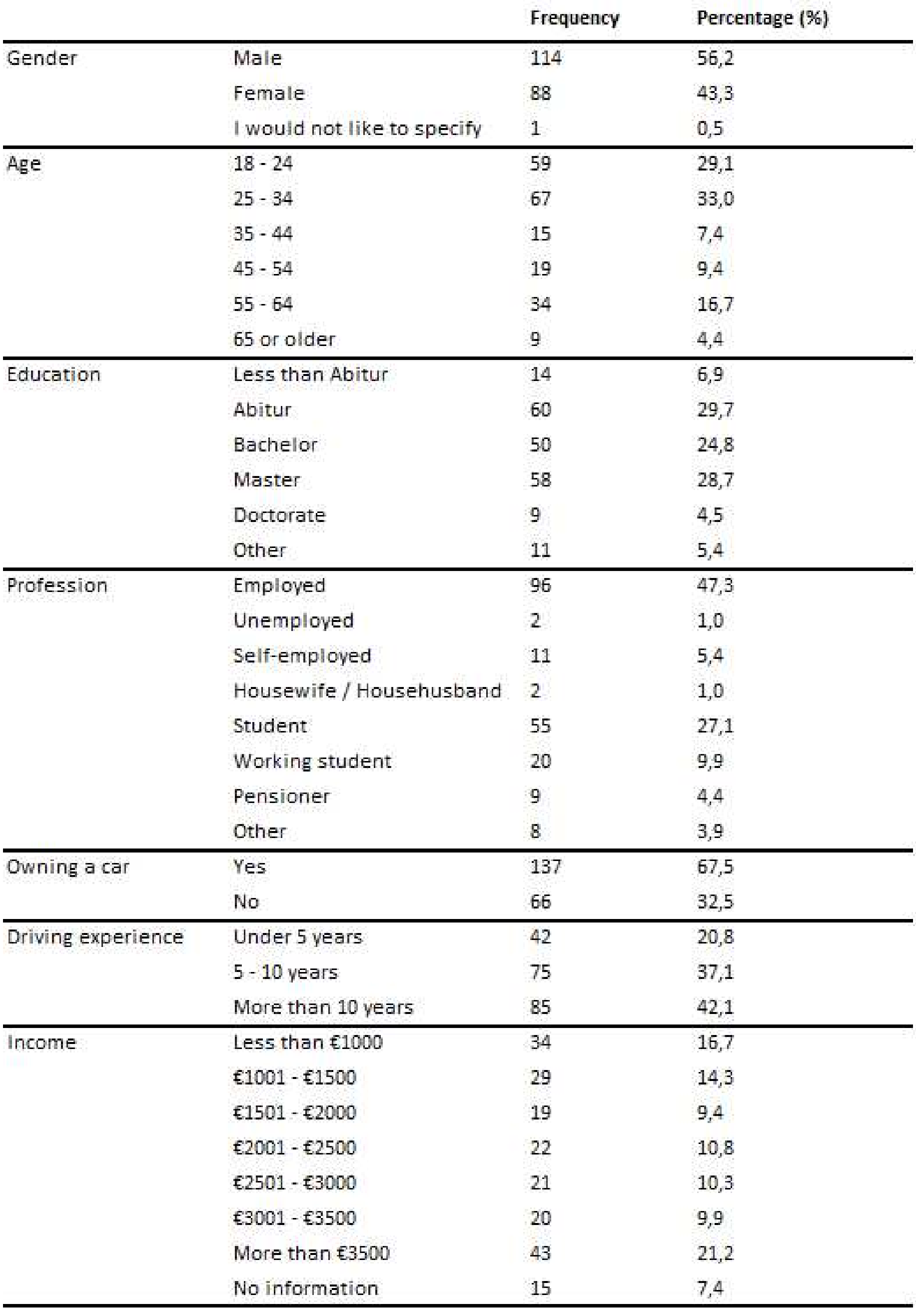
Statistical tests are used to examine the distributional characteristics of the variables. It is important to recognise that the reliability of these statistical tests increases as the sample size increases, as smaller data sets may not accurately detect deviations from normality. Therefore, the Shapiro-Wilk test was used to assess the variables due to its sensitivity to deviations from a normal distribution, providing a p-value for each variable. This analysis indicated that the variables did not follow a normal distribution, as evidenced by the low p-values (Appendix D), and therefore the null hypothesis of normality had to be rejected. Nevertheless, the central limit theorem states that under certain conditions, distributions of variables, regardless of their initial distribution, will approximate a normal distribution (Sirignano & Spiliopoulos, 2020). This premise allows for further analysis.

6.2 Independence of Observations

The survey design ensures independence of observations through randomised distribution and anonymity. By reaching a diverse and broad pool of respondents without longitudinal follow-up, each participant's response is not influenced by others, thus maintaining the integrity of the data for analysis. This cross-sectional approach reduces bias and supports the validity of statistical analyses.

6.3 Descriptive Results

Before proceeding with the hypothesis testing, an overview of the demographics of the participants is provided. The study only included participants from Germany, ensuring that all respondents were resident in Germany. The age distribution of the participants ranged from 18 to over 65 years, with a significant majority (62.1%) in the 18-34 age group. In terms of gender distribution, 56.2% of the sample were male and 43.3% female. In terms of educational attainment, the largest segment (29.7%) reported having completed secondary education, closely followed by 28.7% who had completed a Master's degree. In terms of employment status, the majority were employed (47.3%), while students accounted for 27.1% of the sample. In terms of monthly net income, individuals earning more than €3500 were predominant, accounting for 21.2% of participants, while 7.4% preferred not to disclose their income level. Car ownership was also significant among the participants, with 67.5% reporting that they owned a car. A summarised profile of the characteristics of the sample is presented in Table 3 below.



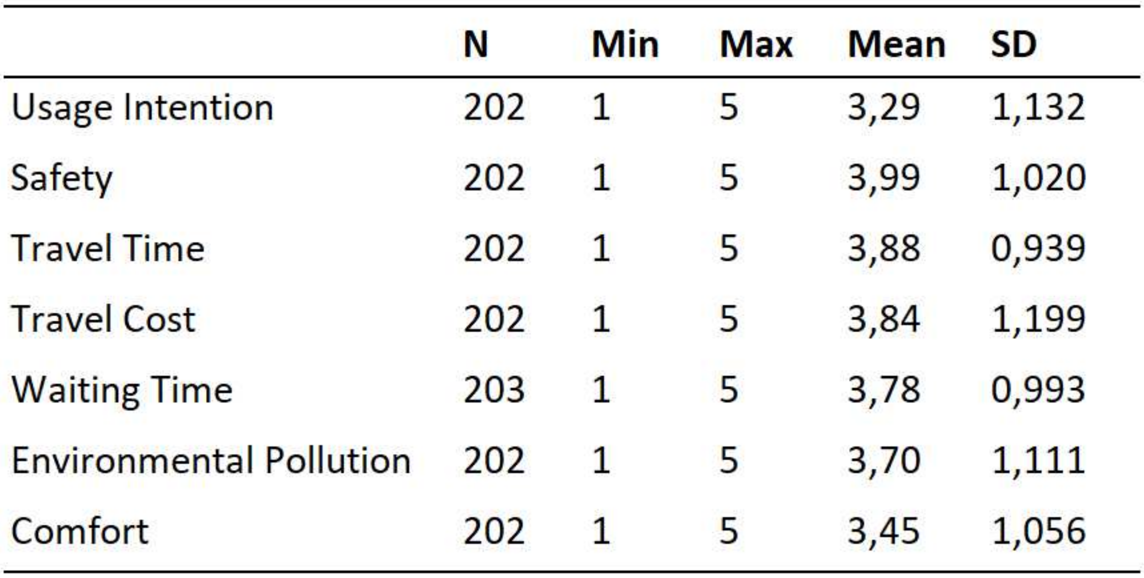
		Frequency	Percentage (%)
Gender	Male	114	56,2
	Female	88	43,3
	I would not like to specify	1	0,5
Age	18 - 24	59	29,1
	25 - 34	67	33,0
	35 - 44	15	7,4
	45 - 54	19	9,4
	55 - 64	34	16,7
	65 or older	9	4,4
Education	Less than Abitur	14	6,9
	Abitur	60	29,7
	Bachelor	50	24,8
	Master	58	28,7
	Doctorate	9	4,5
	Other	11	5,4
Profession	Employed	96	47,3
	Unemployed	2	1,0
	Self-employed	11	5,4
	Housewife / Househusband	2	1,0
	Student	55	27,1
	Working student	20	9,9
	Pensioner	9	4,4
	Other	8	3,9
Owning a car	Yes	137	67,5
	No	66	32,5
Driving experience	Under 5 years	42	20,8
	5 - 10 years	75	37,1
	More than 10 years	85	42,1
Income	Less than €1000	34	16,7
	€1001 - €1500	29	14,3
	€1501 - €2000	19	9,4
	€2001 - €2500	22	10,8
	€2501 - €3000	21	10,3
	€3001 - €3500	20	9,9
	More than €3500	43	21,2
	No information	15	7,4

Table 3: Overview over Sample Characteristics

The descriptive results of the survey are presented in Table 4. The dependent variable *Usage Intention* has a mean of 3.29, which indicates that there is no clear overall tendency regarding the intention to use SAVs considering the used 5-point Likert scale. The table furthermore includes the mean and standard deviation of the independent variables *Safety, Comfort, Environmental Pollution, Travel Time, Waiting Time,* and *Travel Cost.* The missing independent variables *Owning a car, Age, Education* and *Gender* are presented in Table 4, whereby *Age* and *Owning a private vehicle* are considered as dummy variables in the further analysis.

Factors influencing usage intention of SAVs

Analysing the descriptive results, the most important factor for the participants is safety (mean = 3.99), while the least important factor is comfort (mean = 3.45). The difference between the means of the two factors is 0.54, indicating that there is no clear tendency towards certain factors. Participants also seem to be concerned about travel time, as the mean of 3.88 indicates. This is followed by travel costs (mean = 3.84), waiting time (mean = 3.78) and environmental pollution (mean = 3.709).

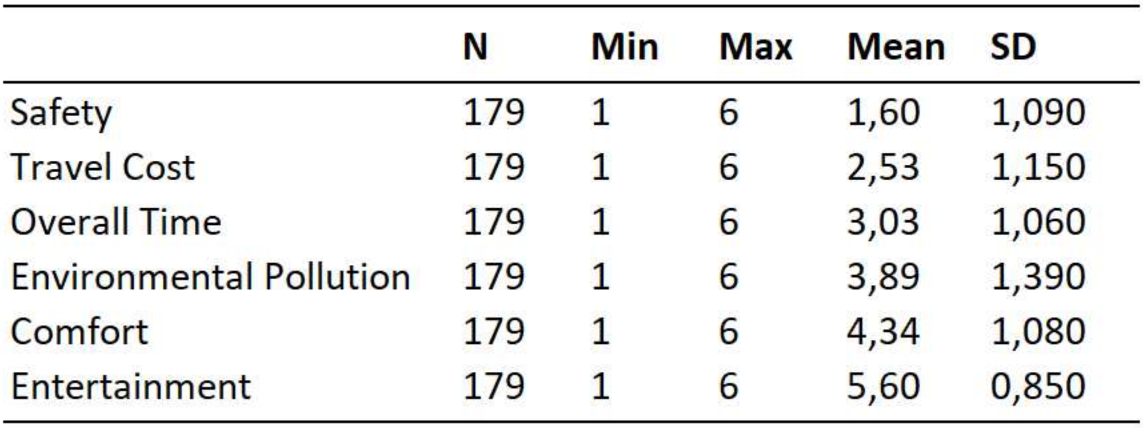


	N	Min	Max	Mean	SD
Usage Intention	202	1	5	3,29	1,132
Safety	202	1	5	3,99	1,020
Travel Time	202	1	5	3,88	0,939
Travel Cost	202	1	5	3,84	1,199
Waiting Time	203	1	5	3,78	0,993
Environmental Pollution	202	1	5	3,70	1,111
Comfort	202	1	5	3,45	1,056

Table 4: Descriptive Overview of Survey Results

In addition to the 5-point Likert scale, a ranking system (1 = most important, 6 = least important) (Table 5) was used to gain a deeper understanding of participants' preferences. This dual approach was important for two reasons. Firstly, while the Likert scale questions assess the intensity of participants' feelings towards different factors, the ranking system forces a direct comparison, providing clear insights into the relative importance of these factors. In addition, rankings help to reduce the central tendency bias often observed with Likert scale responses, where participants may tend towards neutral options (Moore, 2008). As the two factors are closely related, *Travel Time* and *Waiting Time* are combined into *Overall Time* for simplicity. In addition, the factor *Entertainment* was included in the experimental ranking. This factor is not part of the hypothesis tests as there was not enough evidence from the literature review. However, this factor was mentioned in the expert and consumer interviews, so it was included in the ranking as an exploratory finding.

By comparing the two approaches, it is important to mention that the sample size decreased since less participants finished the ranking in the survey. When analysing the results, it is noticeable that by combining *Travel Time* and *Waiting Time* into *Overall Time*, *Travel Cost* is the second most important factor, although in the Likert scale design *Travel Cost* had a lower mean than *Travel Time*. This highlights the importance of splitting *Overall Time* into two factors for hypothesis testing, as has been done in the literature. By calculating the mean of the two time-related factors in the Likert scale to summarize it to *Overall Time*, the results would be consistent with the results of the ranking approach, which explains the differences. With a mean of 5,60, the irrelevance of the factor *Entertainment* to the research question was confirmed.



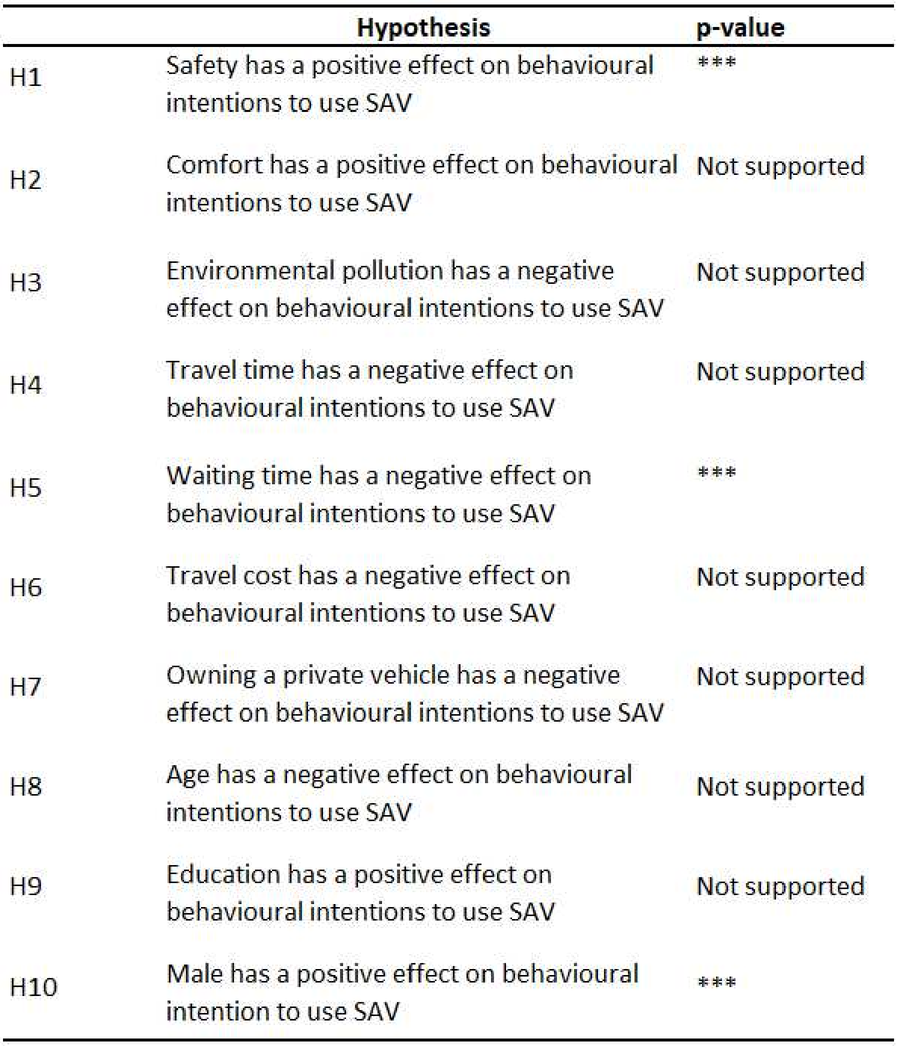
	N	Min	Max	Mean	SD
Safety	179	1	6	1,60	1,090
Travel Cost	179	1	6	2,53	1,150
Overall Time	179	1	6	3,03	1,060
Environmental Pollution	179	1	6	3,89	1,390
Comfort	179	1	6	4,34	1,080
Entertainment	179	1	6	5,60	0,850

Table 5: Descriptive Overview of experimental ranking of factors

6.4 Hypotheses Testing

The results of the regression analyses are listed in Table 6. The detailed results can be found in Appendix E. In the multiple regression, the influence *of Safety, Comfort, Environmental Pollution, Travel Time, Waiting Time, Travel Cost, Owning a Private Vehicle, Age, Education*, and *Male* as a dummy variable for *Gender* (independent variables) on intention towards the usage of SAVs (dependent variable) was explored. The R2 of the regression analysis has a value of 0.496, and thus describes approximately 50% of the variance in intention towards the usage of SAVs. The regression model is significant (F = 18.405; p < .001).

The results show that H1 (ß = 0.496; SE = 0.080; p < .001) is supported. Hence, *Safety* has a significant positive influence on behavioural intention towards the usage of SAVs. For H2 (ß = 0.023; SE = 0.060; p = .686), no significant influence on behavioural intention towards the usage of SAVs was found, and therefore can be rejected. Also H3 (ß = 0.030; SE = 0.063; p = .630) is not significant and can be rejected. In contrast to the expectations resulting from the higher mean of *Travel Time* from the descriptive results, no significant influence on behavioural intention towards the usage of SAVs was found. Thus, H4 (ß = 0.195; SE = 0.085; p = .783) can be rejected. H5 (ß = 0.195; SE = 0.085; p = .009) is supported, which means that a shorter *Waiting Time* has a significant positive influence on behavioural intention towards the usage of SAVs. Contrary to the expectations based on the descriptive results, H6 (ß = 0.051; SE = 0.061; p = .440) is not significant and therefore *Travel Cost* has no substantial influence on the dependent variable. Furthermore, H7 (ß = 0.062; SE = 0.141; p = .297) is not significant and can be rejected. When looking at the demographic factors *Age*, *Education* and *Male*, only the factor *Male* is significant. Therefore H10 (ß = 0.201; SE = 0.127; p < .001) is supported. Hence, the gender *Male* has a positive effect on the behavioural intention to use SAVs. On the other hand, H8 (ß = 0.026; SE = 0.048; p = 0,706) and H9 (ß = 0.029; SE = 0.049; p = .602) are not significant and have no substantial influence on the dependent variable.



	Hypothesis	p-value
H1	Safety has a positive effect on behavioural intentions to use SAV	***
H2	Comfort has a positive effect on behavioural intentions to use SAV	Not supported
H3	Environmental pollution has a negative effect on behavioural intentions to use SAV	Not supported
H4	Travel time has a negative effect on behavioural intentions to use SAV	Not supported
H5	Waiting time has a negative effect on behavioural intentions to use SAV	***
H6	Travel cost has a negative effect on behavioural intentions to use SAV	Not supported
H7	Owning a private vehicle has a negative effect on behavioural intentions to use SAV	Not supported
H8	Age has a negative effect on behavioural intentions to use SAV	Not supported
H9	Education has a positive effect on behavioural intentions to use SAV	Not supported
H10	Male has a positive effect on behavioural intention to use SAV	***

*Table 6: Results (*** $p < 0.01$)*

7 Discussion

The aim of this dissertation was to find out the factors influencing the acceptance of SAVs in order to better understand the perceptions and expectations of potential users of this new technology. The mean of 3.29 indicates that there is no clear overall trend in the intention to use SAVs. It is more important to understand which factors are important for the potential user of this technology in order to adopt the technology according to the user's expectations.

Psychological Perceptions

Safety, identified as a critical determinant, has a strong positive effect on the intention to use SAVs. This is in line with previous studies highlighting safety concerns as a barrier to technology adoption, but also acknowledges the potential for increased safety through automation to encourage adoption (Nazari et al., 2018; Fagnant and Kockelman, 2015). The emphasis on safety by both industry experts and potential users highlights its paramount importance in fostering trust in SAV technology (Miller et al., 2022; Patel et al., 2022). Conversely, *Comfort* does not appear to significantly influence behavioural intentions, contradicting expectations based on previous findings linking comfort to increased SAV adoption (Stoiber et al., 2019; Maghraoui et al., 2020). This discrepancy may indicate that, in the German context, comfort is overshadowed by other, more pressing concerns or expectations regarding SAV use. *Environmental Pollution* also shows no significant effect, challenging assumptions about the weight of environmental concerns in SAV adoption decisions. This finding calls for a reassessment of the impact of environmental consciousness on technology adoption and suggests complex interactions between different factors influencing SAV usage intentions (Haboucha et al., 2017; Si et al., 2023).

Time-related Factors

Contrary to expectations, the hypothesis that increased *Travel Time* would negatively affect behavioural intentions to use SAV was not supported. This finding challenges the notion of Wang et al. (2021), who highlighted the importance of travel efficiency in transport choices, and Stoiber et al. (2019), who suggested that minimising travel time could increase the adoption of pooled autonomous vehicle services. The results suggest that factors other than travel time may be more influential in determining the attractiveness of SAVs to potential users. The factor

Waiting Time was supported, indicating that shorter waiting times significantly improve behavioural intentions to use SAVs. This is consistent with the findings of Etminani-Ghasrodashti et al. (2022), who highlighted the importance of mobility efficiency, and Wang et al. (2021), who noted the universal impact of waiting time on transport choice decisions. Therefore, reducing waiting times is crucial for optimising SAV services, reinforcing the need for efficiency in new mobility solutions.

Economic Considerations

Unlike expected, *Travel Cost* did not significantly affect intentions to use SAVs. This finding differs from research by Wang et al. (2021), who found that cost significantly influenced transport preferences, and Stoiber et al. (2019), who argued the importance of cost-effectiveness in the adoption of new mobility solutions. This suggests that the perceived value of SAVs may reduce concerns about travel costs. The lack of a significant effect of *Private Vehicle Ownership* on SAV usage intentions suggests a more complex relationship than previously thought, challenging Cordera et al. (2022) assumptions about car users' openness to autonomous vehicles and Patel et al. (2022) findings about car owners' resistance to switch to alternative modes of transport. This suggests that SAVs could be complementary to, rather than competitive with private car ownership.

Demographic Influences

Age (H8) and education (H9): Neither age nor education significantly influenced intentions to use SAVs, contrary to expectations based on studies such as Hulse et al. (2018), which highlighted younger individuals' openness to AV technology, and Haboucha et al. (2017), which suggested that early AV adopters were likely to be young and highly educated. This suggests a broader demographic appeal of SAVs beyond young or highly educated individuals. The significant positive effect of *Male* (gender) on behavioural intentions towards SAV use is supported by Hulse et al. (2018), who found that men were more accepting of autonomous vehicles, and Cordera et al. (2022), who found that men were more likely to use AVs for leisure. This highlights gender as a notable factor in SAV adoption, highlighting the need for gender-sensitive approaches to the promotion of SAV technology.

In summary, this discussion highlights the complex and multifaceted nature of SAV adoption in Germany, with safety and waiting time emerging as significant factors, challenging traditional assumptions about the influence of comfort, environmental concerns, and economic considerations. These findings not only contribute to the academic discourse on SAV adoption, but also offer valuable implications for policy makers, developers, and marketers in strategically addressing consumer needs and concerns in the evolving landscape of autonomous mobility.

7.1 Management Implications

The objective of this dissertation was to explore the determinants of the acceptance of Shared Autonomous Vehicles (SAVs) in Germany, with a focus on identifying the key elements that shape consumer attitudes towards this emerging technology. The research was driven by the innovative nature of SAVs and the consequent need for a comprehensive understanding of the factors influencing their acceptance. Through a careful review of existing literature and the collection of empirical data, the study aimed to provide managers and marketers with the critical insights necessary to develop effective strategies for driving SAV adoption.

Given the paramount importance of safety in shaping the willingness to use SAVs, it is imperative for companies to prioritise and effectively communicate safety measures. This can be achieved through targeted marketing strategies that emphasise the safety benefits of SAVs, thereby directly addressing consumer safety concerns. In addition, the findings suggest that emphasising the efficiency and convenience offered by SAVs, particularly in terms of reduced waiting times, could be a key strategy in attracting potential users. Although economic factors such as travel costs and vehicle ownership are not significant barriers to the adoption of SAVs, stressing their economic benefits, such as cost savings over time, could further appeal to a wider audience. In addition, the study's findings on demographic preferences, particularly the positive reception amongst men, suggest the potential for tailored marketing campaigns to engage this demographic more effectively, while also exploring ways to broaden appeal across different consumer segments. Strategic collaboration with stakeholders, including regulators, urban planners, and the technology sector, is recommended to facilitate the seamless integration of SAVs into the urban mobility landscape. Transparent communication with the public on technological advances, safety protocols, and environmental benefits is crucial to build trust and foster positive perceptions of SAVs.

In summary, this investigation highlights the complexity of SAV acceptance in Germany, emphasising the crucial role of safety, time efficiency and targeted communication strategies. By considering these insights, stakeholders can develop solid strategies to navigate the complexities of SAV adoption and contribute to the successful integration of this transformative technology into the mobility ecosystem.

7.2 Limitations

This dissertation aimed to explore the complex landscape of Shared Autonomous Vehicles acceptance in Germany, identifying key factors that shape public attitudes towards this emerging technology. However, the results of the study and their general applicability are subject to several limitations that need to be considered.

The research on user acceptance of Shared Autonomous Vehicles undertaken in this study faced significant limitations, particularly regarding the impact of direct user experience, as highlighted in the findings of Lee et al. (2021) and Etminani-Ghasrodashti et al. (2022). Lee et al. emphasise the critical role of firsthand traveling experiences with SAVs, including the excitement and apprehension associated with the technology's novelty, in shaping user acceptance. Similarly, Etminani-Ghasrodashti et al. identify regular use of SAVs as a key factor that positively influences individuals' willingness to embrace this technology, suggesting that familiarity gained through repeated interactions can foster trust. These insights reveal a potential oversight in the dissertation’s theoretical framework and study design, indicating that it may not fully account for the nuanced effects that direct interactions with SAV technology have on user acceptance. This underscores a need for future research to delve deeper into the experiential aspects of SAV use and their consequential influence on acceptance.

While the study's focus on Germany sheds light on the country's particular automotive landscape, it also narrows the scope of its applicability due to the unique cultural, regulatory, and infrastructural contexts that define the German automotive ecosystem. This limitation in geographical scope hinders the generalisation of the findings to regions with different automotive environments. A related limitation is the demographic bias within the study sample, where an over-representation of male participants as well as a relatively low average age does not reflect Germany's demographic diversity. This bias not only threatens the applicability of the findings, but also masks the rich variance in perspectives and acceptance levels between different demographic groups. These limitations highlight the need for future research to include a larger sample as well as a wider geographical range and to ensure a demographic composition that accurately reflects the target population, thereby increasing the relevance and transferability of findings across different cultural and demographic landscapes.

Finally, the rapidly evolving nature of SAV technology and the regulatory landscape mean that findings may quickly become outdated. Ongoing research is needed to keep pace with technological advances and changes in public policy regarding autonomous vehicles.

These limitations highlight the need for a multifaceted approach to studying SAV acceptance, including direct user experience and ensuring demographic representativeness. Future studies should aim to include long-term data that capture users' evolving perceptions as they gain more experience with SAVs, alongside efforts to achieve demographic balance in the sample. Such efforts will increase the robustness and applicability of the findings and contribute to a deeper understanding of the factors influencing SAV acceptance in Germany and beyond.

8 Conclusion

This dissertation explored the factors influencing the acceptance of Shared Autonomous Vehicles in the German context, navigating the complexities of technological acceptance, societal readiness, and the broader mobility paradigm shift. This study has highlighted the multifaceted nature of SAV acceptance through a careful synthesis of literature, empirical data collection, and in-depth analysis, underscoring the critical importance of safety, the differentiated role of direct user experience, and the vital impact of societal and demographic nuances. After investigating safety as the most important factor for the acceptance of SAVs, it is crucial for industry stakeholders to prioritise and transparently communicate safety measures and advancements. The research also indicates that repeated interactions with SAV technology can build trust and familiarity, leading to more positive perceptions of SAVs.

McKinsey (2023b) highlights the crucial significance of comprehending the consumers' desires from autonomous vehicle technologies. This approach centred on the consumer is essential not only for aligning product development and marketing strategies, but also for navigating the complexities of market dynamics and consumer adoption patterns. By prioritising the identification and satisfaction of consumer needs and preferences, companies can position themselves to effectively leverage the transformative potential of AV technologies. This statement highlights the importance of continuous research and communication to identify and address consumer insights. This will enable a more effective integration of AV technologies into everyday mobility solutions and drive the evolution of the automotive industry in the age of autonomy.

8.1 Further Need for Research

The rise of SAVs as a key component of future mobility solutions requires a comprehensive study of long-term changes in consumer attitudes. As people become more experienced and familiar with SAVs over time, their perceptions, concerns, and levels of acceptance are likely to develop (Lee et al., 2021; Etminani-Ghasrodashti et al., 2022). Therefore, long-term studies are essential to understand these dynamic changes and to provide insights that could inform adaptable strategies for integrating SAVs into the social structure.

Furthermore, it is important to take a closer look at consumer insights, focusing on the nuanced preferences, fears, and expectations that individuals have about SAVs. Understanding these subtleties is critical to designing SAV technologies and their deployment strategies to effectively meet consumer needs.

Finally, while several studies have focussed on examining the adoption of SAVs in different countries, it would be valuable to know how the major markets of Asia Pacific, North America and Europe differ. After conducting the interviews with the experts, it became clear that decision makers in the respective mobility companies are unsure how to change their SAV offering to enter the European market after entering Asia Pacific or North America, based on potential user perceptions.

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Appendices

Appendix A: Expert Interview Summary

List of Interviewees

A: CCO of a SaaS company with focus on mobility
B: Senior Manager for MaaS/TaaS projects at an automotive group
C: Managing Consultant with focus on automotive
D: Financial Lead for MaaS/TaaS projects at an automotive group
E: Managing Consultant with focus on automotive
F: Principal Manager for autonomous driving at an automotive group
G: Senior Expert for autonomous driving at an IT service company
H: Strategy Consultant with focus on Automotive
I: CEO of a shared mobility company
J: Urban Planning expert

Questions and Answers (Summarised and translated from German to English)

Question 1: What were your touchpoints with (shared) mobility and (shared) autonomous driving?

A: 14 years' experience in automotive industry, including seven years of work experience at a German premium car manufacturer. Expertise in strategy and business development of electrical vehicles, SaaS in the automative sector and product compliance for autonomous driving systems.

B: 14 years working experience at a German car manufacturer, including 5 years of experience in autonomous driving. Expertise in technical matters relating to AV (sensors, KI) as well as US & China market expertise.

C: 9 years' experience in (shared) mobility with focus on different German car brands. 2.5 years of working experience in a German consultancy leading project related to autonomous driving.

D: 6 years working experience in automotive industry, including 3 years of working experience in the context of autonomous driving.

E: 6 years working experience in automotive industry, including 4 years related to autonomous driving specialised in joint venture matters and the development of business units.

F: 6 years working experience in automotive industry with focus on smart mobility and Go-To-Market strategy of autonomous vehicles.

G: 7 years working experience in the field of automotive industry with focus on consultancy of digital products for autonomous vehicles.

H: 4 years of work experience in automotive industry, including different consultancy projects related to mobility services and autonomous driving.

I: Founder and 12 years' experience as a CEO of two different shared mobility companies. Expertise in autonomous buses and autonomous air taxis.

J: 8 years' experience in connected mobility and mobility as a service in German urban cities.

Question 2: Can you imagine robotaxis becoming established as a publicly accessible service in Germany in the future? And if so, when?

A: Approximately, the service will be available from 2029 but only limited in terms of number of vehicles as well as different locations.

B: Approximately, the service will be available in Germany in 2028/2029.

C: Fully autonomous driving taxis will be available in Germany around 2030.

D: If the current plans of the German car manufacturers are realised, then I assume that the service will be offered in one of the major German cities from 2027.

E: A time horizon is extremely vague because experience shows that any planning in the past was overambitious on the part of both the OEMs and the tech companies dealing with the topic. I therefore believe that it will be at least 2030 before the service is offered commercially in Germany.

F: In 2029 in some first cities and five years later in most major European cities.

G: I think by 2030 we will have a completely different car driving in Germany than we do now, including the usage of SAV in the big cities of Germany.

H: Approximately, the service will be available in Germany by 2033.

I: N/A

J: By 2028, cities like Hamburg and Munich will offer a first commercial service but it will take up to five more years for the service to become widespread in the bigger cities of Germany.

Question 3: What could be the decisive obstacles that prevent this service from becoming established in Germany?

A: The legal framework for AV and SAV in Germany is clearly defined and one of the best ones for level 4 AV and SAV, but more difficult for companies to navigate than in other countries such as China and the US, where the approach is somewhat more move fast and risk-taking. Often companies first operate in their domestic market and German car manufacturers are more conservative and risk-averse, which makes the process of entering the market with a new technology longer. This is also connected to the fact that these companies do not want to accept the liability.

B: The rollout of this technology in Europe will be more of a gradual, slower process. The fundamentals of the technology are in place, and the offering is already functioning in China and the US. However, their existing products are not yet scalable to the European and thus also to the German market, so I assume that European car manufacturers will offer their service in the future in Germany but not the ones currently operating in the US and China.

C: In the end, you want to earn money with every business model and that is not possible in the SAV sector at the moment. You need large investors or partnerships and the whole thing comes with an increased risk factor, as it is still a very new market.

D: In Germany, it has only recently become law that autonomous driving and testing are permitted. In California, for example, a similar law has been in place for much longer and therefore the experience with testing and therefore also the progress in technology is greater.

E: The two biggest obstacles at the moment are the maturity of the technology and the regulations. The technology must be ~~so~~ mature enough that the error rate of a self-driving car is lower than the error rate of a human driver, and this is not yet the case. This is often due to unforeseeable situations to which the technology sometimes still has no answers.

F: The biggest problem in Germany is that the whole business model has to be accepted in the first place. And that is independent of autonomous driving. Pooled riding, which is now also offered by a Moja in Hamburg, for example, is not yet an accepted form of mobility throughout Germany and Europe.

G: Germany attaches great importance to quality. As a result, it takes longer to launch a product in Germany than in other countries, such as the US or China, because quality standards take time. But I would not describe this as a problem, because the quality standard is important in order to stand out from the competition. In connection with this, there is also the topic of regulations, which also guarantees quality, and thus also the important topic of safety.

H: The biggest problem is regulation, especially when it comes to data protection. A lot of data is collected in these cars, such as monitoring and filming the surroundings. In Germany, for example, you are not authorised to be filmed inside the taxi. But how is the provider supposed to check that you are responsible for any damage?

I: Regulation and complexity of traffic are high.

J: The biggest hurdles at present are the acceptance of the new technology and the complex authorisation process at municipal level.

Question 4: What role does the German population's “acceptance” of fully autonomous driving and robotaxis play?

A: A big and important role. I think we are certainly used to high quality here in Germany as an automotive country. You must familiarise yourself with a technology for it to have a chance on a broad scale.

B: Acceptance always plays a crucial role when it comes to introducing new technologies to the market. The US and China are significantly more open to accepting new technologies and are generally much more technologically inclined than the European market. This is also one of the reasons why the rollout of technology in these two countries is progressing much better than in Europe.

C: Compared to other countries, the German and European population in general are very cautious when it comes to accepting new technologies. Therefore, the relevant companies have a responsibility to create a sense of security among users.

D: It is important to create trust and acceptance, otherwise people will not use the technology and the business model will not work.

E: Acceptance is important, but it depends on the maturity of the technology. And in the AV/SAV case, it is not yet mature enough.

F: N/A

G: Acceptance can often be the biggest problem when it comes to the launch of new technologies.

H: It is like any other new technology. Acceptance is very important, but it is a time-dependent process that is coupled with the amount of experience you gather.

I: Acceptance is an important factor. But acceptance is influenced a lot by changing environmental factors. If there are no more drivers in the future, people will accept the technology rather than waiting for a railway.

J: In my opinion, acceptance currently plays the biggest role when it comes to AV and SAV. The technology will be very mature in a few years. But that will not help the service providers if the population does not accept the technology and therefore will not use it.

Question 5: How do you rate the current attitude of the German population towards fully autonomous driving and robotaxis?

A: In Germany, a lot is about trust in car brands and the associated feeling of safety and quality. It will take time for the majority of the German population to trust and accept AV and SAV, as many people are risk-averse at first and need longer to build trust in new technologies.

B: In Germany, we have very high regulations regarding new technologies, such as AV and SAV. Once these are all met and SAVs have been sufficiently tested, acceptance of this technology will also develop in Germany.

C: The majority of people do not yet have trust in this technology. The issue of trust in AV/SAV is very volatile, as a single accident that is publicised in the media can change everything again. It is typical that not everything runs smoothly in disruptive technology cycles and this example is specifically about car accidents. But then the question is how to deal with it and, unlike in the US, there is no widespread failure culture in Germany.

D: In Germany, confidence in technology is not yet as high as it is in the US, so I think you really have to give people time to develop a feeling for it so that they are not afraid to drive. In the US, there are many people who simply want to try something new and are curious. We also have this kind of people in Germany, but not enough to make the German market attractive for a rollout of this technology.

E: As soon as the population realises the environmental benefits of this technology, acceptance will also increase, especially among the younger generation in Germany.

F: The concept of Pooled Riding is not yet widely accepted. Once this is the case, autonomous driving itself will be the smaller obstacle.

G: In Germany, people are used to high quality, especially in the automotive industry. Assuming that when a German car manufacturer launches an SAV the trust in German car brands will continue to exist, then this service will also be widely accepted.

H: It always depends on the amount of experience. People who have tested AV already are more likely to accept the technology as well as SAV in the future. But in general, people in Germany are still rather sceptical especially before testing it the first time.

I: The majority of the German population is still very cautious.

J: Many Germans are curious about the development of autonomous driving. However, there is still too little urge to use such technology on a regular basis.

Question 6: What are the most crucial factors for the acceptance of this technology and why?

A: Safety is the most important factor. Additionally, the time from starting the order to arriving at the destination and price are really important.

B: Safety is the most important aspect, which must always be present. However, I also believe that people need to try out this technology first to accept it. The apprehension towards a driverless taxi is initially high before the ride, but one quickly gets used to it, and it becomes the norm.

C: Safety will be the basis. And it is therefore important that this safety is signalled by the service providers and car manufacturers. If this is the case, then the population is concerned with the outcome, namely time savings.

D: The first and most important factor is safety. The second most important topic is performance. In other words, how long do I wait for the car, how quickly can I get from A to B and how reliable is the autonomous vehicle. The third point to mention here is the price, which should be lower than alternative offers such as Uber.

E: The decisive factor for acceptance is safety. Other points could be comfort and entertainment because these are points that could give the user the incentive to use an SAV instead of a private vehicle.

F: The two factors, how quickly I can get from A to B and how expensive it is, are really crucial. Of course, safety is also an important issue, but the user no longer worries about this after the second ride, instead he is more concerned about time and money. This also has to do with the fact that people will assume that the technology is safe, otherwise it would not be offered on the European market.

G: The most important issue is the experience with the new technology. After two or three rides, the user will be much more likely to accept SAV than before. Comfort and entertainment will then be very important, as these are issues that could be different from other mobility services.

H: The most important factor is the price. Although experience with the technology is important for the acceptance, you only gain experience if you can afford it. The topics of comfort and entertainment also play a major role, because this is where SAVs will differ greatly from conventional cars in the future.

I: Availability of "cheap drivers". As long as there are people who drive taxis for lower wages, it will be difficult. As soon as this is no longer the case and people have to fall back on alternatives (for the taxi use case), the tide will turn.

J: Safety, price, and time between ordering and arriving at the destination.

Question 7: Are there any (socio) demographic differences in when it comes to the acceptance of robotaxis?

A: In terms of adoption, you will certainly see a classic approach in that there will be many technology-savvy early adopters who also dare to tackle the topic including young target groups with an affinity for technology. The topic will be cool. People will be happy to talk about their first robotaxi ride. You can already see this coming from the US and China on social media today. Furthermore, people who may not be able to drive a car themselves, either not yet or no longer, are more likely to use the service. Either not yet or no longer. But in the end the price will have a big influence on who can afford the service.

B: Young people will rather accept SAV especially right after the rollout.

C: The younger generations are naturally more open to such technological advances and innovations than the older generations, especially when the issue of environmental friendliness is also taken into account.

D: First of all, you have to differentiate between the generations that regularly use their smartphone and those that do not. As this is of course also the basis for ordering such a taxi. In addition, older people are generally more sceptical about new technologies and often remain loyal to familiar concepts.

E: Our younger generation pays a lot of attention to environmental impact. Once it becomes clear that SAV could have a significant advantage in this area, I can imagine that this generation will be more likely to use the service than older people.

F: Younger people are generally more mobile and more on the move than older people, so they are more likely to accept the technology and use it more.

G: N/A

H: There will be the classic early adopter model. In addition, the service will initially be somewhat more expensive compared to alternatives, so that primarily people from higher income groups will use the service.

I: N/A

J: Nowadays, many people in large cities no longer have their own car and rely on car sharing or public transport. So I think people from urban areas in particular, who do not have their own car, will accept the SAV service and therefore also use it.

Appendix B: Qualitative Interview

Participants:

A: Male, 20, Student
B: Male, 54, Employee
C: Female, 56, Employee
D: Female, 19, Student
E: Male, 71, Pensioner
F: Female, 24, Student
G: Female, 32, Employee
H: Male, 45, Employee
I: Male, 68, Pensioner

Questions:

1. How often do you use public transport?
2. How often do you use services such as taxis, Uber, Freenow etc.?
3. Have you heard of autonomous vehicles?
4. Have you heard of Shared autonomous vehicles or robotaxis?
5. Have you had any experience with AV or driver assistance systems?
6. What was your first impression/perception of AVs?
7. How safe do you feel at the thought of travelling in a driverless vehicle?
8. Do you think that autonomous vehicles are safer than conventional vehicles? Please give reasons for your answer.
9. What advantages do you see in using SAVs compared to traditional taxis?
10. How important are the following factors for you when deciding to use a SAV? Rate each factor from 1 (not important) to 5 (very important):
    - Price of the journey
    - Waiting time
    - Journey time
    - Safety of the vehicle
    - Entertainment
    - Comfort
    - Environmental friendliness
11. Under what circumstances would you prefer a robotaxi to a conventional taxi?
12. What concerns do you have regarding the use of autonomous vehicles?
13. What additional services or features should robotaxis offer to be attractive to you?
14. Do you see SAVs as an important part of future mobility? Why or why not?
15. Would you encourage friends or family to use SAVs? Why or why not? Or rather advise against it?

Appendix C: Quantitative Research

Relevant Survey Questions

Socio-demographics

- Do you live or is your main place of residence in Germany? (Necessary for further questions)
- Do you own a private vehicle? (H7: *Owning a private vehicle*)
- How old are you? (H8: *Age*)
- What is your highest level of education? (H9: *Education*)
- What is your gender? (H10: *Male*)
- What is your current occupation?
- What is your monthly income after taxes?
- How much driving experience do you have?

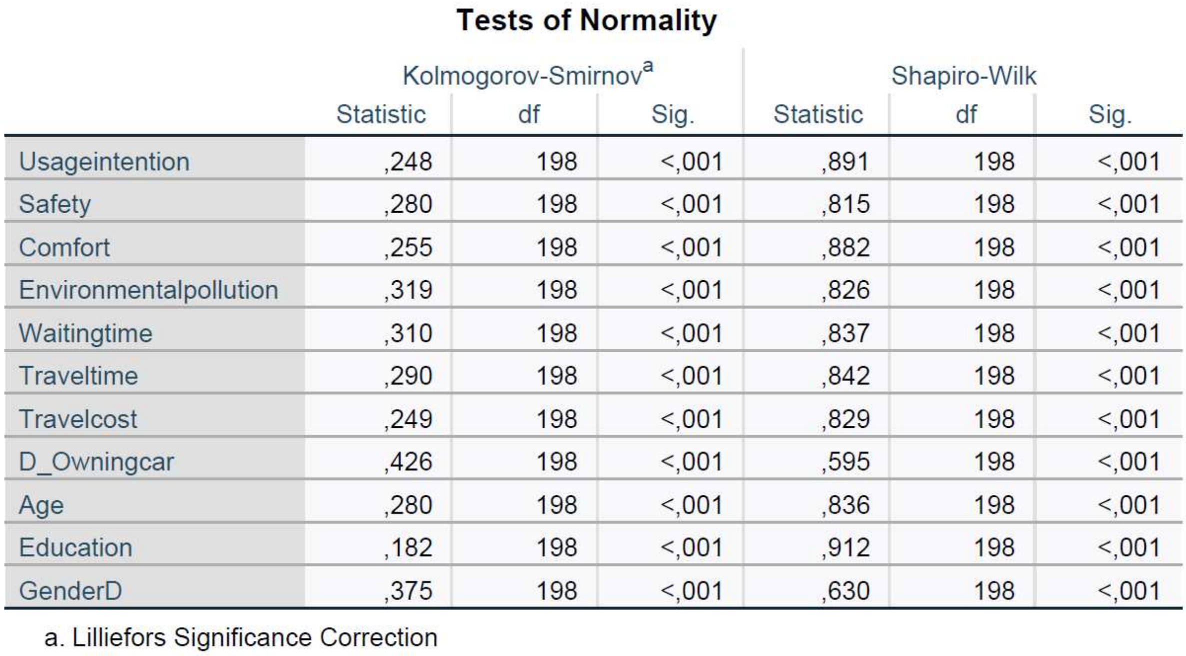
Dependent Variable

- I can imagine using SAVs on a regular basis.

Independent Variables

- I can imagine using SAVs if the technology is guaranteed to be safe. (H1: *Safety*)
- I would use SAVs if they are more comfortable than alternative transportation services. (H2: *Comfort*)
- A higher environmental pollution level compared to alternative transportation services would be a major factor to not use SAVs. (H3: *Environmental Pollution*)
- I can imagine using SAVs if the travel time in comparison to alternative services is significantly lower. (H4: *Travel Time*)
- I would use SAVs if the waiting time in comparison to alternative services is significantly lower. (H5: *Waiting Time*)
- The price would be a major factor in my consideration of using SAVs. (H6: *Travel Cost*)

Appendix D: Normality Test

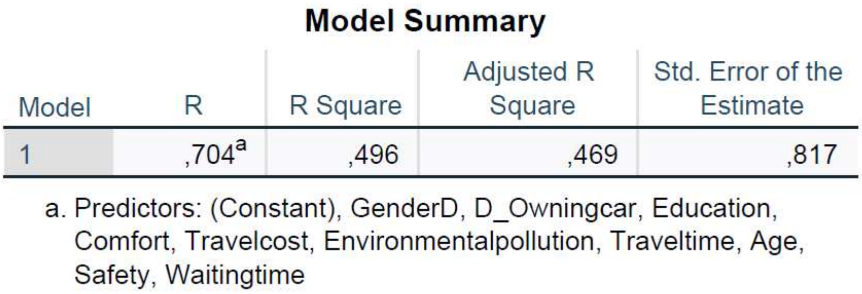


Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Usageintention	,248	198	<,001	,891	198	<,001
Safety	,280	198	<,001	,815	198	<,001
Comfort	,255	198	<,001	,882	198	<,001
Environmentalpollution	,319	198	<,001	,826	198	<,001
Waitingtime	,310	198	<,001	,837	198	<,001
Traveltime	,290	198	<,001	,842	198	<,001
Travelcost	,249	198	<,001	,829	198	<,001
D_Owningcar	,426	198	<,001	,595	198	<,001
Age	,280	198	<,001	,836	198	<,001
Education	,182	198	<,001	,912	198	<,001
GenderD	,375	198	<,001	,630	198	<,001

a. Lilliefors Significance Correction

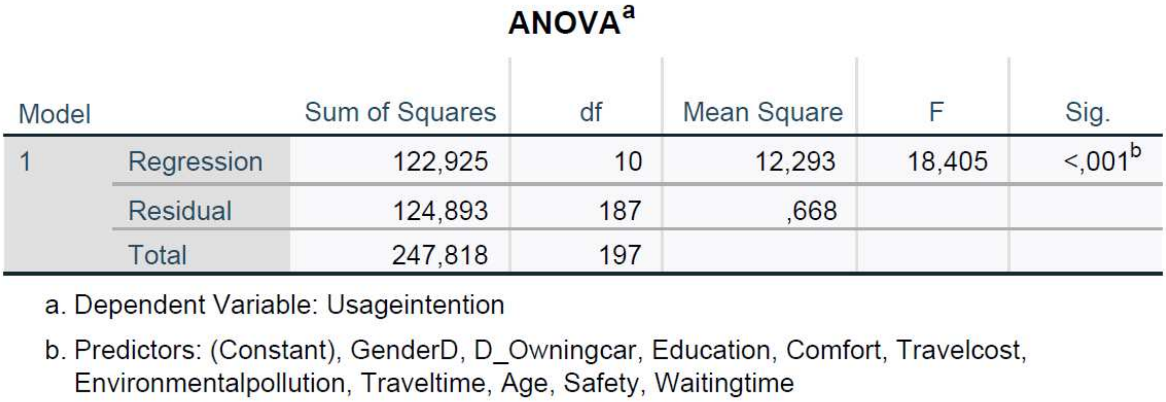
Appendix E: Regression Model



Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,704[a]	,496	,469	,817

a. Predictors: (Constant), GenderD, D_Owningcar, Education, Comfort, Travelcost, Environmentalpollution, Traveltime, Age, Safety, Waitingtime

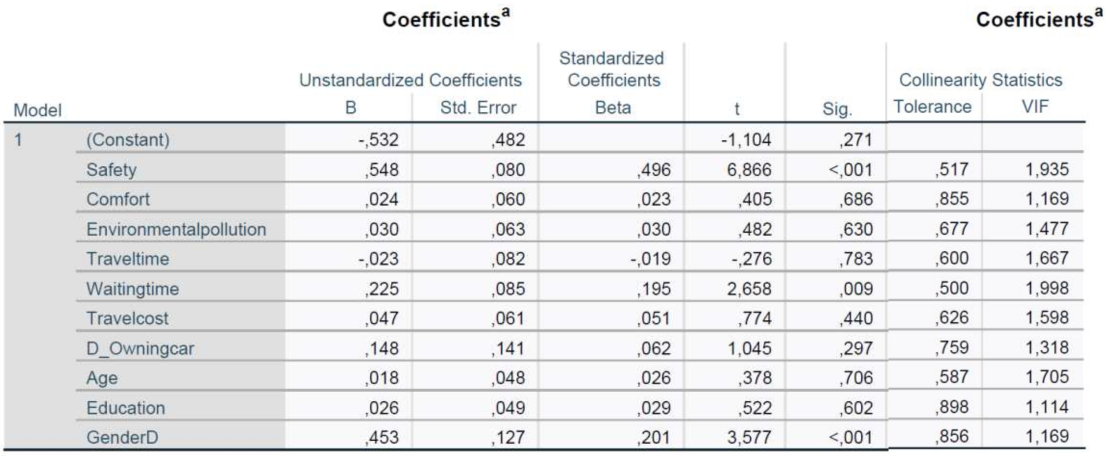


ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	122,925	10	12,293	18,405	<,001[b]
	Residual	124,893	187	,668		
	Total	247,818	197			

a. Dependent Variable: Usageintention

b. Predictors: (Constant), GenderD, D_Owningcar, Education, Comfort, Travelcost, Environmentalpollution, Traveltime, Age, Safety, Waitingtime



Coefficients[a] **Coefficients[a]**

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	-,532	,482		-1,104	,271		
	Safety	,548	,080	,496	6,866	<,001	,517	1,935
	Comfort	,024	,060	,023	,405	,686	,855	1,169
	Environmentalpollution	,030	,063	,030	,482	,630	,677	1,477
	Traveltime	-,023	,082	-,019	-,276	,783	,600	1,667
	Waitingtime	,225	,085	,195	2,658	,009	,500	1,998
	Travelcost	,047	,061	,051	,774	,440	,626	1,598
	D_Owningcar	,148	,141	,062	1,045	,297	,759	1,318
	Age	,018	,048	,026	,378	,706	,587	1,705
	Education	,026	,049	,029	,522	,602	,898	1,114
	GenderD	,453	,127	,201	3,577	<,001	,856	1,169