The Impact of Level 5 Shared Autonomous Vehicles on Suburbanization in Munich

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Abstract

Title: "The Impact of Level 5 Shared Autonomous Vehicles on Suburbanization in Munich"

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Keywords: *autonomous driving, shared autonomous vehicles, robo-taxi, suburbanization, digital transformation, mobility*

Shared autonomous vehicles (SAVs) with an autonomy level of 5 (full automation) are able to provide a combination of taxi-services and conventional car-sharing. The research presented in this dissertation focuses on understanding the perception of Munich residents towards the phenomenon of suburbanization by the introduction of SAVs. The results show that the introduction of SAVs with autonomy level 5 will still take a couple of years. The focus should now be on use cases for level 4 autonomous robo-buses, which are able to link not so well-connected localities to the public transportation system of Munich. The survey showed that (1) a decrease in fuel costs was the leading factor why Munich citizens would move out the city. Insights from literature about previous suburbanization as well as from expert and consumer interviews revealed that suburbanization in Munich will be driven by desire for (2) an increase in comfort, (3) a decrease in travel time and (4) a decrease in travel cost. The results from Munich were not applicable to other cities. Finally, SAVs will impact where citizens will be living in the future. Predicting an exact course of suburbanization in Munich was not possible. This newly generated knowledge is intended to serve as initial preliminary information for urban design and planning institutions.

Sumário

Título: "O impacto dos veículos autónomos partilhados de nível 5 na suburbanização em Munique"

Autor: Yannick Lorentz

Palavras-chave: *condução autónoma, veículos autónomos partilhados, robo-taxi, suburbanização, transformação digital, mobilidade*

Os veículos autónomos partilhados (SAV) com um nível de autonomia de 5 (automação completa) são capazes de fornecer uma combinação de serviços de táxi e de partilha de automóveis convencionais. A investigação apresentada nesta dissertação centra-se na compreensão da percepção dos residentes de Munique sobre o fenómeno da suburbanização através da introdução dos SAV. Os resultados mostram que a introdução de SAV com nível de autonomia 5 levará ainda alguns anos. O foco deve agora ser em casos de utilização de autocarros robotizados autónomos de nível 4, capazes de ligar localidades não tão bem ligadas ao sistema de transportes públicos de Munique. O inquérito mostrou que (1) uma diminuição dos custos de combustível foi o principal factor que levou os cidadãos de Munique a deslocarem-se para fora da cidade. As informações da literatura sobre a suburbanização anterior, bem como de entrevistas a peritos e consumidores revelaram que a suburbanização em Munique será impulsionada pelo desejo de (2) um aumento do conforto, (3) uma diminuição do tempo de viagem e (4) uma diminuição dos custos de viagem. Os resultados de Munique não foram aplicáveis a outras cidades. Finalmente, os SAV terão impacto onde os cidadãos irão viver no futuro. Não foi possível prever um curso exacto de suburbanização em Munique. Este conhecimento recentemente gerado destina-se a servir como informação preliminar inicial para as instituições de concepção e planeamento urbano.

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Glossary

AD	Autonomous Driving (Automation Level 3 to 5)
ADS	Automation Driving System
ADAS	Advanced Driver Assistance System
AV	Autonomous Vehicle (Automation Level 3 to 5)
BASt	German Federal Highway Research Institute
CAV	Connected Autonomous Vehicle
CBD	Central Business District
DRS	Dynamic Ridesharing
G_{city}	Germany City
M_{city}	Munich City
NHTSA	National Highway Traffic Safety Administration
OEM	Original Equipment Manufacturer
ROW_{city}	Rest of the World City
SAE	Society of Automotive Engineers
SAV	Shared Autonomous Vehicles (Automation Level 5)
TNC	Transport Network Companies
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VKT	Vehicle-Kilometres-Travelled

1 Introduction

Cities have been and remain the locus of human economic activity and well-being. It is predicted that by 2050 almost 2/3 of humanity will live in urban regions (Ritchie & Roser, 2018). At the same time, cities are already struggling to cope with growing populations. Increasing commuter traffic, associated traffic emissions and congestion, rising housing costs, noise, infrastructural constraints, etc., present challenges for most cities in the future (Alberti et al., 2019).

The full effects of the COVID-19 pandemic are still unclear. It can be assumed, nevertheless, that urban living, characterized by proximity and density of people, smaller average living conditions, and less availability of green spaces, is being evaluated more critically. On the other hand, urban flight to avoid congestion, coupled with people seeking a better quality of life in the suburbs, are gaining popularity. Living on the outskirts of cities is associated with larger accommodations, greater proximity to nature, and better prospects for raising families (Bogost, 2020; Hughes, 2020).

With the rise of autonomous vehicles (AV) and development of its enabling technology, it is a matter of time before we see level 5, full automation (Manyika et al., 2013), AVs dominating the roads which will cause cities to change radically (Schmidt et al., 2018). Within on-demand service providers as Uber and Lyft, the trend towards a carless world is accelerating. The capabilities are enormous, and a potential use case could look like this: A user opens his/her app, orders a driverless car that picks him/her up and potentially others along the way and drops him/her off at his/her final destination. Allowing to pick up more people seamless and without congestion on its way, can reduce the impact on the environment, travel time and safety (Octavius, 2017).

The aim of this study is to examine consumer behavior regarding the extent to which residents of cities are going to move out of the inner circle of a city as soon as shared autonomous vehicles (SAVs) are fully adopted. The driving intuition of this thesis is that the impact with an autonomy level 5 (full automation) of SAVs will be great and significant, with vehicles allowing people to commute, without any human input, safely from one place to the other. For this dissertation, Munich and its surrounding suburbs are used as an example use case.

1.1 Relevance

AVs are described as an emerging technology by several sources suggesting that this technology will disrupt the automotive industry (Kaur & Rampersad, 2018; Manyika et al., 2013; NHTSA, 2013). Through accurate computing systems, AVs will reduce traffic congestion. Accidents are 93% due to human failure, and reducing 25% of all traffic congestion, roadway capacity would save around $488 billion in material damage, injuries and deaths (Fagnant & Kockelman, 2015; Jonas et al., 2014).

Additionally, productivity during driving can be increased. Commuting time can be spent working according to Diamandis (2014) and this would save $447.1 billion per year in the US alone, and $5.6 trillion worldwide (Jonas et al., 2014). With a penetration rate of 90% of AVs, there would be work hour savings of 2.7 billion in daily work commutes (Diamandis, 2014). Once AVs are put into sharing activity, fewer cars are needed. The effects of AVs are expected to extend to every facet of a country's economy (Clements & Kockelman, 2017).

The topic of AVs is well-researched. It is important not only to understand the impacts of AVs on people's mobility, but also what the collateral effects will be for the economic land use of cities. Current research is mainly concentrated on describing the technology. The impact of level 5 SAVs as a causal trend towards suburbanization has not previously been discussed. With this dissertation, I aim to close this literature gap.

1.2 Research Questions

The following research questions will be answered in the context of this dissertation.

Main research question:

To what extent do shared autonomous vehicles, with an autonomy level of 5, impact the phenomenon of suburbanization in Munich?

Additional research question:

Are the results from Munich replicable for other cities?

2 Literature Review

This section outlines the theoretical foundations and academic concepts related to the following topics: Autonomous vehicles, their technology and the use case of shared autonomous vehicles (SAV), as well as the challenges they are facing. Additionally, the concept of suburbanization, theories and city of Munich and its suburbs are presented. Lastly, the current state of the literature about AVs and suburbanization are elaborated.

2.1 Autonomous Vehicles

Autonomous vehicles are driverless or self-driving vehicles that operate without human intervention (Benenson et al., 2008; NHTSA, 2013; Paden et al., 2016). The Society of Automotive Engineers (SAE) standard, presented in section 2.1.2, or the National Highway Traffic Safety Administration (NHTSA) and the German Federal Highway Research Institute (BASt) standard, are classifications used to categorize AVs (Kyriakidis et al., 2015).

From the internet and smartphone revolution along with drones and the internet of things, AVs have been acknowledged as one of the key technological disruptors for future research (Manyika et al., 2013; NHTSA, 2013). Clayton Christensen (1997) proposed in the *Innovator's Dilemma* that "products based on disruptive technologies are typically cheaper, simpler, smaller, and, frequently, more convenient to use" (Christensen, 1997, p. 11). This has resulted in many companies and governments engaging in efforts to address challenges of driverless cars and developing strategies to implement this technology (Schoettle & Sivak, 2014).

There are two potential AV applications that could redefine the way people travel in the future (Collingwood, 2017; Gruel & Stanford, 2016; Maurer et al., 2016). The first is private ownership of autonomous vehicles: citizens would purchase autonomous vehicle for private usage from the OEM. The second application, the use case this dissertation focuses on, is an on-demand service in the form of an SAV. Commercial AVs are used for public transportation (E.g., Uber, Lyft), bus and freight services. In particular, SAV's, which are also called driverless taxis/robo-taxis, have the potential to complement or completely substitute public transportation. (Faisal et al., 2019).

2.1.1 Technology

Technology used in autonomous vehicles is similar to many robotic systems. It replicates a three-phase design: "sense-plan-act" (Behere & Törngren, 2015; J. DiClemente; S. Mogos; R.

Wang, 2014; Siciliano & Khatib, 2016). One of the challenges for AVs is sensing the dynamic and complex driving environment which demands complex geolocation systems through connections with a variety of cameras, radars and sensors. The surveillance technology used in AVs is a Lidar[1] measuring methodology (Bagloee et al., 2016).

High volumes of data are collected and are forwarded to the corresponding computer system, and a software recommends suitable courses of action. Tasks like accelerating, breaking, lane changing and overtaking occur without any human interaction (Bagloee et al., 2016). It is important to note that the SAE defines different levels of automation, and an AV is only autonomous if *localization*, *perception* and *planning* are conducted by the automated driving system of the car (Faisal et al., 2019; SAE, 2016). From level 3 onwards, all cars are defined as autonomous (Swan, 2019).

2.1.2 Levels of Automation

The NHTSA has been the first to introduce a 4-level taxonomy of vehicle autonomation in 2013 (Bagloee et al., 2016). One year later, the SAE introduced its 5-level principle and updated it in 2016 (Coppola & Morisio, 2016; SAE, 2016). The classification starts at level 0, describing zero automation. Level 2 is the state in which Tesla is currently at (Swan, 2019). Self-driving vehicles are defined from level 4 on, as vehicles fully autonomous and without human interaction. Level 5 describes full automation, and the human driver does not have to take over any driving capabilities in any operational scenario. The SAE taxonomy represents the industry standard and is frequently cited in the literature (Rubin, 2016; Walker & Marchau, 2017).

In the recent years, many companies have AV pilot projects. Waymo, one of the pioneers of autonomous vehicles, has reached levels 3 and 4 of automation on closed roads (Bailo et al., 2018). Besides Waymo, Lyft and Uber, as on-demand service providers, are interested in having public road readiness cars ready as this could enhance their commuting strategy (Business Insider, 2016) although Uber has abandoned its in-house AV research initiative in December 2020 and Lyft never had one (Kollowe, 2020).

Table 1 displays the *operational functions* and *capabilities* of the *automated driving system (ADS)* and *human driver* for each level of automation.

[1] Distance measuring method using laser light to illuminate a target and measure its reflection (Tang & Shao, 2015).

Table 1: Different level of driving automation (according to Faisal et al., 2019; based on SAE J3016).

Level of automation	**Automated driving system**		**Human driver**	
	Operational function	Capability	Operational function	Capability
Level 0 (No automation, the driver performs all tasks)	n/a	n/a	Localisation Perception Planning Management	In all driving modes
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	
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 to that of human driver in every driving scenario)	Control: lateral and longitudinal Localisation Perception Planning Management	In all driving modes	n/a	n/a

2.1.3 Shared Autonomous Vehicles

Autonomous vehicles are used in both, the private and the commercial vehicle sector (Collingwood, 2017; Gruel & Stanford, 2016; Maurer et al., 2016). SAV, also called commercial vehicles, driverless taxi, robo-taxis etc., are vehicles that are operated as bus, taxi and

freight services. They provide a wide range of services as a combination of taxi-services and conventional car-sharing. (Fagnant & Kockelman, 2015; Krueger et al., 2016) For the purpose of this dissertation, the following differentiation will be proposed: 'short-term car-sharing' (customer has control over the vehicle for a short amount of time) and point-to-point car-sharing (SAVs move customer only between pickup and drop-off point) (Hyland & Mahmassani, 2017). The SAV system discussed throughout this dissertation corresponds to the latter type, as its impacts on short-term car sharing have not been discussed in many articles yet (Narayanan et al., 2020). The trend appears to be that SAVs will supplement traditional public transport services. This substitution of conventional taxis and private cars will be helped by low prices, the fact that people can multitask during a ride and shorter travel time (Krueger et al., 2016; Malokin et al., 2019; Milakis et al., 2017). Through SAVs, transport network companies (TNC) will be able to engage in potential profit maximizing while optimizing rideshares compared to conventional TNCs and taxi services (Fagnant & Kockelman, 2015).

2.1.4 Challenges

Although the technology of AVs is improving, challenges remain that must be addressed by automotive incumbents, governments and TNCs. There are five main challenges for AVs: (a) Safety, (b) Infrastructure, (c) Legal, (d) Ethics and (e) Business.

(a) Safety Challenge

The biggest limitation concerning AVs is safety (Bagloee et al., 2016; Fagnant & Kockelman, 2015). The computer systems must have high computing power and work under all conditions, including weather, road and traffic. Reliability and safety are key to successfully implementing autonomous vehicles in roads of the future (Koopman & Wagner, 2017; Martínez-Díaz & Soriguera, 2018).

Operating vehicles without human occupants increases the risk of targeted manipulation and sabotage for illegal activities and terrorist attacks (Fagnant & Kockelman, 2015; Wollschlaeger et al., 2017). The connectivity needed makes it impossible to isolate the autonomous vehicle and thus shield it from attacks. Any security concept for operation without a security driver must therefore ensure the greatest possible protection against attacks on the system. Insofar as control of vehicles via radio data transmission is possible, additional security requirements exist, especially for protection against sabotage and cybersecurity (Maurer et al., 2016).

An example of a failure of an AV was the incident of an Uber self-driving car that accidentally killed a pedestrian in March 2018. This represents just one of several incidents that occurred

and are major setbacks for implementation of AVs. (Zaveri, 2019) For market adoption, it is important that consumer trust and acceptance are ensured (Kaur & Rampersad, 2018).

(b) Infrastructural Challenge

Partly because of their high communication needs, AVs have different requirements from conventional vehicles. AVs must become connected autonomous vehicles (CAV), able to communicate with the cloud, infrastructure, mobile phones, etc., termed vehicle-to-infrastructure (V2I) communication. The transport infrastructure networks are not yet fully equipped for AVs and must be adapted. (Kallmeyer, 2019; Martínez-Díaz & Soriguera, 2018). There is also data exchange with the vehicle manufacturer, vehicle-to-x (V2X) communication to the direct environment, networking with traffic management systems as well as vehicle-to-vehicle (V2V) communication (Martínez-Díaz & Soriguera, 2018; Zeadally et al., 2012).

In addition, the speed of data exchange is important. The 5G mobile radio standard enhances communication in real time. This, among other things, enables outsourcing of vehicle calculation processes. To continuously transport the data in real time, an expansion of nationwide network coverage is necessary for operating autonomous vehicles (Shaheen et al., 2018).

(c) Legal Challenge

According to German law, in the event that the operation of a motor vehicle "[...] kills a person, injures the body or health of a person or damages a property [...]" the user or its owner is primarily liable (Bundesgesetzblatt, 2003, p. 14). However, the user of the vehicle cannot be prosecuted to the same extent when driving occurs without a driver, analogous to a passenger in a bus working autonomously (Johanning & Mildner, 2015).

The legislator must therefore redefine the axes of fault where different parties are potentially liable for damages caused by autonomous vehicles: E.g., the manufacturer, the software supplier and the insurance company (Johanning & Mildner, 2015). There is no doubt that this problem is complex, but clear legal clarifications are necessary, otherwise the path towards adoption of AVs will be more problematic (Eisenkopf et al., 2017). The European Commission is already working on finding a coherent legal solution (European Commission, 2017).

(d) Ethical Challenge

Ethics surrounding self-driving vehicles will influence their acceptance in society. This is already apparent after several recent accidents that have provoked debates about driverless

driving (Kallmeyer, 2019), especially concerning questions in so-called *dilemma situations* about whether to privilege the life of a passenger over a pedestrian (Bonnefon et al., 2016).

The system algorithm of autonomous vehicles requires behavioral instructions, even in conflict and dangerous situations. The challenge is to find a socially acceptable, ethical consensus on how the autonomous vehicle should behave in a dilemma situation, for example, when the choice is between killing a child (pedestrian) or elderly person (occupant). Additionally, there is also the dilemma of the *trolley problem* which entails deciding whether to divert the direction of a vehicle to save many people versus preserving the life of one person (Henry et al., 2017). The MIT Media Lab, in cooperation with the Scalable Cooperation Media Group, provides a simulator that allows users to experience the same moral dilemma an AV would. This *moral machine* enables crowdsourcing ethical issues for machines (Massachusetts Institute of Technology, 2018).

Dilemma situations must be kept to a minimum. If the scale of ethical issues can be reduced, barriers for the introduction of the technology can be lowered (Kallmeyer, 2019).

(e) Business and Managerial Challenge

With rising flexibility of public transportation, the system boundaries between public transport, on-demand services, neighborhood transport and taxi services are disappearing (Beckmann & Sammer, 2016). In the future, public transport will be exposed to competition that has not existed up to now, and against which it will have to assert itself (Franckx & Mayeres, 2016).

The production of conventional vehicles essentially involves design and technical development (hardware). Autonomous vehicles, on the other hand, also require a great deal of electronic-technical development (software). Ultimately, software will become the most important distinguishing feature of a vehicle (Serban et al., 2018).

As a result, manufacturers in the automotive industry that have been active to date will be increasingly exposed to competition from the software industry (Johanning & Mildner, 2015). These disruptive players are primarily large companies from the information technology sector (IT sector) with large amounts of investment capital (E.g., Google, Apple, etc.). An attractive business opportunity is evolving with new parties emerging in the market of autonomous vehicles. For the companies in the IT sector, replacing the human driver represents growth in demand for services (Bertoncello & Wee, 2015).

The challenge for automotive incumbent's will be how to position themselves in this emerging market. It is to be expected that in twenty to thirty years the automotive industry will be hardly recognizable (Johanning & Mildner, 2015; Kallmeyer, 2019).

2.2 Suburbanization

Suburbanization is the expansion of cities into their surrounding areas caused by urban exodus, and the associated intraregional shift in growth of population, production, trade and services from a city's core to urban surroundings. Suburbanization leads to a variety of spatial planning problems between the city and its environment (E.g., increased traffic loads from commuter traffic) and to a loss of function of the core city (Mieszkowski & Mills, 1993).

The extent of suburbanization can be measured by focusing on how the population density function changes over time (Mills & Tan, 1980).

$$D(x) = a * e^{-bx} \quad (1)$$

D(x) represents the population density relative to a distance, *x,* from the city center. The parameter *a* is an estimate for the density at the city center, as *b* represents the population density gradient (measurement of rate by which population density falls with distance). The extent of suburbanization that has taken place over a certain period of time can be measured by the percentage change in the gradient of population density function (Mills & Tan, 1980).

2.2.1 Suburbanization Theories

Urban economists, geographers and historians have proposed different suburbanization theories over the years. The standard theory of suburbanization explains that it is a phenomenon driven by a combination of rising incomes and technological progress. The spatial distribution of households is affected by transportation innovations such as subways, commuter rails, automobiles and streetcars as they lower the time cost of intra-urban travel. Those, able to afford the new technology move to outlying areas, which represents a trade-off swapping expensive apartment for cheaper land and more spacious houses. With rising income and technological progress improving, the relative price of new transportation modes is declining and more urban households are adapting to this technology (Kopecky & Suen, 2010).

Warner (1978) supports the standard theory of suburbanization by discovering that the introduction of streetcars in the city of Boston led to the first movements of wealthy households to the suburbs throughout the 1850's and the 1860's. Additionally, Taylor (1966) argued that the

invention of commuter rail, streetcar and omnibus transportation encouraged city inhabitants to travel to work and live outside of the city. Also, Kopecky & Suen (2010) recently added that diffusion of the automobile is concurrent with suburbanization. Driving forces of suburbanization include rising real incomes, falling automobile prices, urban population growth, and changing costs of traveling by car and with public transportation (Kopecky & Suen, 2010, p. 1). Lastly, Baum-Snow (2007) stated that "between 1950 and 1990, the aggregate population of central cities in the United States declined by 17 percent despite population growth of 72 percent in metropolitan areas as a whole." This decline is attributed to the new interstate highway system reducing average travel time from suburbs to the central business districts (CBD) of metropolitan areas (Baum-Snow, 2007). Baum-Snow and others posit *land use* theory, developed by Alonso (1964), which predicted that "faster commuting times push up the demand for space in suburbs relative to central cities".

2.2.2 Munich and its Suburbs

The literature does not provide a clear definition of suburbs in Germany. It can be stated that suburbs are an outlying part of a city or town representing a smaller community adjacent to and within commuting distance of a city (Cambridge Dictionary, n.d.).

The suburbs of Munich can be defined by the politically associated district, the Munich district, districts geographically bordering to Munich such as Dachau, Fürstenfeldbruck and Starnberg, and additionally the districts Bad Tölz Wolfratshausen, Ebersberg, Erding and Freising that are part of the *Münchner Verkehrs- und Tarifverbund (MVV)*, Munich Transport and Tariff Association (MVV, 2020). These districts are located in short commuting distance to the CBD of the city and can so be defined as suburbs. 176 communities form the greater Munich economic area. They are networked with each other through the MVV. The entire area covers 5.711 square kilometers and provides mobility for almost 3 million people, almost 1.5 million of whom live in Munich and just as many in the surrounding area (MVV, 2020).

Munich's suburbs are superior in most respects to the city. In suburbs such as Haar, Neubiberg and Unterföhring, families can save an average of 18 percent on rents and 29 percent on real estate costs compared to the big city. In addition, people live in space that is 16 percent larger on average. Munich's suburbs also offer a quieter environment, 47 percent more leisure facilities (playgrounds, swimming pools, cinemas and sports clubs) and greater safety in terms of road traffic and crime. Even in terms of employment, the cities in the Munich suburbs are better positioned than the Bavarian capital. The proportion of employees subject to social

insurance contributions at the place of work is 28 percent higher in the suburbs than in the big city (Borngaesser, 2019).

2.3 AVs and Suburbanization

It is clear that autonomous vehicles in form of on-demand services are entering the market and their effects must be analysed thoroughly (Möller et al., 2019; Schmidt et al., 2018; Stead & Vaddadi, 2019).

Swan (2019) states that AVs will reduce the frequency of accidents, reduce congestion and lower the opportunity costs of travelling - suburbanization will be a likely result of these effects. Stead & Vaddadi (2019) analysed two opposing perspectives on the way AVs could disrupt land use and the environment. They suggest that "the quality of the built environment will be improved (re-centralization or regeneration of inner areas, re-densification, land use changes to new green public areas, residential locations). AVs are seen as a way of promoting better quality of life in cities" (Stead & Vaddadi, 2019, p. 126). A contrary view predicts that "the built environment will be reshaped to accommodate the needs of AVs and their users in preference to the needs of other social groups. AVs increase suburbanization or sprawl due to the comfort of trips" (Stead & Vaddadi, 2019, p. 126). Gibson (2017) agrees with the notion that suburbanization and sprawl will be exacerbated by ease of travel.

And lastly, Faisal et al. (2019) state that one of the "frequently claimed benefits of AVs in the literature are that they will reduce congestion through optimum use of road spaces using the platooning technology". An alternative view is that multitasking during commuting will result in more suburbanization and urban sprawl, increasing vehicle kilometres travelled (VKT) and using more road space. Faisal et al. (2019) also states that the claim that AV's increase ride sharing is debatable and should be further researched.

3 Methodology

Our methods of empirical data collection are presented in this section of the dissertation.

3.1 Research Approach and Design

The main objective is to understand the effects of level 5 full autonomy SAVs on residential decision making and their related consequences for the phenomenon of suburbanization in Munich. Through expert interviews, survey analyses and consumer interviews, we examined the perception of Munich citizens. In a second step, the results were compared with other cities.

This Master Thesis is structured with two research questions. To answer the main research question, analyses are displayed in sections 4.2 and 4.3, based on descriptive knowledge from the survey and qualitative feedback from consumers and experts. In 4.4.2 factors influencing the suburbanization are analyzed using regressions. As they represent likert-likert type variables (1 to 5), normal procedure would be an Ordinal Regression. But, Hair et al. (2015) justified that Multiple Regression can also be used for ordinal data representing likert-likert type questions. Research question 1 will be answered in chapter 4.4.4. With research question 2, a larger picture of the impact of SAVs on the phenomenon is considered. For this purpose, subjects from Munich, other cities in Germany and around the world were polled. The results from Munich city serve as a reference value. The general procedure of this dissertation was that the results from the literature were compared with knowledge from the experts interviewed. On the basis of the discussions with experts from different fields, the survey questionnaire could be compared.

3.2 Data Collection

For the purpose of answering the two research questions, both primary and secondary data have been chosen as relevant sources.

3.2.1 Primary Data

Three different primary data sources were used in this dissertation.

Expert Interviews

Expert interviews provided an important basis for creating the survey and answering the research questions. Semi-structured and guideline-based interviews were used as a methodology. Furthermore, by sending the interview guide in advance, experts could prepare

answers. The purpose of both – semi-structured and guideline-based interviews – was to enable the interviewees to answer more openly and freely.

The interviews were conducted in the last week of November 2020. The interviewer communicated the goals of the work at the beginning and pointed out that the interview would be recorded and transcribed anonymously. Thus, a verbal declaration of consent was requested for this. Due to the current pandemic situation and the geographical distance, the interviews were conducted online via *Zoom*, with the exception of Experts B and D where the interviews were conducted in written form only. All interview partners were selected based on their backgrounds and functions in their companies.

The expert interview partners are presented in Table 2. The interview guide and the responses are listed in Appendix I and II.

Table 2: Expert interview partners indicating their job description, industry and the employer range of revenue of 2019.

ID	Job Description	Type of Company	Range of Revenue (2019)
Expert A	Consulting and Urban Planning	Munich Planning Association	Public institution
Expert B	Research associate in the Chair of Transportation Systems Engineering	Higher Education & Research (Technical University Munich)	-
Expert C	Head of Department Test Field Drive (incl. AVs)	Automotive (OEM)	€ 80 – 120 billion
Expert D	Traffic Engineer	Startup, on-demand Platform Provider (subsidiary of German railway company)	€ 40 – 50 billion (parent company)

Survey

For the purpose of testing consumer perceptions, a survey was created with the software *Qualtrics*. To ensure that a broad network of people participated in the survey, people from *LinkedIn*, *Facebook*, *WhatsApp*, *Instagram* and various professional groups were targeted. For this purpose, well-known groups with up to 35,000 participants in the field of autonomous driving and city/town planning were considered. The survey was also shared on notice boards at Munich universities. Respondents were categorized according to their current place of residence. For this purpose, location-related questions were asked at the beginning of the survey, in which the users were divided into six different observational groups. The questions

were adapted to the respective group. More information about the exact questions can be found in Appendix III. SPSS was used as the analysis tool. 238 people participated in the survey.

Consumer Interviews

Following the survey, three additional consumers were directly asked about their qualitative opinions on the questions in the survey. These subjects were either born in Munich or currently still live there. Two interviews were accomplished in person as group interviews. The third interview was conducted via *Zoom* due to the geographical as well as pandemic situation.

3.2.2 Secondary Data

In addition to primary data sources, secondary sources were also used and analyzed. The main focus of the literature research on autonomous driving was reports from Tier A consultancy firms, other urban planning institutions and the journals of Transportation Research part A, C and F of the last 3 to 5 years. As this is still a fairly new technology, previous sources would be far outdated and could not provide accurate forecasts and developments. On the contrary, suburbanization, Grade A and other urban research journals were used to state suburbanization as a significant phenomenon. These articles could already reach far into the 20th century. For the analysis and the reference to Munich, articles of German newspapers have additionally been taken into account.

4 Findings and Discussion

This section is focusing on the results from the research including literature review, survey analyses, expert and consumer interviews. The subsections are summarized into the different steps that had to be taken into account when answering the main research question 1 in section 4.4.4 and the additional research question 2 in 4.5.2. Prior to this, general demographic results of the study are presented in 4.1.

4.1 Demographic Survey Results

The potential sample of the study represented 238 respondents. 7 respondents chose not to accept the terms and conditions (n = 231). Another 54 respondents did not participate correctly in the survey by not answering all questions or by stopping the survey early (n = 177). Finally, 18 respondents failed the control question by not clicking on *somewhat likely*. These responses also had to be removed from the study to arrive at a final sample of n = 159. The sample size that was achieved, is considered sufficient.

The participants of the survey are mostly from Germany (72.3%) and are evenly distributed with the exception of France (4.6%), Netherlands (3.1%), Austria (3.1%) and USA (3.1%). For the classification and subsequent analysis of the groups to be studied in this survey, new variable *groups* and *city* sets were created. More than two thirds of the respondents (67.1%) live in a city. Looking at the observation group, it can be seen that most of the data comes from rest of the world city (also ROW_{city}; 29.6%), followed by Munich city (also M_{city}; 20.8%) and Germany city (also $G_{city;}$ = 17.0%). The gender distribution is almost identical distributed (male = 52.8%, female = 46.5% and diverse = 0.6%). The survey was mainly answered by younger people. The age group breakdown is 18 - 24 years (37.1%), closely followed by 25 - 34 years (34.6%) which reflect the core of the respondents. In this case, few conclusions can be drawn about the very young versus the older generation.

A summary of the core demographic variables is provided in Table 3, and additional demographic information about the respondents is appended in Appendix IV.

4.2 Munich Metropolitan Area

In the following section results from the expert interview with the urban planner as well as results from the consumer interviews with Munich residents are discussed. This information is backed by data obtained from the survey.

Table 3: Key demographic variables of respondent group (own presentation).

Variable	Category	Sample	Ratio	Mean	Mode	SD
gender	Male	84	52.8	1.48	1	.583
	Female	74	46.5			
	Divers	1	0.6			
groups	Munich city	33	20.8	-	-	-
	Munich suburb	23	14.5			
	Germany city	27	17.0			
	Germany sub-urb/rural	14	8.8			
	Rest of the world city	47	29.6			
	Rest of the world suburb/rural	15	9.4			
national-ity	Germany	115	72.3	-	-	-
	not Germany	44	27.7			
city	city	107	67.3	-	-	-
	suburb or rural	52	22.7			
agegroup	Under 18	2	1.3	3.19	2	1.374
	18 – 24	59	37.1			
	25 – 34	55	34.6			
	35 – 44	12	7.5			
	45 – 54	15	9.4			
	55 – 64	13	8.2			
	65 or older	3	1.9			
Total	-	159	100	-	-	-

4.2.1 Definition and Differences in Munich City and Suburbs

Expert A confirmed that when speaking of Munich suburbs, one may use it to describe the adjacent counties. This reflects the results from the literature.

> *„The concept of the suburb does not exist at all in the current discussion on spatial structure in Munich. […] In principle, however, it is not completely wrong to call the districts around Munich suburbs." (Expert A, 2020)*

The results are graphically displayed in Figure 1. The inner ring reflects the state capital of Bavaria, Munich. The outer eight counties represent and include the surrounding suburbs.

A notable difference between the county and the city of Munich is the cost of land. With the exception of the district of Starnberg, price level in all surrounding cities is significantly lower

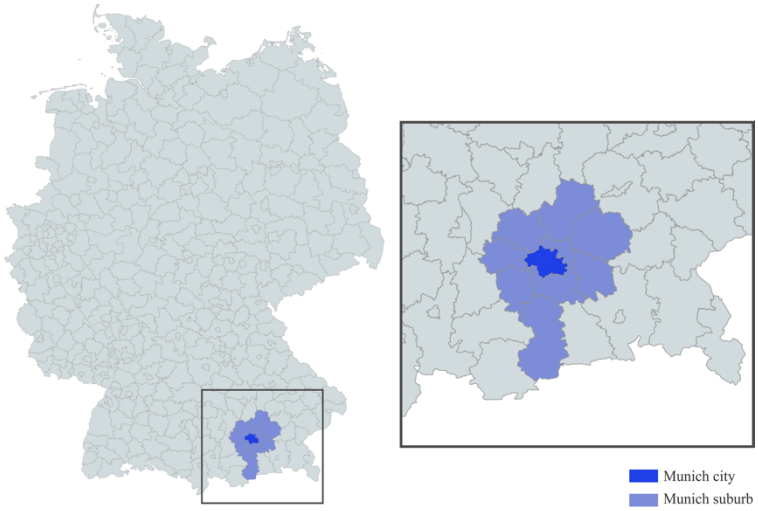

Figure 1: Munich city and its corresponding suburban region (own presentation).

(Consumer A, 2020). Other differences between Munich city and the suburbs are user behaviors with cars, represented by the variable *car ownership.* Almost 74 % of the respondents in the suburbs of Munich stated that they are owners of a car. In comparison, only about 42% of Munich city residents indicated that they own a car, see Appendix IV. The two most popular alternatives to cars (*car_alternative)* among participants are public transportation (M_{city} = 38% ; M_{suburb} = 45%) and bicycles (M_{city} = 36% ; M_{suburb} = 36%). As the third most popular, city participants indicated that they prefer walking (M_{city} = 14%) while in the suburbs, participants prefer using the services of transportation network companies such as Uber and Lyft (M_{suburb} = 45%). Due to the small size of the sample, a comparison of weekly car use (*car_usage)* is not reasonable.

4.2.2 Land Settlement Decisions in Munich Metropolitan Area

The land settlement decisions in the Munich Metropolitan area differ between respondents. Residents of the city (n = 33) prefer to live near the city center (n = 27), near their job (n = 19), and family and friends (n = 11) as well as the price (n = 10) are important to them. In contrast, the most important reasons for the residents of the suburbs value a garden (n = 12) and the proximity to nature (n = 12), followed by a large living space (n = 11) and family and friends (n = 11). Other reasons indicated by the residents of the city are the proximity to the university, the offer of nightlife and the proximity to places with a wide range of activities. Figure 2 represents relative values for the stacked boxes. Through this, a comparison of preferences can be drawn.

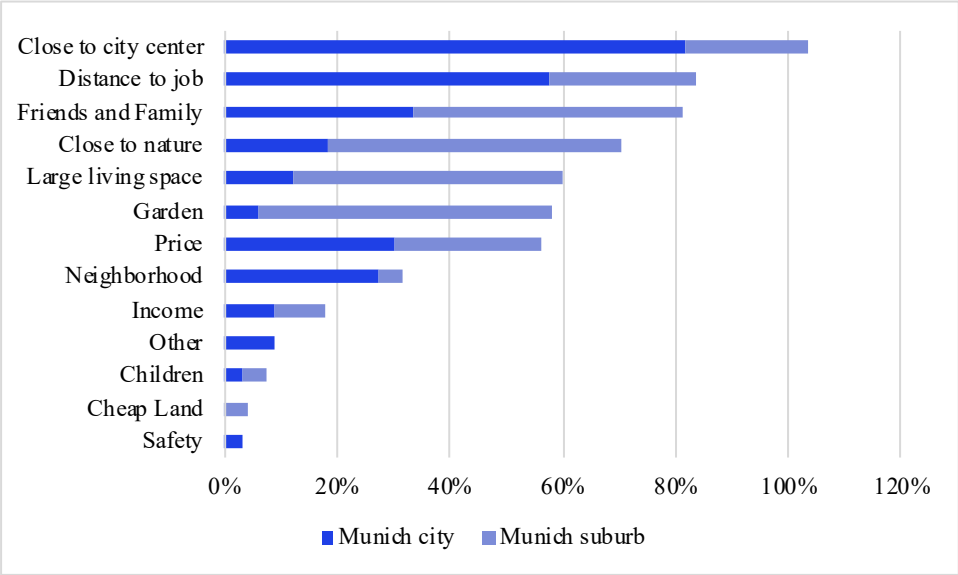

Figure 2: Relative land settlement preferences of citizens from the Munich metropolitan area (own presentation).

The results from the survey are also consistent with statements from the consumer interviews. Consumer A and Consumer B (2020) stated that Munich is still unique when it comes to where one lives. Since Munich has expensive public transportation compared to other cities, it is even more important to live within walking distance of the most important facilities.

4.2.3 Current Suburbanization in Munich Metropolitan Area

> *„In the period from 2008 to 2018, both the surrounding area and the city have grown considerably.“ (Expert A, 2020).*

Expert A (2020) stated that the city had a slight increase in inhabitants, with a rise of 150k in the city compared to 110/120k in the suburbs. From this, it cannot be concluded that Munich is currently undergoing a phase of suburbanization.

Some years ago, the city of Munich examined the reasons for urban migration, urbanization and suburbanization and recorded them in the "Migration Motive Survey”. Key findings include if urban sprawl occurs, in most cases to the adjacent suburb, this means that people from the north of Munich usually move to Ismaning or Oberschleissheim, but much less often to Starnberg. In addition, it was found that one of the main reasons why people leave the city refers to an increase in family members. With larger families, preferences change and so do needs for larger living spaces and more access to nature (Lang, 2012; Expert A, 2020). This coincides with the results from the survey as the respondents from Munich city had less children than respondents from the Munich suburb, see Figure 3.

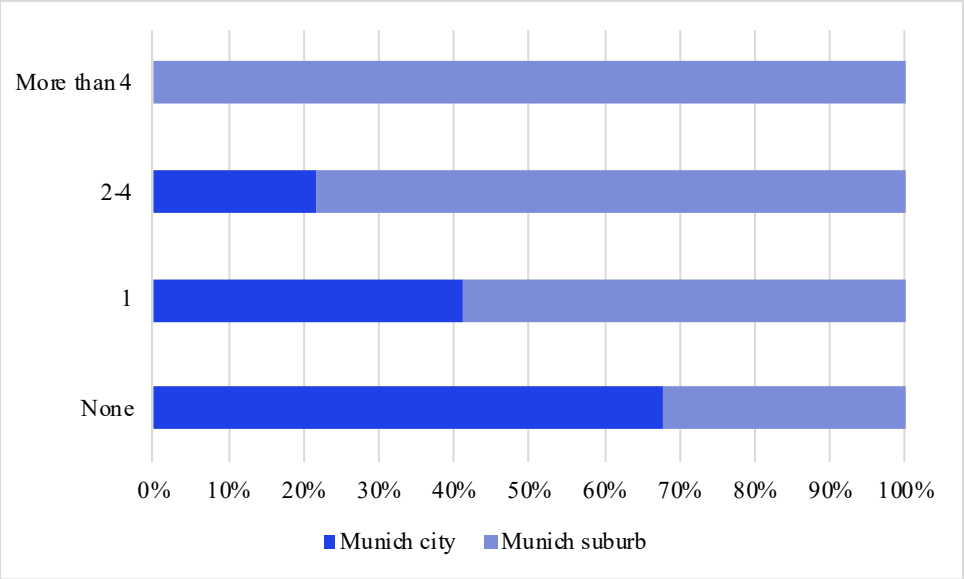

Figure 3: Relative number of children in Munich city and Munich suburb (own presentation).

> *"When I get older, I would definitely consider moving out of the city. I would then need more living space. A 2-3 room apartment is no longer enough, and I want to give my children the opportunity to grow up in nature." - (Consumer A)*

Another factor mentioned by Expert A (2020) is the price of land. People will also consider it important to move out of the city because housing prices in the city are significantly higher than in the suburbs. Consumer A (2020), on the other hand, argues that the proximity to nature and having a garden does not provide much benefits to him as he has long commutes and working hours. But if more emphasis were placed on home-office and homeschooling, his opinion would change in this respect.

> *"What actually is a game changer is the homeschooling, home-office. If this should become generally accepted, it would of course be a game changer and then I could imagine giving up my good location in the city. For example, if I only have to go to the office once or twice a week, I will move to the country." (Consumer C, 2020)*

Based on the survey, the mode of the two variables *work_pre_covid* (mode = 5 days) and *work_post_covid* (mode = 2 days) suggests that the near future will require going to work for fewer days which enhances the trend towards suburbanization as an external and additional factor.

4.3 Shared Autonomous Vehicles

In the following chapter, insights about shared autonomous vehicles are displayed. First, the focus will be on enabling technologies followed by presenting drivers and challenges- They provide input for part 4.4 and finally 4.4.4 and answering the first research question.

4.3.1 Digital Enabler

Self-driving vehicles will not hit the roads overnight. For the major automotive original equipment manufacturer, this means competing or partnering with new players in the future. Self-driving mobility is not a single technology, but rather a wide variety of systems. It started with the advanced driver-assistance system (ADAS), which are described by SAE as autonomy level 1. And with every further level of autonomy up to the self-driving car, demands on the technology in the car become greater and greater. (Horvath, 2018). Further development in the field of artificial intelligence has led to new possibilities. Due to the permanent scanning of the environment, quick decisions have to be made in different environments. Through Deep Learning, the system can improve its processes, receptiveness and decision-making ability. As the data grows, so do the demands on the CPU performance of the in-built PC. McKinsey expects quantum computing technology to be one of the primary value pools for the automotive sector, especially for electric and autonomous vehicles. (Burkacky et al., 2020). Equally important for autonomous vehicles is the expansion of 5G networks, since the exchange of data between individual vehicles or road users must be possible at all times. As 5G networks are enabling higher data transimission rates and lower latency (Horvath, 2018).

4.3.2 Development of SAVs Level 5

Experts agreed that it will take some time before fully autonomous vehicles with an Autonomy level of 5 are on the market. Expert C (2020) noted that currently most SAVs are in phase 2+. There are already several test-runs on highways of level 3 vehicles, but these have not been released in cities. Expert B (2020) also did not expect level 5 autonomous vehicles in the next decade, but rather sees possibilities in level 4 robo-buses that cover certain use cases. Expert D (2020) additionally mentions that there are still various preliminary stages to be reached until autonomy level 5 and this mainly concerns the whole approaching challenges.

> *"Today, however, we are still years away from that. In my opinion, the development of autonomous vehicles is often portrayed much better than it actually is. We are still at the preliminary stages of autonomous driving.*

> *Various challenges still need to be solved before automation level 5 can be reached, especially in the area of algorithms and information and communication systems." (Expert D, 2020)*

Nevertheless, the development of SAVs is interesting as expectations are very high. Self-driving fully autonomous cars were predicted to be introduced as early as this year, 2020 (Gibson, 2017), which has not occurred. Expert C (2020) also mentioned that the focus should not first be placed on fully autonomous vehicles, but rather on special use cases.

> *„The biggest hype is already rather again over and one is clearly more reserved than we have been a couple of years back. We rather look at potential use cases." (Expert C, 2020).*

As potential use cases, survey participants as well as Experts A and C (2020) considered robo-buses as a much more likely use case in the near future. According to Expert A (2020), cars can deposit feeder routes to the S-Bahn and U-Bahn on-demand and thus provide poorly located places far from public stations with access to the public transport network. Land prices in poorly served areas are significantly lower than in localities that are directly connected. Expert C, on the other hand, saw the possibility of robo-buses, more in continuously travelling the same course. Routes in Munich could be served by robo-buses, such as those from the Frankfurter Ring to the Föhringer Ring. This information was also backed by a survey respondent:

> *„I am currently studying a similar topic in my Master's program. Just keep in mind that AV have been promised for years and it's still far away - it is more likely for autonomous busses to be implemented earlier because they have set routes - making it easier to program/train the AI." (25 – 34-year-old female German student living in an UK city, 2020)*

4.3.3 Drivers of SAVs

With the help of the literature as well as expert interviews, potential drivers of SAVs could be identified. The most important factors for the experts appeared to be (1) *decrease in price*, (2) *decrease in traveltime* and (3) *increase in comfort* (Expert A, 2020; Expert B, 2020; Expert D, 2020). Only Expert C (2020) did not suspect that price will be as favorable as everyone imagines. On average, 50% of the cost of a cab trip goes to the driver. But if you take the significantly higher prices for electric vehicles and then autonomous vehicles, the maximum

potential is a saving of 40%. The development of autonomous vehicles is often portrayed much better than it actually is.

In addition to these factors, five other factors were included in the survey. (1) *decrease in land use*, (2) *decrease of air pollution*, (3) *decrease of fuel costs*, (4) *decrease of congestion*, and (5) *increase in safety* (see Appendix III). In the following, the variables can appear alone without the prefix *increase in* or *decrease of/in*.

4.3.4 Challenges of SAVs

Based primarily on the literature, many challenges of autonomous vehicles have already been mentioned in chapter 2.1.4. With the help of the experts, these challenges could be further concretized. On the one hand, experts mentioned regulatory and political problems (Expert B, 2020; Expert D, 2020) and safety concerns (Expert C, 2020) in different scenarios.

> *„In addition to the technical prerequisites, the legal framework still needs to be created. There are still many questions to be clarified in the legal areas of road traffic, licensing law, civil liability for damages, criminal law and data protection before a regular license can be issued in Germany." (Expert D, 2020)*

Based on knowledge from the literature and experts, survey participants were asked about the following challenges: (1) *I am afraid that people are able to sabotage and hack the AV (Safety & sabotage)*, (2) *I am afraid that the AV will not be reliable in all driving scenarios (Trust & reliability)*, (3) *I am concerned about the question of fault in case of an accident (Legal)* and (4) *I am not sure how AV will react in a dilemma situation (e.g. kill one elderly person or a child)*.

4.4 SAV Factors Impacting Suburbanization

In the following subsection of this dissertation, the gap between shared autonomous vehicles and suburbanization will be closed. First some statistical analysis will be undertaken concerning the impact of SAVs on the willingness to leave the city. In the last part of this section research question 1 will be answered.

Before analysing different factors, two pre-analyses were carried out. One on the *sav_excitement* and another one on the *sav_requirements.* The results show that the respondents from Munich city and Munich suburb both *somewhat agree* that SAVs fit their requirements and are

probably yes excited for their introduction. Therefore, the assumption of a high acceptance to use the new technology can be made.

4.4.1 SAVs Defining Where we Live in the Future

According to Expert A (2020), SAVs can have a significant impact on living situations especially in geographies that have not been favoured before. This could influence real estate prices. Expert D (2020) states that the shorter travel time and the increase in comfort will lead to an additional acceptance to travel longer distances for everyday activities as for example work, gym etc. Other criteria, such as the purchase and rental price or the quality of the residential environment are given greater influence on the residential choices.

Expert B (2020) stated that there are going to be changes but they will not be particularly disruptive.

> *"However, I do not think there will be a disruptive change since their penetration will be less for at least next couple of decades and several cities are already framing regulative policies to curtail the possible negative impacts." (Expert B, 2020)*

Contrary to this, Expert C (2020) did not predict any impact on residential choices as it will take too many years for SAVs to be implemented and for the full effects to bring visible changes to society.

On the Likert-type (1 – 5) question whether SAVs define where we will be living in the future, the responses differed between M_{city} and M_{suburb}, see Figure 4. The mode for M_{city} was *probably yes* compared to M_{suburb} *definitely yes,* showing a tendency on the probable effects on our residential decision caused by SAVs. Consumer C (2020) suspected that SAVs could strongly

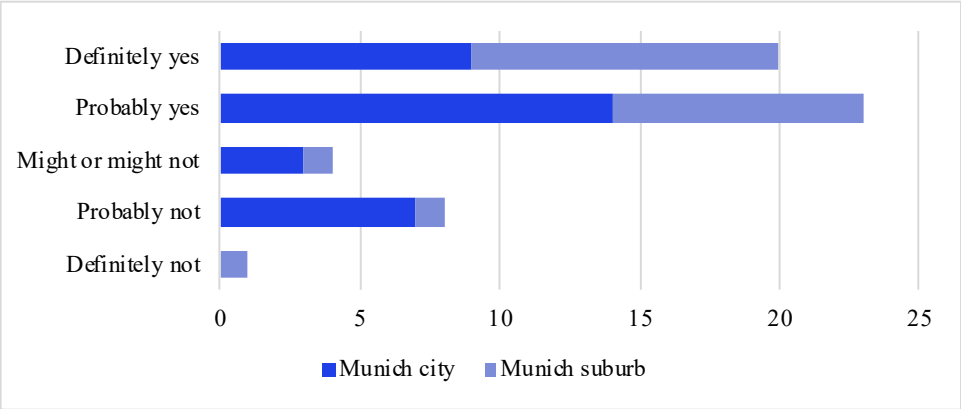

Figure 4: Frequency count on likert-type question whether SAVs define where we are going to be living in the future (own presentation).

influence traffic and thus tend to attract residents back to the city. In conclusion, according to the respondents, there will be many new migration motives due to the change in mobility.

4.4.2 Perceived Drivers of SAVs Affecting Willingness to Leave City

A Cronbach's analysis was conducted on the sav factors to leave city (*city_sav*) in the subscale of *drivers affecting willingness to leave city*. It was found that the subscale's alpha level is .773, which indicates that the subscale has an adequate level of inter-item reliability. However, the analysis revealed by deleting the item, *increase in driving safety* the alpha level could be increased to .779. As the difference in the cronbach's alpha is not significantly higher, no variables have to be removed from the analysis as a cronbach's alpha higher than .700 represents reliability (Cronbach, 1951). The independent variables were also checked on collinearity, since a significant collinearity above .800 is critical for an independent analysis of the variables. The Pearson correlation result show that none of the variables are correlated at a critical level, see Table 4.

Table 4: Pearson correlation within the likert-scale "drivers affecting willingness to leave city" and Munich citizens (own presentation).

	safety	**comfort**	**time**	**travelcost**	**congestion**	**fuelcosts**	**airpollution**	**landuse**
safety	1	.487**	.072	-.073	.239	.247	.167	.139
comfort	.487**	1	.527**	.156	.268	.324	.171	.428*
time	.072	.527**	1	.318	.436*	.252	.360*	.287
travelcost	-.073	.156	.318	1	.164	.366*	.345*	.232
congestion	.239	.268	.436*	.164	1	.424*	.350*	.282
fuelcosts	.247	.324	.252	.366*	.424*	1	.389*	.455**
airpollution	.167	.171	.360*	.345*	.350*	.389*	1	.708**
landuse	.139	.428*	.287	.232	.282	.455**	.708**	1

** Correlation is significant at 0.05 level*
*** Correlation is significant at 0.01 level*

Figure 5 displays the results of the descriptive analysis. It can be interpreted that in general residents would not be averse to moving out of the city if SAVs were present. This can be seen from the likert-type questions that the mode as well as the median is on the side of *likeliness to leave city* independently within each question.

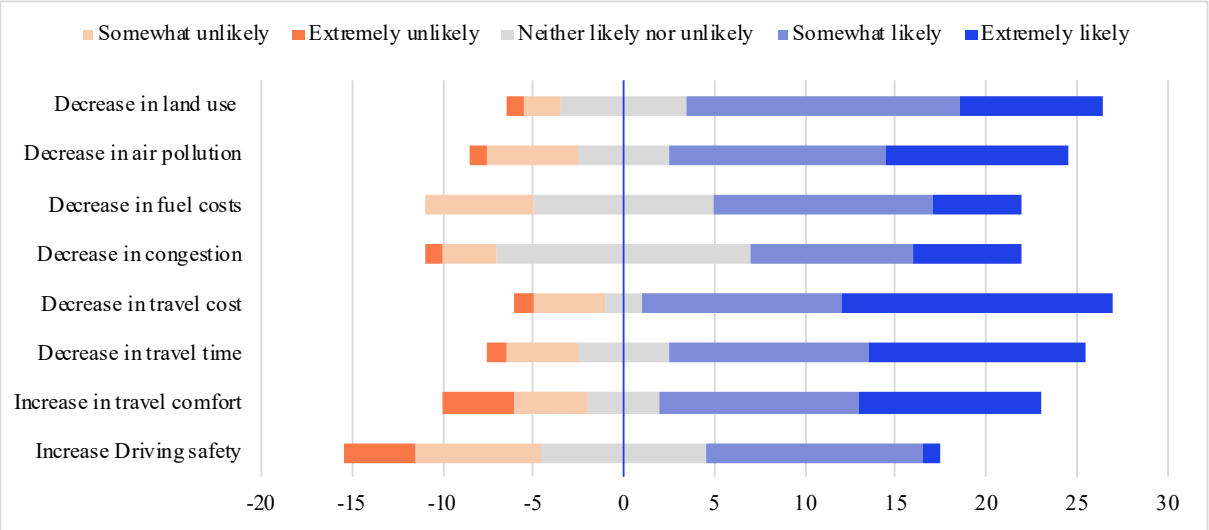

Figure 5: Stacked box plot with number of respondents (M_{city}) on likert-scale "drivers affecting willingness to leave city" (own presentation).

In order to determine if the above-mentioned factors have an effect on *city_leave*, Multiple Regression was implemented. Equation 2 represents the Multiple Regression model.

$$city_{leave} = \beta 0 + \beta 1 * safety + \beta 2 * travelcomfort + \beta 3 * travelcost + \beta 4 * congestion + \beta 5 * fuelcost + \beta 6 * airpollution + \beta 8 * landuse \quad (2)$$

On a stepwise multiple regression, the only variable significantly predicting *city_leave* was *decrease in fuelcost*. Stepwise regression was chosen as a methodology to reduce multicollinearity. The result showed that an increase of one point in the likert-type question of *decrease in fuelcost*, will increase on average, the willingness to leave the city by .508, at an alpha level of 5%. This means that we could predict at a likert value of *fuelcost* = 3 that people would leave the city at a significance level of 95%. The result of the multiple regression model is presented in equation 3.

$$city_{leave} = 1.957 + .508 * fuelcost \quad (3)$$

Despite the results from the regression analyses, consumers see *decrease in travelcost* as a defining factor for suburbanization (Consumer A & B, 2020).

> *"Costs are definitely the most important thing! We already have Uber, that can drive us everywhere and pick us up, the comfort is also relatively good, but the price is not right." (Consumer A, 2020)*

Consumer B (2020) stated that another important factor will be *increase in travelcomfort*, as the effective use of time will bring much added value. A trip in an SAV robo-taxi can be compared with a trip on the train. This comfort, which is familiar to the train, will then be

transferred to the car. Another input was also the *increase in safety*, as if SAVs are introduced, safety risk will then be lower as with a normal taxi. Relaxation during the ride is also enhanced.

Consumer C (2020) stated travel time as the most important factor. This indicates the main reason he chose to live in the city center. Being able to get quickly to work would make him want to leave the city center.

As the regression analysis did not deliver too many significant results, we took another look at the descriptive results, see Figure 5. Here, we see that apart from *decrease in congestion*, the mode is always on the likeliness to leave the city side. The result is clearest for *travelcost*, where the mode is *extremely likely* to leave (n = 15).

Finally, on the basis of the results, a tendency in the direction of *city_leave* can be expressed. All factors pointed towards the direction that the variable *city_leave* would have a positive influence. However, this can only be significantly confirmed by *fuelcost* in the model. Based on the interviews, *price*, *comfort* and *traveltime* played the most decisive role.

4.4.3 Perceived Challenges of SAVs in Munich

Consumers were not concerned when it came to *safety*, *trust and reliability*, *legal* and *ethical* issues. The arguments regarding *trust & reliability* were that under current circumstances human beings are the most dangerous aspects of cars (Consumer C, 2020) and that you could compare autonomous driving with airplanes. Planes have been flying with autopilots for decades and are currently the most reliable means of transportation. To solve road safety issues, the same mechanism as for trains has to be implemented, whereby it should be possible to detach the car from the network, so the car can stop immediately (Consumer A, 2020). Regarding *ethics* and *legal* issues, Consumer B (2020) saw these as preconditions for launching autonomous vehicles in the German market. This would not happen if these questions were not resolved.

> *"Legal and ethics is not an issue at all for me. If autonomous vehicles are permitted on German roads, then these problems should already be regulated. These are preconditions, so to speak." (Consumer B, 2020)*

Consumer B (2020) had some concerns when it comes to *data privacy*, *safety* and *sabotage*. Because cars are attached to the network, sabotage could easily occur as there is no 100% secure system. This could lead to opportunities for terrorists. Also, Consumer C (2020) was worried about *data privacy* leading to a postponement of SAV adoption. German citizens will

find it more difficult dealing with these issues than other countries such as the United States and China.

Expert D (2020) additionally mentioned that there is an autonomous vehicle readiness index provided by KPMG which is assessing the preparedness of the 30 leading countries in this development (incl. Germany, Singapore, United States, The Netherlands etc.). This index shows that Germany is currently situated in place 14 and their main challenges are infrastructure, consumer acceptance and policy and legislation. The first place goes to Singapore followed by the Netherlands and Norway (Threlfall, 2020).

The descriptive analysis allows us to conclude that the perceived challenges are similarly dispersed, with a small tendency on the *agree* side. The mode for safety and sabotage is n = 12 (*somewhat disagree* and *somewhat agree)*, for trust and reliability n = 14 (*somewhat agree*), for Legal n = 14 (*somewhat agree*) and for ethics n = 12 (*somewhat disagree* and *somewhat agree*), see Figure 6.

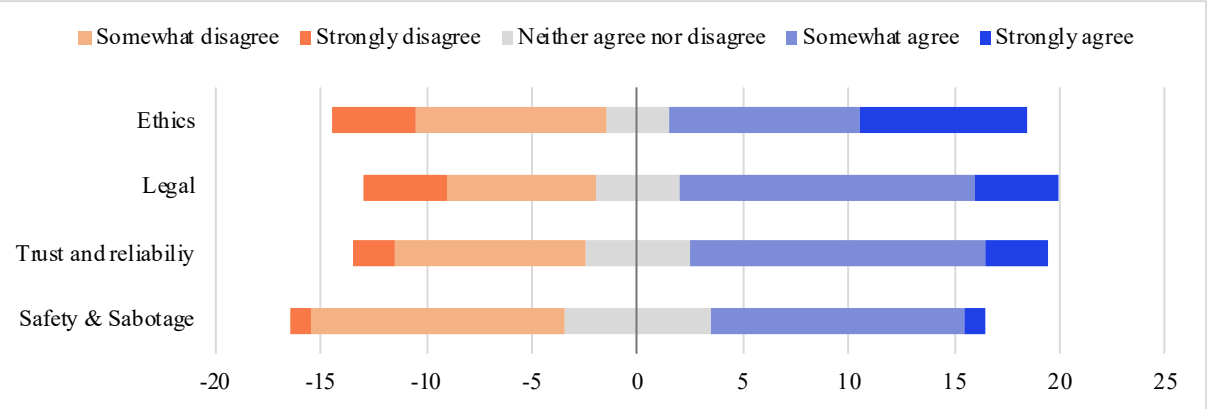

Figure 6: Stacked box plot with number of respondents (M_{city}) on likert-scale "challenges" (own presentation).

4.4.4 Conclusion of Research Question 1

Based on the knowledge about shared autonomous vehicles and suburbanization in Munich as well as findings from the literature, the first research question can now be answered.

To what extent do shared autonomous vehicles, with an autonomy level of 5, impact the phenomenon of suburbanization in Munich?

Mobility, transport and urban or local planning are closely linked. Urban considerations play an important role when companies and households make mobility decisions. Densely populated cities like Munich encourage walking, cycling and the efficient use of public transport. By choosing to move to more sparsely populated surrounding areas, the suburbs of Munich, the

advantages of many mobility innovations and solutions have to be given up for cheaper and more spacious living space, proximity to nature and gardens.

The literature pertaining to previous studies showed that the automobile, as well as new mobility innovations (train, commuter rail, highways), have influenced suburbanization (Alonso, 1964; Baum-Snow, 2007; Kopecky & Suen, 2010; Taylor, 1966; Warner Jr., 1978). These studies focused on past models and confirm the phenomenon rather than predicting it. Based on results of previous studies and those from my consumer survey, the implications of shared autonomous vehicles level 5 can be linked. Respondents expected drivers such as *fuel costs*, *comfort*, *travel costs* and *travel time* to have the greatest impact. If we now link the results with those from the literature, according to Baum-Snow (2007), especially *travel costs* and *travel time* could have a probable impact on suburbanization in Munich. With an expected lower as well as cheaper commute time, many Munich residents will likely move to neighboring suburbs. These two factors are also strongly influenced by the external factor home office, which, in parallel, is gaining more and more importance. Munich residents also see a decline in the obligation to go to work in the future. The price of fuel is marginally but positively correlated with *travel costs*. This means that the price of fuel will also positively influence suburbanization. *Comfort* is a new factor cited by consumers and experts as an important influencing factor.

Munich residents do not see the aforementioned challenges as major influencing factors. Since the challenges are factors that must be settled before autonomous vehicles are introduced, they will not impede suburbanization. Consumer acceptance and adoption is currently still a major problem. However, as a result from the survey, residents tend to be excited and confident that AVs are going to be fitting their requirements.

4.5 Results in Other Cities

To compare these results with other cities, participants from other cities in Germany and Europe were asked to take part in the survey. They were divided into six different groups as described in section 4.1. For the following analysis, the most relevant results from Munich city are compared with those from other German cities and citizens from the rest of the world. Section 4.5.2 then answers the second research question.

4.5.1 Comparison of Results in Munich, Germany and Rest of World

Comparing land settlement decisions of the groups Munich city with Germany city and ROW city, we saw that the results were very similarly distributed. *Close to city* center as well as *distance to job* were seen by all three groups as the most decisive factors for their land settlement decisions. In third place, residents in cities outside Germany (ROW_{city}) saw price as well as neighborhood as the third and fourth most important factors. The results from the German cities (G_{city}) were accordingly quite similarly dispersed, see Figure 7.

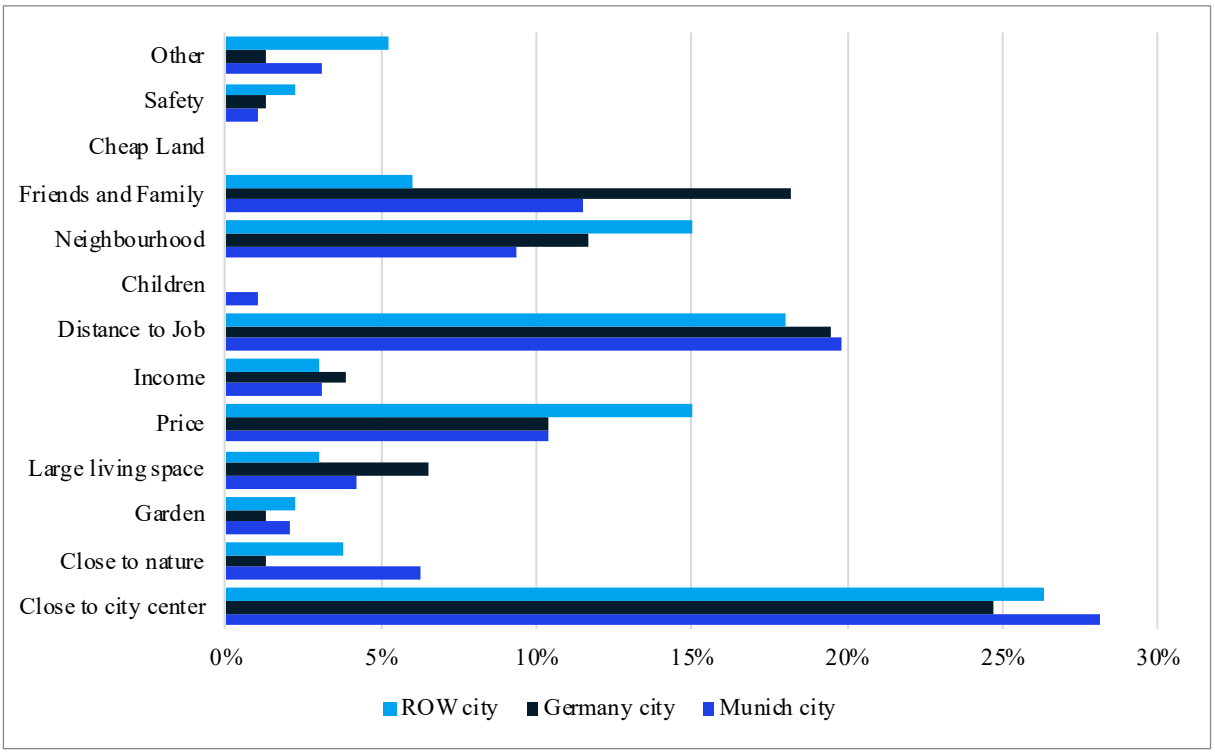

Figure 7: Distribution of land settlement decisions in ROW_{city}, G_{city} and M_{city} (own presentation).

A cronbach's alpha was also conducted on the likert-scale *drivers affecting willingness to leave the city* for the groups of ROW_{city} and G_{city}. It turned out that the subscale's alpha level is for ROW_{city} = .812 and G_{city} = .852 which indicated a high level of inter-item reliability. There were no items needing to be deleted to increase the level of reliability. The independent variables were also checked for collinearity. The Pearson correlation result showed that none of the variables were correlated at a critical level of > .800, see Table 11 and 12 in Appendix IV.

A first descriptive analysis on the boxplot of the likert-scale between the three observation groups was performed. The result showed a similar result, see Figure 8. Additionally, the provided boxplot also displayed four potential outliers. Two for the group of M_{city} and two for

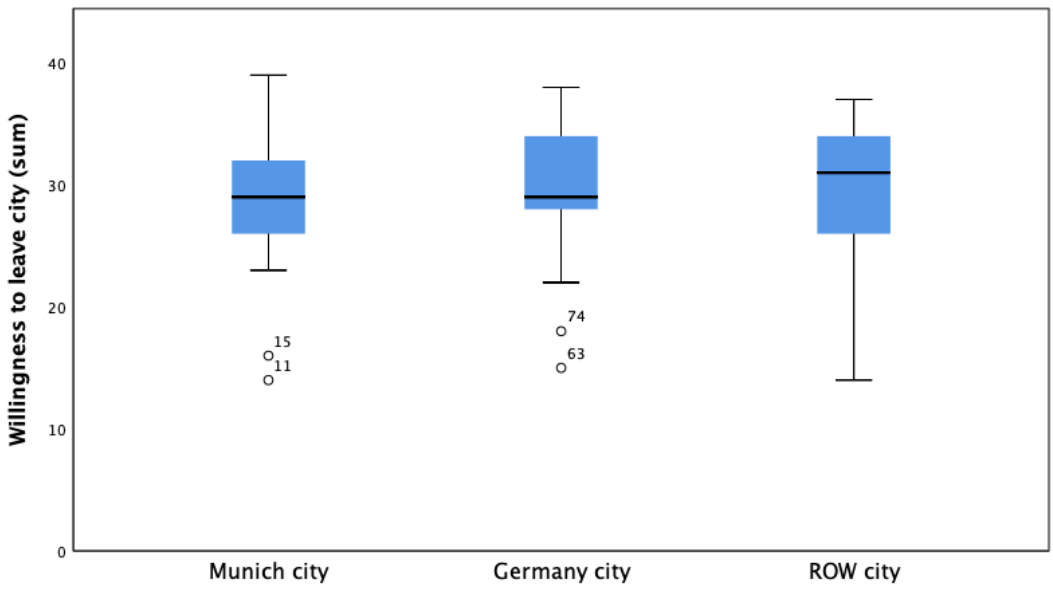

Figure 8: Simple boxplot of likert-scale sum "drivers affecting willingness to leave city" (SPSS output).

the G_{city}. Rechecking individual answers, we did not consider any of the four variables as an outlier.

A stepwise multiple regression was conducted to check which of the independent variables of the likert-scale *drivers affecting willingness to leave city* have a significant effect on the dependent variable *city_leave.* Additionally, a multiple regression of the group *city* (M_{city}, G_{city} and ROW_{city}), including the three groups was conducted.

Germany city (n = 27):

$$city_{leave} = -.084 + .908 * airpollution \quad (4)$$

Rest of World city (n = 47):

$$city_{leave} = 2.290 + .317 * safety \quad (5)$$

City (n = 107):

$$city_{leave} = 2.290 + .508 * fuelcost + .916 * airpollution + .317 * safety \quad (6)$$

For the respondents in G_{city}, a one-point increase in the likert-type question of *air pollution* increased willingness to leave the city on average by .908. This result was significant at a level of 1%. The estimate of -0.084 was not significant. For ROW_{city} a one-point increase in likert-type question of *air pollution* increased willingness to leave city on average by .317. This result was significant at a level of 5%. The corresponding estimate 2.290 was significant at a level of 1%.

Some nonparametric research was conducted concerning whether there is a difference in the scoring tendency between the demographic variables inside each group. For this a Mann-Whitney U test was conveyed for the variables *gender* (*Male* and *Female)* and *age* (adapted from variable *agegroup* to *under 18 to 35* and *35 and older*). For the variables *occupation* and *children* the Kruskal-Wallis Test was conducted as it enables us to compare the scoring difference for more than two categories. The p-value must be lower than 5% to reject the Null hypothesis, expecting that there is a significant difference in the scoring difference of these groups.

The result showed that there was a significant scoring difference between *Male* and *Female* in the subgroup of G_{city} and we are allowed to reject the Null hypothesis at a 5% level of significance (p-Value = 0.019). This result indicated that in German cities *Males* were more willing to leave the city than females.

Between the two *age* groups *under 18 to 34* and *35 or older* there was no significant difference in the scoring tendency. This means we cannot reject the Null hypothesis in this case.

The Kruskal-Wallis Test did not deliver any significant results for a difference in scoring for the variable *occupation.* This means we cannot reject the Null hypothesis.

The Kruskal-Wallis Test did not deliver any significant difference in scoring tendency between all categories within the variable *children.* We are not allowed to reject the Null hypothesis. An additional Mann-Whitney U Test was conducted between *none* and *more than 1* children. For this, a variable *children2* was created and divided all observations into two groups. No significant scoring difference could be found through this analysis.

The result from the first Mann-Whitney U as well as the Kruskal-Wallis tests can be found in Appendix IV under the Tables 13 and 14. By summarizing the results from the Mann-Whitney U and Kruskal-Wallis tests, we can state that there was only one significant scoring tendency to be found between *Male* and *Female* in Germany. On average, *Males* in Germany were more willing to leave the city than *Females*, at a 95% level of significance. As we were creating groups within the variable *location_group* (M_{city} G_{city} and ROW_{city}), we were mostly not able to have enough subgroups to provide significant results.

When having a look at the mode in the three observation groups of the challenges of SAVs, results are identical to those from Munich. The descriptive analysis shows identically dispersed results. The mode and median are similarly distributed in every case except of safety in M_{city},

where the Median is located at 3 instead of 4, see Table 5. Generally, this means that respondents are concerned from the introduction of autonomous vehicles.

Table 5: Descriptive statistics about challenges in the three observation groups M_{city}, G_{city} and ROW_{city} (own presentation).

Obs. Group		Safety	Trust	Legal	Ethics
M_{city}	N	33	33	33	33
	Median	3	4	4	4
	Mode	2[a]	4	4	2[a]
	Std. Deviation	1.000	1.139	1.269	1.415
G_{city}	N	27	27	27	27
	Median	4	4	4	4
	Mode	4	4	4	4
	Std. Deviation	1.006	.934	.974	1.075
ROW_{city}	N	47	47	47	47
	Median	4	4	4	4
	Mode	4	4	4	4
	Std. Deviation	1.210	1.140	1.269	1.415

[a] Multiple Modes (in this case 2 and 4)

4.5.2 Conclusion of Research Question 2

With the consideration of SAVs implications alongside the results from Munich, Germany and rest of the world, the second research question can now be elaborated conclusively.

Are the results from Munich replicable for other cities?

To measure or interpret replicability, the results of the three different groups were compared. If results from different data sets give the same results, we can speak of replicability.

When it came to land settlement decisions, the respondents from Munich as well as citizens from other German cities had identical preferences. The respondents from the rest of the world considered price and neighborhood more important than proximity to family and friends. Thus, a small preference occured here. In terms of willingness to leave the city based on SAVs (level 5), all three observation groups weighted different factors. In Munich, the only significant factor was the expected *decrease in fuel cost*, in Germany it was the *decrease in air pollution* and for the rest of the world it was *increase in safety* while driving. The Munich citizens are

the least concerned when it comes to challenges about SAVs. Compared to other German cities and ROW cities, concerns are present.

The results in Munich are generalizable to those other cities. But still, the results showed similar tendencies. German citizens as well as inhabitants in cities of the rest of the world, showed a willingness to leave the city affected by the introduction of shared autonomous vehicles, level 5.

5 Conclusion

This work sought to understand the effect of level 5 fully autonomous vehicles on residential decision making and related consequences on the phenomenon of suburbanization for the city of Munich. Data was gathered through expert interviews, survey analyses and consumer interviews. In a second step and for a greater scope, the results were to be compared with other cities.

Fully autonomous level 5 SAVs are still a hope for the future, but for now, we can look forward to initial use cases of robo-buses with lower autonomy levels in Munich in the near term. These can connect new routes and towns to the existing public transport network and create mobility solutions for older as well as younger people. Many residents in Munich do not want to give up their cars completely and continue to make use of the advantages of bicycles and public transportation. Despite all this, Munich residents are not averse to exchanging the advantages of the city with those of the suburb through the introduction of SAVs. The respondents of the survey considered a reduction in fuel costs as the most decisive factor for urban migration. This differed from the results of the consumer and expert interviews. There, factors such as decrease in travel cost, decrease in travel time and increase in comfort had the most decisive influence on the phenomenon of suburbanization in Munich. Backed with theories from the literature, we can state that travel cost, fuel cost and travel time most impact the phenomenon of suburbanization in Munich.

The seresults cannot simply be extrapolated to other cities. However, it was found that for German cities as well as for cities outside of Germany, that there is a tendency towards proliferation of urban sprawl due to SAVs.

Many respondents were also critical towards the new technology. However, the results showed that a country like Germany would not give AVs road traffic approval as long as problems like data privacy, ethics, safety etc. are not solved. The expected benefits for the urban and rural landscape are positive, as new green or residential areas in the city as well as in the countryside will arise from reduced need for parking spaces.

These results provide promising signs for the future and may be a step for future predictions as well as serving as a guide for urban planning and design.

5.1 Limitations and Critical Reflection of Results

The results are also subject to limitations. In the context of the quantitative study, the sample could have been significantly larger as the sample had to be divided into six different observation groups. Parts of the analysis are only answered on the basis of descriptive approaches. In addition, the acceptance of the technology was not addressed. The results of the study are less compelling because we did not know for certain whether respondents would actually use this technology. Almost 73% of the respondents were from Germany but the survey was only written in English and so language bias could have occured.

In qualitative research, more experts as well as consumers could have been interviewed to generate a broader cross section of opinion. Furthermore, the case of selection bias occurred, as all consumers interviewed were from the personal environment of the interviewer.

However, considering these and other limitations, it is not claimed that the results are definitive or conclusive. Rather, it is suggested that this approach represents the first insights about significant impacts of shared autonomous vehicles on the phenomenon of suburbanization.

5.2 Further Need for Research

It will take time for fully autonomous shared autonomous vehicles to enter the market. Thus, it is not possible to predict suburbanization based on perspectives and preferences of users. This would only be possible by running complex simulations with accurate and location-specific data and information about previous suburbanization. For this purpose, data from the past must generate a model, which can then be fed with future data to perform accurate city-by-city simulations. However, this is beyond the scope of a Master Thesis.

In the same way, further use cases in the suburbs as well as in rural area should be worked on. Since robo-buses will most likely be implemented first, initial use cases with these buses could potentially be interesting to explore. In this case, the input of Expert A (2020) could be valuable, stating that many localities around bigger cities are currently not well enough connected for public transportation and they could benefit the most from such mobility options. It would be interesting, for example, to look at the economic impact on real estate prices in these areas.

Reference List

Alberti, V., Alonso Raposo, M., Attardo, C., Auteri, D., Ribeiro Barranco, R., Batista E Silva, F., Benczur, P., Bertoldi, P., Bono, F., Bussolari, I., Louro Caldeira, S., Carlsson, J., Christidis, P., Christodoulou, A., Ciuffo, B., Corrado, S., Fioretti, C., Galassi, M. C., Galbusera, L., … Zulian, G. (2019). *The Future of Cities: Opportunities, challenges and the way forward* (Issue JRC116711). https://doi.org/10.2760/375209

Alonso, W. (1964). Location and land use. Toward a general theory of land rent. *Harvard University Press*.

Bagloee, S. A., Tavana, M., Asadi, M., & Oliver, T. (2016). Autonomous vehicles: challenges, opportunities, and future implications for transportation policies. *Journal of Modern Transportation*, *24*(4), 284–303. https://doi.org/10.1007/s40534-016-0117-3

Bailo, C., Dziczek, K., Smith, B., Spulber, A., Chen, Y., & Schultz, M. (2018). The Great Divide : What Consumers Are Buying vs. The Investments Automakers & Suppliers Are Making in Future Technologies, Products & Business Models. In *Center for Automotive Research* (Issue February). https://www.oesa.org/sites/default/files/resource/OESA_Resources_Ind_Overview_CAR_The-Great-Divide-What-Consumers-Are-Buying-vs-The-Investments-Feb 2018.pdf

Baum-Snow, N. (2007). Did highways cause suburbanization? *Quarterly Journal of Economics*, *122*(2), 775–805. https://doi.org/10.1162/qjec.122.2.775

Beckmann, J. K., & Sammer, G. (2016). *„Autonomes Fahren im Stadt - und Regionalverkehr“*. *December*, 1–11. https://www.researchgate.net/publication/311371581_Autonomes_Fahren_im_Stadt-und_Regionalverkehr_Autonomes_Fahren_im_Stadt-_und_Regionalverkehr_Autonomes_Fahren_im_Stadt-_und_Regionalverkehr_Memorandum_fur_eine_nachhaltige_Mobilitatsentwicklung_aus_de

Behere, S., & Törngren, M. (2015). A functional architecture for autonomous driving. *2015 First International Workshop on Automotive Software Architecture (WASA)*. https://doi.org/10.1145/2752489.2752491

Benenson, R., Petti, S., Fraichard, T., & Parent, M. (2008). Special Issue on Advances in Autonomous Vehicle Technologies for Urban Environment. *International Journal of*

Vehicle Autonomous Systems, Inderscience, *1*(2), 4–23. https://hal.inria.fr/inria-00115112v2

Bertoncello, M., & Wee, D. (2015, January). Ten ways autonomous driving could redefine the automotive world. *McKinsey*. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world

Bogost, I. (2020, June 19). *The Pandemic is Making the Suburbs Even More Appealing*. The Atlantic. https://www.theatlantic.com/technology/archive/2020/06/pandemic-suburbs-are-best/613300/

Bonnefon, J.-F., Shariff, A., & Rahwan, I. (2016). The social dilemma of autonomous vehicles. *Science*, *352*(6293), 1573 LP – 1576. https://doi.org/10.1126/science.aaf2654

Borngaesser, A. (2019, January 7). *Großstadt vs. Vorort: Wo leben Familien in München besser besser?* Betreut. https://www.betreut.de/magazin/kinder/grossstadt-versus-vorort-muenchen/

Bundesgesetzblatt. (2003). Bekanntmachung der Neufassung des Straßenverkehrsgesetzes. In *Bundesgesetzblatt*. https://www.bgbl.de/xaver/bgbl/text.xav?SID=&tf=xaver.component.Text_0&tocf=&qmf=&hlf=xaver.component.Hitlist_0&bk=bgbl&start=%2F%2F*%5B%40node_id%3D%27645220%27%5D&skin=pdf&tlevel=-2&nohist=1

Burkacky, O., Mohr, N., & Pautasso, L. (2020). Will quantum computing drive the automotive future? *McKinsey Global Publishing*, *September*.

Business Insider. (2016). *Companies making driverless cars by 2020*. Business Insider. https://www.businessinsider.com/google-apple-tesla-race-to-develop-driverless-cars-by-2020-2016-7

Cambridge. (n.d.). *No Title*. Cambridge Dictionary. https://dictionary.cambridge.org/dictionary/english/suburb

Christensen, C. (1997). The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail. *Harvard Business School Press*.

Clements, L. M., & Kockelman, K. M. (2017). Economic effects of automated vehicles. *Transportation Research Record*, *2606*(1), 106–114. https://doi.org/10.3141/2606-14

Collingwood, L. (2017). Privacy implications and liability issues of autonomous vehicles. *Information & Communications Technology Law*, *26*(1), 32–45. https://doi.org/10.1080/13600834.2017.1269871

Coppola, R., & Morisio, M. (2016). Connected car: Technologies, issues, future trends. *ACM Computing Surveys*, *49*(3). https://doi.org/10.1145/2971482

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*(3), 297–334. https://doi.org/10.1007/BF02310555

Diamandis, P. (2014). Self-driving Cars Are Coming. *Forbes Magazine. Retrieved from Http://Www. Forbes. Com/Sites/Peterdiamandis/2014/10/13/Self-Driving-Cars-Are-Coming*.

Eisenkopf, A., Fricke, H., Gerike, R., & Friedrich, M. (2017). Automated driving in road transport. *Strassenverkehrstechnik*, *61*(8+9). https://trid.trb.org/view/1489370

European Commission. (2017). *On the road to automated mobility: An EU strategy for mobility of the future*. https://connectedautomateddriving.eu/mediaroom/europe-leading-patent-race-autonomous-driving/

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice*, *77*, 167–181. https://doi.org/10.1016/j.tra.2015.04.003

Faisal, A., Yigitcanlar, T., Currie, G., Journal, S., Use, L., & Yigitcanlar, T. (2019). *Understanding autonomous vehicles : A systematic literature review on capability, impact, planning and policy*. *12*(1), 45–72.

Franckx, L., & Mayeres, I. (2016). Future trends in mobility: the rise of the sharing economy and automated transport Deliverable 3.3-ANNEX A. In *Mind Sets* (Issue 3). https://doi.org/10.13140/RG.2.2.34864.46083

Gibson, B. (2017). Analysis of Autonomous Vehicle Policies. *Kentucky Transportation Center*, 95. https://doi.org/https://doi.org/10.13023/KTC.RR.2016.29

Gruel, W., & Stanford, J. M. (2016). Assessing the Long-term Effects of Autonomous Vehicles: A Speculative Approach. *Transportation Research Procedia*, *13*, 18–29. https://doi.org/10.1016/j.trpro.2016.05.003

Hair, J. F., Celsi, M., Money, A., Samouel, P., & Page, M. (2015). The essentials of business

research methods: Third Edition. *The Essentials of Business Research Methods: Third Edition*, 1–494. https://doi.org/10.4324/9781315716862

Henry, A., Barone, R., Pichardo, A., Roach, E., Keegan, T., Simons, D., Thenhaus, E., & Oldenburg, B. (2017). New Mobility: Autonomous Vehicles and the Region. In *Regional Plan Association (RPA)* (Issue October). http://library.rpa.org/pdf/RPA-New-Mobility-Autonomous-Vehicles-and-the-Region.pdf

Horvath, K. (2018). *The Key Enabler Technologies of Autonomous Driving*. https://content.intland.com/blog/the-key-enabler-technologies-of-autonomous-driving

Hughes, C. J. (2020, May 8). *Coronavirus Escape: City to Suburbs - The New York Times*. The New York Times. https://www.nytimes.com/2020/05/08/realestate/coronavirus-escape-city-to-suburbs.html

Hyland, M. F., & Mahmassani, H. S. (2017). Taxonomy of Shared Autonomous Vehicle Fleet Management Problems to Inform Future Transportation Mobility. *Transportation Research Record*, *2653*(1), 26–34. https://doi.org/10.3141/2653-04

J. DiClemente; S. Mogos; R. Wang. (2014). Autonomous Car Policy Report. *Carnegie Mellon*.

Johanning, V., & Mildner, R. (2015). Car IT kompakt. In *Car IT kompakt* (Vol. 1). Springer Vieweg. https://doi.org/10.1007/978-3-658-09968-8

Jonas, A., Byrd, S. C., Shankar, R., & Ono, M. (2014). Nikola's Revenge: TSLA's New Path of Disruption. *Morgan Stanley & Co., LLC*.

Kallmeyer, F. (2019, December 11). *Autonomes Fahren – Chancen und Herausforderungen*. Zukunft Mobilität. https://www.zukunft-mobilitaet.net/170765/strassenverkehr/autonomes-fahren-chancen-und-herausforderungen-sae-level5/

Kaur, K., & Rampersad, G. (2018). Trust in driverless cars: Investigating key factors influencing the adoption of driverless cars. *Journal of Engineering and Technology Management - JET-M*, *48*(May), 87–96. https://doi.org/10.1016/j.jengtecman.2018.04.006

Kollowe, J. (2020). *Uber ditches effort to develop own self-driving car*. The Guardian. https://www.theguardian.com/technology/2020/dec/08/uber-self-driving-car-aurora

Koopman, P., & Wagner, M. (2017). Autonomous Vehicle Safety: An Interdisciplinary

Challenge. *IEEE Intelligent Transportation Systems Magazine*, *9*, 90–96. https://doi.org/10.1109/MITS.2016.2583491

Kopecky, K. A., & Suen, R. M. H. (2010). A quantitative analysis of suburbanization and the diffusion of the automobile. *International Economic Review*, *51*(4), 1003–1037. https://doi.org/10.1111/j.1468-2354.2010.00609.x

Krueger, R., Rashidi, T. H., & Rose, J. M. (2016). Preferences for shared autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, *69*, 343–355. https://doi.org/10.1016/j.trc.2016.06.015

Kyriakidis, M., Happee, R., & De Winter, J. C. F. (2015). Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. *Transportation Research Part F: Traffic Psychology and Behaviour*, *32*, 127–140. https://doi.org/10.1016/j.trf.2015.04.014

Lang, A. (2012). Wanderungsmotivuntersuchung. In *Perspektive München: Vol. II*.

Malokin, A., Circella, G., & Mokhtarian, P. L. (2019). How do activities conducted while commuting influence mode choice? Using revealed preference models to inform public transportation advantage and autonomous vehicle scenarios. *Transportation Research Part A: Policy and Practice*, *124*, 82–114. https://doi.org/10.1016/j.tra.2018.12.015

Manyika, J., Chui, M., & Bughin, J. (2013). Disruptive technologies: Advances that will transform life, business, and the global economy. *McKinsey Global …*, *May*, 163. www.mckinsey.com/mgi.

Martínez-Díaz, M., & Soriguera, F. (2018). Autonomous vehicles: Theoretical and practical challenges. *Transportation Research Procedia*, *33*, 275–282. https://doi.org/10.1016/j.trpro.2018.10.103

Massachusetts Institute of Technology. (2018). *The Moral Machine Project*. MIT Media Lab. https://www.moralmachine.net/

Maurer, M., Gerdes, J. C., Lenz, B., & Winner, H. (2016). Autonomous driving: Technical, legal and social aspects. In *Autonomous Driving: Technical, Legal and Social Aspects*. https://doi.org/10.1007/978-3-662-48847-8

Mieszkowski, P., & Mills, E. S. (1993). The Causes of Metropolitan Suburbanization. *Journal of Economic Perspectives*, *7*(3), 135–147. https://doi.org/10.1257/jep.7.3.135

Milakis, D., Van Arem, B., & Van Wee, B. (2017). Policy and society related implications of automated driving: A review of literature and directions for future research. *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations*, *21*(4), 324–348. https://doi.org/10.1080/15472450.2017.1291351

Mills, E. S., & Tan, J. P. (1980). A Comparison of Urban Population Density Functions in Developed and Developing Countries. *Urban Studies*, *17*(3), 313–321. https://doi.org/10.1080/00420988020080621

Möller, T., Padhi, A., Dickon, P., & Tschiesner, A. (2019, December 19). *The future of mobility is at our doorstep*. McKinsey. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-future-of-mobility-is-at-our-doorstep

MVV. (2020). S-Bahn, U-Bahn und Regionalzug im MVV. In *Münchner Verkehrs- und Tarifverbund GmbH (MVV)*.

Narayanan, S., Chaniotakis, E., & Antoniou, C. (2020). Shared autonomous vehicle services: A comprehensive review. In *Transportation Research Part C: Emerging Technologies* (Vol. 111, Issues 155–293, pp. 255–293). https://doi.org/10.1016/j.trc.2019.12.008

NHTSA. (2013). National Highway Traffic Safety Administration Preliminary Statement of Policy Concerning Automated Vehicles. *National Highway Traffic Safety Administration*, 14.

Octavius. (2017). *What do Driverless Cars Mean for Suburban Planning*. Smartcities Dive.

Paden, B., Čáp, M., Yong, S. Z., Yershov, D., & Frazzoli, E. (2016). A survey of motion planning and control techniques for self-driving urban vehicles. *IEEE Transactions on Intelligent Vehicles*, *1*(1), 33–55. https://doi.org/10.1109/TIV.2016.2578706

Ritchie, H., & Roser, M. (2018). Urbanization. In *Our world in Data*. https://ourworldindata.org/urbanization

Rubin, J. (2016). *Connected Autonomous Vehicles: Travel Behavior and Energy Use*. https://doi.org/10.1007/978-3-319-40503-2_12

SAE. (2016). *"Levels of Driving Automation" Standard for Self-Driving Vehicles*. https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-"levels-of-driving-automation"-standard-for-self-driving-vehicles

Schmidt, A., Reers, J., & Gerhardy, A. (2018). *Mobility as a Service*.

Schoettle, B., & Sivak, M. (2014). A survey of public opinion about connected vehicles in the U.S., the U.K., and Australia. *2014 International Conference on Connected Vehicles and Expo, ICCVE 2014 - Proceedings*, 687–692. https://doi.org/10.1109/ICCVE.2014.7297637

Serban, A. C., Poll, E., & Visser, J. (2018). A Standard Driven Software Architecture for Fully Autonomous Vehicles. *2018 IEEE International Conference on Software Architecture Companion (ICSA-C)*, 120–127. https://doi.org/10.1109/ICSA-C.2018.00040

Shaheen, A., Totte, H., & Stocker, A. (2018). Future of Mobility White. *UC Berkeley*. https://doi.org/10.7922/G2WH2N5D

Siciliano, B., & Khatib, O. (2016). *Springer Handbook of Robotics*. Springer International Publishing. https://books.google.pt/books?id=RTvADAAAQBAJ

Stead, D., & Vaddadi, B. (2019). Automated vehicles and how they may affect urban form: A review of recent scenario studies. *Cities*, *92*, 125–133. https://doi.org/10.1016/j.cities.2019.03.020

Swan, B. (2019). Connected and Automated Vehicles: Urbanization Versus Suburbanization. *New Visions for Public Affairs*, *11*(Spring 2019), 63–70.

Tang, L., & Shao, G. (2015). Drone remote sensing for forestry research and practices. *Journal of Forestry Research*, *26*(4), 791–797. https://doi.org/10.1007/s11676-015-0088-y

Taylor, G. R. (1966). *The beginnings of mass transportation in urban America*. Smithsonian Institution.

Threlfall, R. (2020). 2020 Autonomous Vehicles Readiness Index. *KPMG Global Mobility*, 70.

Walker, W. E., & Marchau, V. A. W. J. (2017). Dynamic adaptive policymaking for the sustainable city: The case of automated taxis. *International Journal of Transportation Science and Technology*, *6*(1), 1–12. https://doi.org/10.1016/j.ijtst.2017.03.004

Warner Jr., S. B. (1978). Streetcar suburbs: The process of growth in Boston, 1870-1900. *Cambridge: Harvard University Press*, *133*.

Wollschlaeger, M., Sauter, T., & Jasperneite, J. (2017). The future of industrial communication: Automation networks in the era of the internet of things and industry 4.0. *IEEE Industrial Electronics Magazine*, *11*(1), 17–27. https://doi.org/10.1109/MIE.2017.2649104

Zaveri, M. (2019, March 5). Prosecutors Don't Plan to Charge Uber in Self-Driving Car's Fatal Accident. *The New York Times*, 1. https://www.nytimes.com/2019/03/05/technology/uber-self-driving-car-arizona.html

Zeadally, S., Hunt, R., Chen, Y. S., Irwin, A., & Hassan, A. (2012). Vehicular ad hoc networks (VANETS): Status, results, and challenges. *Telecommunication Systems*, *50*(4), 217–241. https://doi.org/10.1007/s11235-010-9400-5

Appendices

Appendix I. Expert Interview Guide

Introduction

a. Presentation of the work and the associated goals.
b. Reference to anonymization, dissemination and submission of the oral consent.

1. Warm Up

a. Please briefly introduce yourself, your company and your current position and industry in which you work.
b. Which intersections do you and your profession have with autonomous vehicles?
c. Which intersections do you and your profession have with urban or suburban planning in connection with Munich?

2. Status Quo

a. How do you assess the current development of autonomous vehicles?

3. Core of the interview

3.1. Suburbanization in Munich

a. Is Munich currently affected by the phenomenon of suburbanization? What are the arguments for or against it?
b. On the basis of which factors do the inhabitants settle in Munich's Metropolitan area?
c. In your opinion, what are the potential drivers of suburbanization? Which of the drivers apply to Munich?

3.2. Shared autonomous vehicles and Suburbanization

a. Which positive factors of SAVs lead to suburbanization in Munich?
b. Which challenges of SAVs pose the biggest problems for suburbanization in Munich?
c. Do you think that the effects of SAVs have a decisive role where we will live in the future?
d. Where do you see the development of SAVs in the upcoming 20 years?
e. In your opinion, which consumers benefit most from SAVs?

3.3. General impact

a. In summary, how do you think SAVs influence the phenomenon of suburbanization in Munich? Which are the **main SAV factors** that would lead to this phenomenon?

4. Conclusion

a. Is there anything else we haven't mentioned, or do you want to add something to a point?

Acknowledgement and farewell

Appendix II. Results Expert Interviews

Table 6: Consolidation of expert interview results.

Int.	Response
1. Warm Up	
a.	Please briefly introduce yourself, your company and your current position and industry in which you work.
EA	*I am an urban planner and studied spatial planning in Dortmund and have been with the Planning Association for the Outer Economic Area in Munich for 21 years. The Planning Association is a municipal special-purpose association that works for its members, municipalities and districts in the Munich region, for these member municipalities. I am active in the field of municipal and supra-local planning and look after communities, especially in the north of Munich. This can be a utilization or development plan, but also mobility concepts. You could say a little bit like a public consulting.*
EB	*I am currently a research associate in the Chair of Transportation Systems Engineering in TU, Munich. My research focus is on emerging transport modes, such as shared mobility, autonomous vehicles and cargo cycles.*
EC	*I work for an automobile manufacturer. I work in the development department, since I am in the drive development department. I am now responsible for the entire test field of engine development. All drives have to be tested on the test bench. This is in my care including garages, endurance testing, foreign testing, actually everything that is necessary for testing.*
ED	*I am a traffic engineer and work as a project manager for an on-demand mobility service provider. In addition, I am jointly responsible for the conceptual development of the in-house software tools used in our analyses.*
b.	Which intersections do you and your profession have with autonomous vehicles?
EA	*It has not happened yet that municipalities have come to me with this topic. But it is probably not yet concrete. At best, I have encountered it at many trade fairs and congresses.*
EB	*One of my research focus is on autonomous vehicles, especially SAVs. Relevant publications:* *https://www.sciencedirect.com/science/article/abs/pii/S0968090X19303493* *Currently one of the most popular review papers in the field* *https://www.sciencedirect.com/science/article/pii/S254300092030007X* *https://www.tandfonline.com/doi/abs/10.1080/19427867.2020.1824309* *Soon, there will be another publication, which explores the modelling of SAVs based on game theory.*

EC	*Autonomous driving is exclusively related to electromobility, which is where I come in. I am only involved in propulsion but not directly in autonomous driving, because that is a vehicle issue. But that's why I am still familiar with the topic. The demands of autonomous driving are also relatively different, because as a rule you want to have much less dynamics. A very sporty car with a lot of power is a car that you want to drive yourself and not just sit in the back seat. For an AV, a car with much less dynamics is usually sufficient.*
ED	*At the moment, I am still mainly involved in the planning of flexible driver-based mobility services. However, the requirements of autonomous driving are taken into account in the development of our tools. (e.g., in the automated planning of virtual stops). In addition, about 3 years ago, I became very involved with the topic of autonomous driving as part of a research project while working as a student assistant at the Institute for Traffic Engineering and Transportation Planning at the TU Darmstadt. This also resulted in the topic of my master's thesis.*

c. Which intersections do you and your profession have with urban or suburban planning in connection with Munich?

EA	*My office is located in Munich, but we do not work for the city of Munich at all, but more for the municipalities in the surrounding area. The concept of the suburb does not exist at all in the current discussion on spatial structure in Munich. One can draw hints from the state development program. One can take a look at the densely populated area around Munich. In principle, however, it is not completely wrong to call the districts around Munich suburbs.*
EB	*--Question not covered in this interview—*
EC	*--Question not covered in this interview—*
ED	*--Question not covered in this interview—*

2. Status Quo

a. How do you assess the current development of autonomous vehicles?

EA	*--Question not covered in this interview--*
EB	*I think this question is very general and could be interpreted in different ways. Nevertheless, my general opinion on AV development: I am expecting that a level 5 AV (which can operate in any surrounding) will not be available for at least another decade.*
EC	*One must differentiate between the different degrees of autonomy. I wouldn't really see SAVs as just a part of AVs with a degree of autonomy of 5. When it comes to that, I think they are exclusively shared autonomous vehicles. Because the fact that a private person buys a level 5, I see it as unrealistic. At level 5, I am honestly skeptical. We are now at 2, 2+, which works*

	and is in series. Level 3 technology is ready, with a focus on the highway, but it doesn't work in the city yet and is therefore a really long way off.
ED	*Some vehicle manufacturers and technology companies announced 5 years ago that autonomous vehicles would be ready for series production by 2020 (by autonomous vehicles, I mean vehicles that perform all tasks at the navigation, guidance and stabilization level independently in every situation from start to finish - i.e. automation level 5). Today, however, we are still years away from that. In my opinion, the development of autonomous vehicles is often portrayed much better than it actually is. We are still at the preliminary stages of autonomous driving. Various challenges still need to be solved before automation level 5 can be reached, especially in the area of algorithms and information and communication systems. In addition to the technical prerequisites, the legal framework still needs to be created. There are still many questions to be clarified in the legal areas of road traffic, licensing law, civil liability for damages, criminal law and data protection before a regular license can be issued in Germany. For example, the German Road Traffic Regulations (StVO) contain specifications that are very abstract and cannot be complied with by a vehicle (e.g., on time or unclear traffic conditions). This means that for manufacturers, the criminal and liability risks associated with regular operation are still immense. Even the current draft of the law on autonomous driving does not manage to get away from the idea of a human vehicle driver as the central addressee of road traffic law (external infrastructures are not considered, for example). An insight into how well prepared Germany currently is for the introduction of autonomous vehicles compared to other countries is provided by the Autonomous Vehicles Readiness Index.*
3. Core	
3.1. Suburbanization in Munich	
a.	Is Munich currently affected by the phenomenon of suburbanization? What are the arguments for or against it?
EA	*In the period from 2008 to 2018, both the surrounding area and the city have grown considerably. In fact, the city has grown even more than the surrounding area. The city has grown by almost 150 thousand and the surrounding area by 110/120 thousand.*
EB	*--Question not covered in this interview--*
EC	*--Question not covered in this interview--*
ED	*--Question not covered in this interview--*
b.	On the basis of which factors do the inhabitants settle in Munich's Metropolitan area?
EA	*In case you are interested, there is a so-called "Wanderungsmotivbefragung" (motive for migration), which was commissioned by the city of Munich to find out exactly why people move*

	to the city or the countryside. These are rather people who do not come from Bavaria, but from all over Germany, nationwide or Europe-wide. And, of course, there are also people who move from the city to the surrounding area.
EB	*--Question not covered in this interview--*
EC	*--Question not covered in this interview--*
ED	*--Question not covered in this interview--*

c. In your opinion, what are the potential drivers of suburbanization? Which of the drivers apply to Munich?

EA	*A very interesting finding is that when they move to the surrounding area, they move to the adjacent area. Those who have lived in the north of Munich before are more likely to move to Ismaning or Oberschleissheim but not to Starnberg. Often the move is accompanied by an increase in household size, which means that people are having a child. Then they have different living requirements and then move out. Of course, land prices also play a very special role in Munich. Many people may stay in the city, perhaps not in the center, but in the outskirts, but prices do play a role there. People move out because then they can live more cheaply. The price level of the district of Starnberg is comparable to that of the city of Munich, the other districts are already cheaper in comparison to Munich.*
EB	*--Question not covered in this interview--*
EC	*--Question not covered in this interview--*
ED	*I consider the spatial separation of living and working to be an important driver of suburbanization. The high concentration of jobs in the big cities (especially in the service sector) together with high real estate prices and rents, cause people to move to the Speckgürtel. This migration pattern naturally leads to increased mobility and thus increases transportation demands. The response to higher traffic volumes is usually infrastructure expansion (especially roads), resulting in time gains between home and work, but often leading to increasing acceptance of longer distances between home and work. This relationship can be well illustrated by looking at the travel time budget and average commuting distances simultaneously: the travel time budget, i.e., the time a person spends moving around, has been constant for years, while commuting distances have been steadily increasing.* *Thus, it can be concluded that transportation access to the surrounding area is considered a prerequisite for suburbanization. At the same time, the continuous improvement of the transport system makes the choice of places to carry out everyday activities increasingly independent of the spatial distribution of living, working, utilities and leisure, which leads to further dispersion tendencies (higher traffic volume à creation of new capacity à time gains and growing path lengths à further settlement dispersion).*

3.2. Shared autonomous vehicles and Suburbanization	
a.	Which positive factors of SAVs lead to suburbanization in Munich?
EA	*Even the buses you mentioned cannot replace a mass transportation system like the suburban train. That would also be the question whether it makes sense to replace the S-Bahn at all. We are now building a new "Stammstrecke" again. I don't think that SAVs will replace PT, but rather complement it. Especially where public transport is not so well represented.* *It is somehow more comfortable, you can work on it. If you do a mix of HOV (High occupancy vehicle lane) and SAV. Especially on the most important feeder roads. People would get in and out of the city much faster. I think that the autonomous pooling vehicles are much more comfortable and attractive than the current car pooling ideas that exist now. What is also exciting is the independence that can be gained.* *I see robo buses in the communities as an interesting application example. When autonomous vehicles cruise through the whole neighborhood to collect people and take them to the suburban train. If you go one step further, Munich itself is the most expensive, but then there are always higher ground and rent prices along these S-Bahn branches than in the spaces in between. And there the land prices are the lowest. Now I can well imagine that autonomous vehicles will drive between the gaps and the branches. If you take the idea even further, you will need as a family two cars if you are living in the spaces between the branches.*
EB	*SAVs can cause a wide range of impacts. My comprehensive review paper summaries them. Copying down a figure from the study, which provides an overview: (figure not displayed). Also, my AV book chapter summaries the factors that influence some of these impacts. There might not be a greater impact in suburbs, since SAV services in such areas may not be profitable to the operators, when compared to urban areas. However, if introduced in such areas and properly regulated, SAVs may result in positive impacts, by substituting private car trips.*
EC	*With Robobuses I can imagine that this will work. If they always travel the same route. In Munich, for example, driving along the Föhringer Ring to Frankfurter Ring, I don't see any major problems. The technological prerequisites are already largely in place. I think that if you have a long drive, you can read something, check your e-mail or do other things, so the comfort should also be relevant.*
ED	*Public transport systems are not only contained in a space, but constitute it. That is, they are an important driver of spatial change and thus can fundamentally lead to counterproductive effects such as the expansion of suburbanization. SAVs have the potential to make mobility cheaper, more convenient, and more time-efficient (e.g., through better use of road capacity or the ability to use time differently during travel), which compensates for the locational disadvantages of surrounding communities (greater distances). Thus, there is a risk that the cycle of higher capacity, time gains, growing trip lengths and further dispersion tendencies will*

	occur. The design of the framework conditions, from infrastructure to regulation, will be decisive for how the technology changes transport and spatial development.
b.	Which challenges of SAVs pose the biggest problems for suburbanization in Munich?
EA	*--Question not considered in this interview--*
EB	*Depends on the time horizon. There will be governance and traffic issues at least for a decade.*
EC	*I don't know exactly how it all works then. For example, someone sees a robo-taxi and stops the car. The car then stops. If you are standing with your friend, you can talk to him for a longer time and the car won't get any further. Another example in a dead end. When a boy knocks over the garbage can and the car has to stop. What happens then? Also snow, there are no traces left. Does everyone have to pull over and you have to walk in the cold? I am already very critical there. I am still unsure about the speed. It is not only necessary that the technology exists, but also that a large number of people use it. I will see that again much later. If 50-70% decide not to have a car, it will have an impact on traffic. For me, the issue of costs is also relatively predictable. The theoretical potential is relatively simple. Today there are already shared cars. Namely cabs. A cab driver costs about 50%. That is the maximum potential for AVs, minus the fact that the car is more expensive. For a current cab company, the range will be 40%. Not much more is possible. That is not a quantum leap for me. In the foreseeable future, electric vehicles will not become cheaper than combustion engines.*
ED	*In addition to the challenges already mentioned above, I see acceptance of and trust in the technology as a potentially major initial hurdle for autonomous vehicles. Many people today do not have a realistic picture of the technology and are therefore skeptical. Once they have experienced the autonomous car, acceptance will probably increase slowly but steadily.*
c.	Do you think that the effects of SAVs have a decisive role where we will live in the future?
EA	*I think it will have an impact. It will make places more attractive that were only moderately attractive until now. I don't think that suburbanization will become much stronger because the city of Munich has a lot of attractive offers. I don't believe that this will explosively strengthen the trend towards suburbanization.*
EB	*SAVs will have some impact on the residential choice of certain segments of the population. However, I do not think there will be a disruptive change since their penetration will be less for at least next couple of decades and several cities are already framing regulative policies to curtail the possible negative impacts.*
EC	*Actually no. If there is autonomous level 5, that it has become widely accepted and the traffic situation has visibly changed. Then it could be, but honestly, that the issue where I live is more likely to be overcompensated by other factors.*

ED	*Due to the greater convenience of driving and the shorter travel times, people are more willing to travel longer distances to carry out everyday activities (e.g. work). This could have the consequence that other criteria for the choice of residential location, such as the purchase and rental prices or the quality of the residential environment, are given greater importance. In my opinion, SAVs can definitely influence the attractiveness of residential locations and thus have a decisive role in where we live in the future.*

d. Where do you see the development of SAVs in the upcoming 20 years?

EA	*--Question not covered in this interview--*
EB	*Several cities are already testing the application of SAVs in specific areas. Hence, Level 4 (operating in certain environments) is achievable. However, reaching level 5 is still a big question. There are a number of technical and governance issues yet to be resolved. It is safe to assume that there will be mixed traffic (non–, semi– and fully autonomous vehicles) for at least the next couple of decades.*
EC	*It is difficult to say. We German car manufacturers are all already working on future solutions, but the one that dares the most is already the Tesla. He can afford it. It has already had three deaths in the USA. If we had even one death, we wouldn't sell a single car anymore. The Tesla works because it is a local company, because it is a start-up. Whether that makes sense or not remains to be seen. I think it's pretty embarrassing what he's doing there. It is clear that this has nothing to do with cowardice, if a BMW, a Mercedes, an Audi does this, it has to be 100% sure. The argumentation that so many people have been saved by Tesla's autopilots and that they are still positive in the balance is of no use. That is A, rather cynical and B unthinkable for the classic manufacturer like us. The biggest hype is already rather again over and one is clearly more reserved than we have been a couple of years back. We rather look at potential use cases.*
ED	*By 2040, not even half of road vehicles will be fully autonomous. However, vehicle ownership will be reduced due to the increased transfer of the sharing economy to the transport sector. Mobility will increasingly be transformed into a product that can be ordered as needed.*

e. In your opinion, which consumers benefit most from SAVs?

EA	*I could imagine people who are not so mobile today. Older people who don't have a car or public transport is too far away from the front door. The same applies to children who are usually brought to the sports club by their mom. They can then do that virtually on their own. In fact, commuters who would replace their own vehicle with such an SAV.*
EB	*Depends on how the system is going to be introduced. Different types of SAV systems are possible. Nevertheless, if subsidized and introduced as a complement to public transport, they may serve a large group, especially under privileged (in terms of mobility) people.*

EC	*--Question not covered because of time constraints--*
ED	*Persons with limited mobility, elderly persons and persons without a driver's license*

3.3. General Impact

a. In summary, how do you think SAVs influence the phenomenon of suburbanization in Munich? Which are the main SAV factors that would lead to this phenomenon?

EA	*From the point of view of the climate debate, mobility is already changing. I believe that sub-urbanization would be limited by aspects like climate protection. The individual use of driving time is actually harmful to the climate. Both with combustion engines and as long as the electricity does not come from regenerative methods, the electricity is not 100% ingenious either. Against this background, all pooling offers are to be evaluated rather positively. Perhaps sub-urbanization will not be increased. It will be stabilized at the current level.*
EB	*SAVs may cause suburbanization to a very smaller extent. This depends mainly on the cost and quality of SAV services and city regulations.*
EC	*I wouldn't make it dependent on the money. As previously mentioned, I am not sure if this will be the case. People decide their living on other reasons and not sure if they come from SAVs. I therefore believe that this decision is not clearly influenced by autonomous vehicles.*
ED	*--Question was not answered--*

4. Conclusion

a. Is there anything else we haven't mentioned, or do you want to add something to a point?

EA	*I still have the question of what speeds the cars are travelling at?*
EB	*--Question was not answered--*
EC	*The question of owning a car has already decreased considerably when it was still like this in my time. This will probably decrease even more. I don't think that this will tilt completely. My daughter doesn't have a car either and lives in the city and has 200m to the subway and we live directly to the subway. Nevertheless she wanted to have a car, even though it is only 7km away. If she has no traffic, it takes her 15min, in the same time she would only be at the main station with public transport. She needs three times as much time in public transportation systems, although Munich is very well served by public transport. I think the trend will continue but I don't think you are an exotic person if you own a car in the future. You have to go to the beverage market or to the furniture store, I still find the use of robo-taxis difficult.*
ED	*--Question was not answered--*

Appendix III. Survey Questionnaire

The survey was structured into five different blocks: (1) General information and consent, (2) current living situation, (3) land settlement, car usage and alternatives (4) SAVs and suburbanization and (5) demographics. In addition, the respondents were divided into 4 groups: (1) Munich city, (2) Munich suburb, (3) city but not Munich and (4) suburb but not Munich.

Table 7: Survey questionnaire including variable, question, possible answers and group.

Variable	Question	Possible Answers incl. Score	Group
help	Will I have time to help?	1 – Yes, of course! 2 – No, I don't like helping.	all
country_residing	Thank you for taking time in answering my survey. In which country do you currently reside?	(1 – 195) – All countries	all
munich	Are you currently residing in the Munich metropolitan area?	1 – Yes 2 – No	1, 2
munich_settlement	Please indicate whether you live in the city or in the suburb of Munich	1 – Munich city center 2 – One of Munich suburbs	1, 2
land_settlement	In which kind of land settlement are you residing?	1 – Urban 2 – Suburban 3 – Rural	3, 4
settlement_decision	Please choose the three most important factors that defined your decision in which land settlement (urban/suburban/rural) you are living right now? (Choose max 3 options)	1 – Close to city center 2 – Close to nature 3 – Garden 4 – Large living space 5 – Price 6 - Income 7 – Distance to Job 8 – Children 9 – Neighborhood 10 – Friends and Family 11 – Cheap Land 12 – Safety 13 – Other	all
work_bef_covid	How many days are you commuting to your work place every week? (Before COVID19)	1 – 0 days 2 – 1	all

		3 – 2 4 – 3 5 – 4 6 – 5 days 7 – Not working 8 – Other	
work_post_covid	How many days are you expecting to be commuting to your work place? (Post COVID19)	1 – 0 days 2 – 1 3 – 2 4 – 3 5 – 4 6 – 5 days 7 – Not working 8 – Other	all
car_ownerhship	Do you currently own a car?	1 – Yes 2 - No	all
car_usage	How many times per week are you using your car?	1 – Daily 2 – 4-6 times a week 3 – 2-3 times a week 4 – Once a week 5 – Never	all
car_alternative	What are your two best alternatives to using a car? (choose max 2 options)	1 – Public Transportation 2 – Bike 3 – E-Bike 4 – Transport Network Companies as Uber/Bolt/Lyft etc. 5 – Taxi 6 – E-Scooter 7 – Motorcycle 8 – Walking 9 – Other	
tnc_usage	How often per week are you using on-demand mobility services as Uber/Lyft/Bolt?	1 – Daily 2 – 4-6 times a week 3 – 2-3 times a week 4 – Once a week 5 – Never	all

Inf	Thank you for filling out the first part of the survey! Please read the following information carefully and imagine shared autonomous vehicles are introduced: Let me point out how shared autonomous vehicles (SAV) with autonomy level 5 will potentially look like in the future. As autonomous vehicles are categorised by 5 levels of automation, autonomy level 5 represents the state in which autonomous vehicles' performance is equal to that of a human driver in every driving scenario. As this represents future technology, there are still several implementation theories. For this survey we will look at on-demand Robotaxi services as well as ride-hailing systems. The trend prevails that SAVs are to supplement traditional public transport services. Prices are expected to be relatively low, enable tasks as multitasking during a ride, could reduce congestions significantly and many other advantages. SAVs could be operated by transport network companies (TNC), as for example Uber, Lyft and Bolt.	Enable submit after 20 seconds	all
sav_excitement	Are you excited for the introduction of shared autonomous vehicles?	1 – Definitely Yes 2 – Probably Yes 3 – Might or might not 4 – Probably not 5 – Definitely not	all
sav_requirement	SAVs will fit my requirements	1 – Strongly agree 2 – Somewhat agree 3 – Neither agree nor disagree 4 – Somewhat disagree 5 – Strongly disagree	all
comment_sav_fit	Please justify your answer. (optional)	Input box	all

city_sav	Now, please indicate based on the previously described scenario about SAVs how much the following drivers would increase your willingness to move to the suburb of your city. Matrix: *_safety:* Increase in driving safety *_comfort:* Increase in travel comfort *_travelcost:* Decrease in travel cost *_congestion:* Decrease in congestion *_fuelcost:* Decrease in fuel costs *_somewhatlikely:* Please click on "somewhat likely" *_airpollution:* Decrease in air pollution *_landuse:* Decrease in land use through less parking spaces needed	1 – Extremely unlikely 2 – Somewhat unlikely 3 – Neither likely nor unlikely 4 – Somewhat likely 5 – Extremely likely	1, 3
suburb_sav	Now, please indicate based on the described scenario, by how much do the following drivers increase your willingness to continue living at the suburb or rural region? Matrix: *_safety:* Increase in driving safety *_comfort:* Increase in travel comfort *_travelcost:* Decrease in travel cost *_congestion:* Decrease in congestion *_fuelcost:* Decrease in fuel costs *_somewhatlikely:* Please click on "somewhat likely" *_airpollution:* Decrease in air pollution *_landuse:* Decrease in land use through less parking spaces needed	1 – Extremely unlikely 2 – Somewhat unlikely 3 – Neither likely nor unlikely 4 – Somewhat likely 5 – Extremely likely	2, 4
city_leave	From what you have heard about SAVs, are you considering moving out of the city?	1 – Definitely Yes 2 – Probably Yes 3 – Might or might not 4 – Probably not	1, 3

		5 – Definitely not	
sav_challenge	Are you concerned by the challenges of SAVs? Matrix: *_safety:* I am afraid that people are able to sabotage and hack the AV. (Safety & sabotage) *_trust:* I am afraid that the AV will not be reliable in all driving scenarios. (Trust & reliability) *_legal:* I am concerned about the question of fault in case of an accident. (Legal) *_ethics:* I am not sure how AV will react in a dilemma situation. (e.g. kill one elderly person or a child)	1 – Extremely unlikely 2 – Somewhat unlikely 3 – Neither likely nor unlikely 4 – Somewhat likely 5 – Extremely likely	all
car_ownership_future	Would you still be interested in privately owning a car in the future?	1 – Definitely Yes 2 – Probably Yes 3 – Might or might not 4 – Probably not 5 – Definitely not	all
av_definelocation	Do you think that autonomous/self driving vehicles will be redefining the way where we live in the future?	1 – Definitely Yes 2 – Probably Yes 3 – Might or might not 4 – Probably not 5 – Definitely not	all
comment_anything	Do you want to add or comment on anything? (optional)	Input box	all
nationality	Great work! I just need some more demographics about you. Where are you from?	(1 – 195) – All countries	all
gender	What is your gender?	1 – Male 2 – Female 3 – Divers 4 – Prefer not to tell	all
agegroup	How old are you?	1 – Under 18 2 – 18 – 24 3 – 25 – 34 4 – 35 – 44 5 – 45 – 54 6 – 55 – 64	all

		7 – 65 or older	
occupation	What is your current occupation?	1 – Student 2 – Employed 3 – Self-employed 4 – Unemployed 5 – Maternity/Paternity leave 6 – Retired 7 – Other	all
children	How many children do you have?	1 – None 2 – 1 3 – 2 – 4 4 – More than 4 5 – Prefer not to say	all

Appendix IV. Results Survey

a. Qualitative results from comment sections

The survey was providing two possibilities for potential qualitative statements from respondents. The first was whether SAVs would fit their requirements and the second one was a general input box (variables *comment_sav_fit* and *comment_anything*). Both of the comment sections were optional to be filled in. The results are summarized in the following Tables 8 and 9 with corresponding characteristics about the respondent. Important notice is that non-relevant statements have been deleted.

Table 8: Justification of personal fit.

Comment	**Characteristics**
I prefer carless city centers. SAVs increase the utility of cars and might therefore increase the number of cars in the city center.	German, male, 18 - 24 student, Munich city center
As long as I'm living in the city Centre, I don't think that SAVs will become part of my commuting experience that much, since there are many other viable options of transport available. But I can see them potentially becoming of much bigger interest to me when I will most likely leave the city to live in the suburbs sometime in the future. Then my needs will have changed and SAVs could be an option.	German, male, 18 – 24, student, Munich city center
Having more time through working while driving	German, male, 25 – 34, self-employed, city in Austria
As long as there is so much traffic on the road, public transport& biking is faster for short trips in urban areas.	German, female, 18 – 24, employed, Munich city center
I'm not sure the service will be readily available in rural areas.	Spanish, female, 45 – 54, self-employed, rural in Spain
Many studies from early 2010's already predicted for autonomous vehicles to arrive years ago - study after study the possible introduction of autonomous vehicles (speaking about FULLY autonomous) was discussed. Creating a hype which until now couldn't be fully justified- decreases the excitement. The functions of SAV are very various making it hard to say if its suits my „requirements". Hope it will though!	German, female, 18 – 24, student, city in UK

I do not see an advantage compared to a normal taxi (unless it's getting way cheaper which I don't expect). And I don't see how I would use these taxis for private daily use instead of my personal car. For 3 reasons: (1) Seems like something more for the upper class, (2) seems scary to give the driving task to a machine and (3) I like driving	German, female, 25 – 34, employed, city in Germany
The concept is super efficient in several aspects. First of all it provides a high level of individual mobility which people are currently striving for. Also I recall from some text that cars are standing at some place for 96% of their lifetime which is just ridiculous. Thus using the service of SAVs will probably lead to people buying less cars and less cars being parked somewhere. I'm going to search for the reference of this and then send it to you.	German, male, 25 – 34, student, suburb in Germany
Not interesting in rural areas. Too expensive, not available if needed, not personalised (seats for children).	German, male, 55 – 64, employed, rural in Germany
My requirement is that they will reduce the amount of parked cars and thus making living areas better	Dutch, male, 35 – 44, employed, city in Germany
I think it will depend how reliably they get to their destination on time. If I have different people in the car with me each day, the detours will be different each day as well.	German, male, 18 – 24, student, city in Germany
I like to drive and my car is stuffed with personal belongings :)	German, female, 45 – 54, employed, city in Germany
I live very close to university/city center/supermarket/friends, so I will probably keep walking there.	German, female, 18 – 24, student, city in Slovakia
I think its a good idea, but I am worried about the safety	Finish, female, 25 – 34, student, city in Netherlands
it would only fit if its available alle the time when theres a need for me. Price indication must be attractive	German, male, 25 – 34, employed, city in Germany
no repair insurance tax nct gov tests worry about my driving shills when i am older etc	Irish, male, 55 – 64, self-employed, suburb in Ireland
What have we learned from car sharing? If it is not your property no one cares about it. Those are going to be filthy, not taken care off, or worse tempered with. I will avoid	Polish, male, 25 – 34, student, city in Poland

it really depends on the price and still, the city I live in is small enough to prefer a bike over alternative transportation	Italian, male, 25 – 34, employed, city in Italy
Interesting add-on, but I get by with my current mobility options.	German, male, 35 – 44, employed, Munich city center
I don't trust or support fully autonomous driving. Intelligent systems should support the driver, and not drive fully autonomous.	German, female, 18 – 24, Munich city center

Table 9: General comments about the survey.

Comment	**Characteristics**
I will only buy a car when I am not living in the city anymore.	German, female, student, 25 – 34, city in Portugal
Interesting topic - I am currently studying a similar topic in my master's program. Just keep in mind that AV have been promised for years and it's still far away - it is more likely for autonomous busses to be implemented earlier because they have set routes - making it easier to program /train the AI. They are starting test-runs in Singapore already and I think the country is planning to fully implement autonomous busses by mid 2020s.	German, female, student, 18 – 24, city in UK
I am quite sure that autonomous vehicles will be coming, and we need to adapt to the new upcoming changes.	German, male, self-employed, 45 – 54, Munich city center
Do you see level 5 cars in the near future? I don't see them in the next 20 years.	German, male, employed, 55 – 64, rural in Germany
Before autonomous drives I think that people have to embrace leasing cars better than buying. France has still a challenge because many people prefer owning a car	French, male, self-employed, 55 – 64, suburb in France
AV are great option for children, older or disabled people and sustainable development of the cities with less parking spaces, air pollution and more green places, they are great example of sharing economy as I predict they will be used on- demand	Polish, Female, self-employed, 55 – 64, city in Poland
Autonomous driving will be able to impact the daily life, what will still hold people to own a car is the free time travel. In our country moving from a city to another for a holiday trip is still mostly done by private car even for those who usually use public transportation	Italian, male, self-employed, 35 – 44, city in Italy

b. Additional Survey Results

All graphs and tables represent own presentations.

Figures

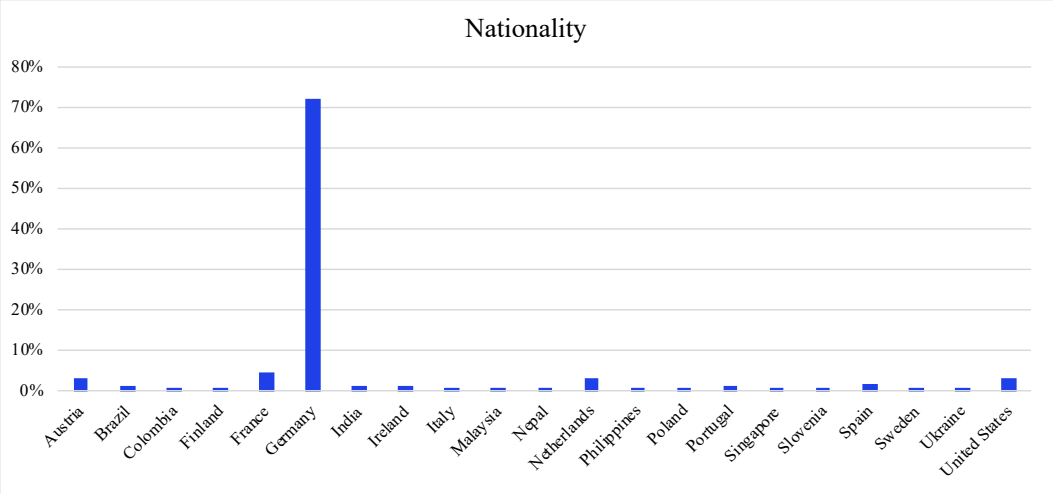

Figure 11: Nationalities (entire sample).

Figure 10: Occupation (entire sample).

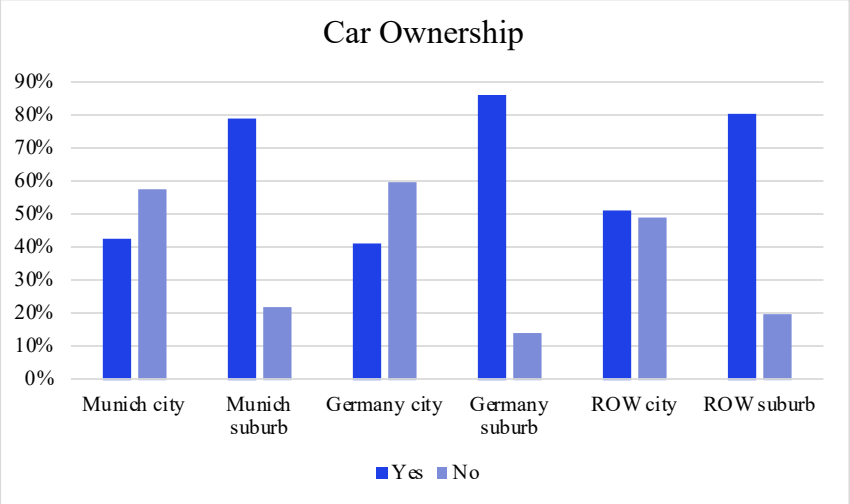

Figure 9: Car Ownership (entire sample).

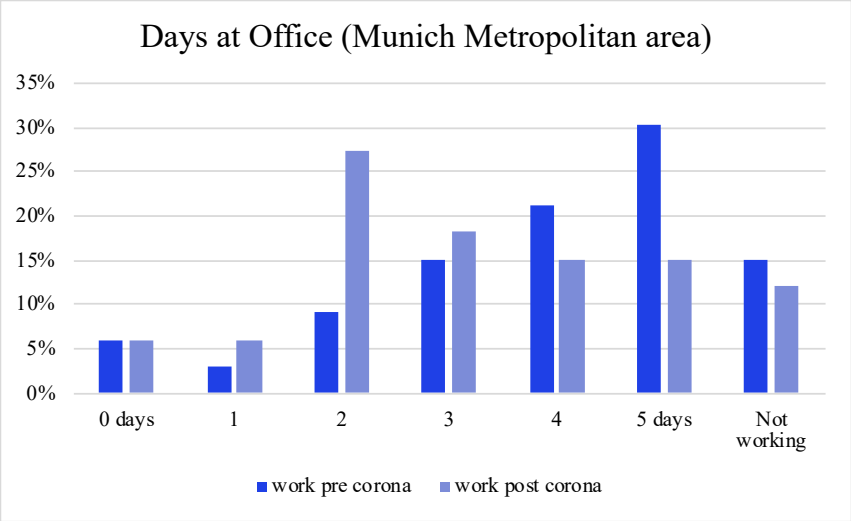

Figure 12: Number of days going to work pre and post corona (Munich metropolitan area).

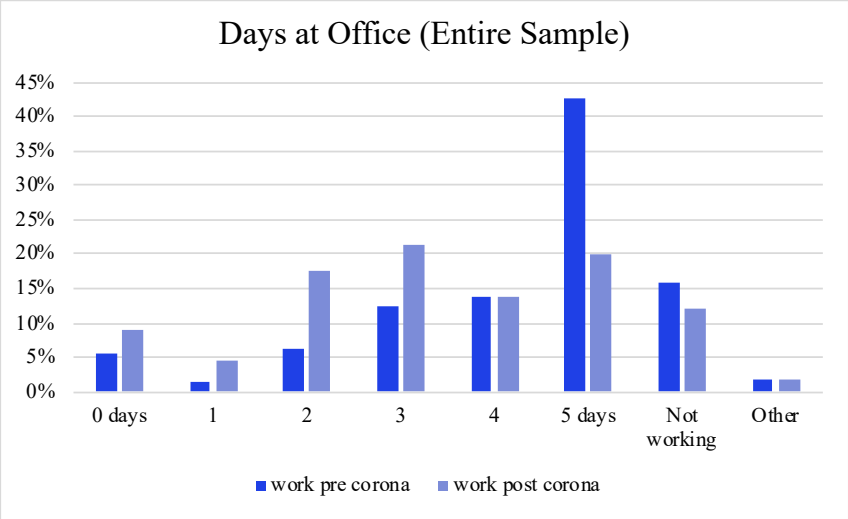

Figure 13: Number of days going to work pre and post corona (entire sample).

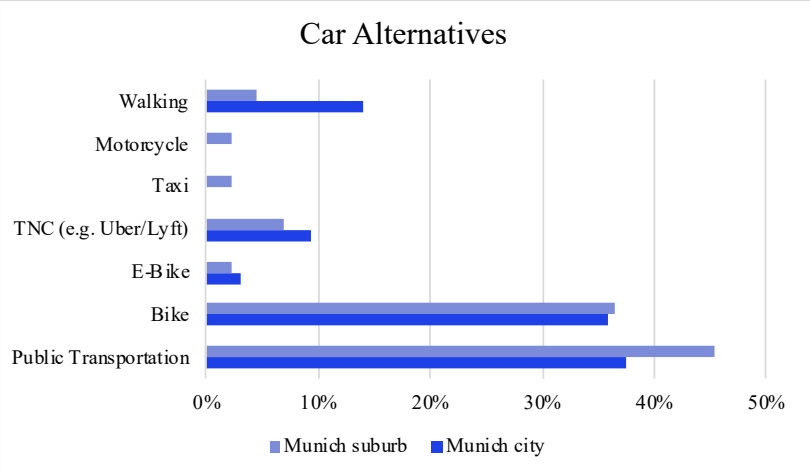

Figure 14: Car alternatives (Munich metropolitan area).

Tables

Table 10: Comparison M_{city}, G_{city} and ROW_{city} for additional variables. All numbers in percent.

Variable	Category	Munich city	Germany city	ROW city
sav_excitement	Definitely yes	10	12	15
	Probably yes	18	10	19
	Might or might not	5	2	7
	Probably not	0	3	5
	Definitley not	0	0	1
sav_fit	Strongly agree	6	3	9
	Somewhat agree	18	17	24
	Neither agree nor disagree	7	5	8
	Somewhat disagree	2	2	4
	Strongly disagree	0	0	2
car_alternative	Public Transp.	38	45	33
	Bike	36	33	25
	E-Bike	3	2	0
	TNC	9	0	18
	Taxi	0	0	4
	E-Scooter	0	2	2
	Motorcycle	0	2	4
	Walking	14	14	13
	Other	0	2	0
Total	-	100	100	100

Table 11: Pearson correlation within the likert-scale "drivers affecting willingness to leave city" and G_{city} (own presentation).

	safety	**comfort**	**time**	**travelcost**	**congestion**	**fuelcosts**	**airpollution**	**landuse**
safety	1	.487**	.072	-.073	.239	.247	.167	.139
comfort	.487**	1	.527**	.156	.268	.324	.171	.428*
time	.072	.527**	1	.318	.436*	.252	.360*	.287
travelcost	-.073	.156	.318	1	.164	.366*	.345*	.232
congestion	.239	.268	.436*	.164	1	.424*	.350*	.282
fuelcosts	.247	.324	.252	.366*	.424*	1	.389*	.455**
airpollution	.167	.171	.360*	.345*	.350*	.389*	1	.708**

landuse	.139	.428*	.287	.232	.282	.455**	.708**	1

** Correlation is significant at 0.05 level*
*** Correlation is significant at 0.01 level*

Table 12: Pearson correlation within the likert-scale "drivers affecting willingness to leave city" and ROW_{city} (own presentation).

	safety	**comfort**	**time**	**travelcost**	**congestion**	**fuelcosts**	**airpollution**	**landuse**
safety	1	.442**	.400**	.316*	.344*	.401**	.355*	.203
comfort	.442**	1	.513**	.504**	.370*	.382**	.185	.234
time	.400**	.513**	1	.732**	.688**	.572**	.404**	.334*
travelcost	.316*	.504**	.732**	1	.723**	.701**	.411**	.178
congestion	.344*	.370*	.688**	.723**	1	.519**	.457**	.308*
fuelcosts	.401**	.382**	.572**	.701**	.519**	1	.274	.116
airpollution	.355*	.185	.404**	.411**	.457**	.274	1	.284
landuse	.203	.234	.334*	.178	.308*	.116	.284	1

** Correlation is significant at 0.05 level*
*** Correlation is significant at 0.01 level*

Table 13: Results from the Mann-Whitney U test.

Variable	**Result**	**Munich city**	**Germany city**	**ROW city**
gender (1, 2)	Mann-Whitney U	112.000	38.500	263.500
	Significance	.461	0.009**	.806
age	Mann-Whitney U	93.000	41.000	256.000
	Significance	.135	.216	.669
children	Mann-Whitney U	75.000	3.000	77.000
	Significance	.803	.296	.755

Additional Information: *For G_{city} on gender (1, 2) the mean rank male was 18.04 and mean rank female was 10.25*

Table 14: Results from the Kruskal-Wallis test.

Variable	**Result**	**Munich city**	**Germany city**	**ROW city**
occupation	Kruskal-Wallis	112.000	38.500	263.500
	Significance	.461	.009	.806
children	Kruskal-Wallis	1.548	1.669	0.131
	Significance	.461	.196	.937

Table 15: Descriptive statistics about the likert-scale "drivers affecting willingness to leave city" in the three observation groups M_{city}, G_{city} and ROW_{city} (own presentation).

Obs. Group		Safety	Com-fort	Trav-eltime	Trav-elcost	Con-gestion	Fuelcost	Pollu-tion	Landuse
M_{city}	N	33	33	33	33	33	33	33	33
	Median	3	4	4	4	3	4	4	4
	Mode	4	4[a]	4[a]	4[a]	3	4	4	4
	SD	1.156	1.439	1.226	1.286	1.088	.972	1.146	.983
G_{city}	N	27	27	27	27	27	27	27	27
	Median	4	4	4	4	4	4	4	4
	Mode	4	4	4[a]	4[a]	4	4	4	4
	SD	.884	1.059	1.111	1.141	.839	1.149	.864	.818
ROW_{city}	N	47	47	47	47	47	47	47	47
	Median	4	4	4	4	4	4	4	4
	Mode	4	4	5	4	4	4	4	4
	SD	1.173	.993	1.311	1.224	1.072	1.074	1.013	.970

[a] Multiple Modes exist. The smallest value is shown | SD = Standard Deviation

Appendix V. Consumer Interview Guide

The consumer interview guide represents an *adapted* version of the survey questionnaire.

Introduction

Overview about the topic of my Master thesis and the corresponding research questions.

1. Land settlement, car usage and alternatives

a. Why are you currently residing in the city center? Would you consider other factors to be relevant? Which are the factors that are changing when you are getting older?
b. Do you currently own a car? Why are you owning it?
c. What is your best alternative to a car?
d. How many days a week are you using on-demand mobility services?

2. SAVs and Suburbanization

a. Are you excited about the introduction of shared autonomous vehicles and why?
b. Are SAVs fitting your requirements?
c. What do you think are the main drivers that would lead to suburbanization? What enhances the phenomenon of suburbanization?
d. What do you think are the main challenges of autonomous vehicles? What prevents SAVs being introduced?
e. Have you thought about leaving the city? Why or why not?
f. When do you think shared autonomous vehicles are going to be introduced?
g. Do you think that autonomous/self driving vehicles will be redefining where we live in the future?

3. Open discussion

a. Is there anything else we haven't mentioned, or do you want to add something to a point?

Appendix VI. Results Consumer Interviews

a. Consumer Interview Partner

Table 16: Consumer Interview partners indicating their current role, age and additional personal information.

Interviewee	Role	Age	Additional Information
Consumer A	Early Career Millennial	23	- Group Interview - Native from Munich
Consumer B	Early Career Millennial	24	
Consumer C	Project- and IT-Manager	55	- Living in the city center of Munich with his wife and daughter.

b. Responses (Reduction Table)

Table 17: Consolidation of consumer interview results.

	Int	Response
1.	**Land settlement, car usage and alternatives**	
a.	Why are you currently residing in the city center? Would you consider other factors to be relevant? Which are the factors that are changing when you are getting older?	
	CA	*Getting from A to B quickly and economically and being able to do everything within walking distance. In Munich it is even more important to live in the city center than in another city, where it is more expensive. In other cities, where the Uber is cheap, you can simply live outside. The factor of comfort plays an important role Assuming SAV come, and it's almost free, then it would be really cool for me as a student to have a garden and live in a flat share in a small house. PT does not provide the solution because we are dependent on time, location and reliability.*
	CB	*I live in the city mainly because of the proximity to everything. Short distances, by foot, to the workplace. Munich has a real city center and that makes it very interesting to live there, especially in the youth. But, when I get older I would definitely consider moving out of the city. I would then need more living space, a 2-3 room apartment is no longer enough and I want to give my children the opportunity to grow up in nature.* *Using the S-Bahn is not much fun because for short distances you have to travel long distances.*

	I am from the Black Forest and therefore extremely environmentally conscious and would like to live as close to my workplace as possible. Because my work is in the city, I also live in the city.
CC	*The second reason is that the city offers an incredible number of advantages in short distances, whether it's schooling, health care, you don't have to travel. I ride my bike to work and am still very active. The closeness to nature, gardening does not help me if I work long hours every day and come home late.*
b. Do you currently own a car? Why are you owning it?	
CA	*Yes, not being dependent from the public transportation system. I often use it because fortunately I got a parking space directly with my apartment. This is not a matter of course as there are hardly any parking spaces left.*
CB	*No, it is too expensive.*
CC	*Yes of course, even a new one, haha. Specifically, for the Mountains! I primarly bought it for my wife. I would be the guy who goes by foot or bike due to environmental and meaningful reasons. I just need it for the weekends.*
c. What is your best alternative to a car?	
CA	*I think in Munich, especially the bike.*
CB	*Yes,bike or drivenow/sharenow.*
CC	*Public Transportation and bike.* *I can't find any other relevant alternative. If you can not walk 5min by foot than you seriously have a problem, so I don't see a lot of different possibilities.* *Uber and so are also at the borderline, because they exploit a loophole in the law that runs past the cab companies. One undermines the welfare state, as with Airbnb. That is nice for the individual user, but it is bad for the traditional businesses.*
d. How many days a week are you using on-demand mobility services?	
CA	*Rarely, because the prices are too high. Mostly (before COVID19) when I went out for dinner/partying, I enjoyed the luxury not having to use public transportation.*
CB	*Not much, too expensive at the moment.*
CC	*Never using it. The only thing that I sometimes use is carsharing or drivenow.*
2. SAVs and Suburbanization	
a. Are you excited about the introduction of shared autonomous vehicles and why?	

CA	*Absolutely!! I am an absolute comfort person. A lot could change for me and I also find the comfort of travelling super exciting, because then I can use the time effectively. I believe that the way we live will change completely.*
CB	*So super excited. But I'm still a bit split in two, because I think that there are still many challenges ahead.*
CC	*I would be very pleased. I think you can use the vehicles like a short time cab.*
b. Are SAVs fitting your requirements?	
CA	*It would extent my requirements!*
CB	*(No comment)*
CC	*Absolutely. I hope, that I experience it in my life!*
c. What do you think are the main drivers that would lead to suburbanization? What enhances the phenomenon of suburbanization?	
CA	*Costs are definitely the most important thing! We already have Uber, that can drive us everywhere and pick us up, the comfort is also relatively good, but the price is not right. So it can't become the main means of transport at the moment, because it's just too expensive. Comfort would also be important, but not so important.* *Environmental factor is not so important to me, I think that electric mobility should be completely independent of autonomous driving.*
CB	*I also see the cost as the most important factor, but I am convinced that as soon as autonomous vehicles become established, i.e. really prove that they are safe, thus increasing confidence in safety, the journey will be even more relaxed. At the moment I often check out if the driver is making any mistakes.* *The comfort of the train, for example the ICE, is transferred to the car.* *The environment in SAVs is not such a big issue for me either. But in general, it is. I will not only use SAVs because they are environmentally friendly.*
CC	*No, there are no factors that would make me want to move out of the city. What actually is a game changer is the homeschooling, homeoffice. If this should become generally accepted, it would of course be a game changer and then I could imagine to give up my good location in the city. For example if I only have to go to the office once or twice a week, I would move to the country. I am basically already a country person.* *The principle is that I want to be as close to work as possible and if the work can be with me, then I would definitely consider it. Your factor travel time would be the counterpart to that.*

d.	What do you think are the main challenges of autonomous vehicles? What prevents SAVs being introduced?
CA	*I don't see it so critically. You can also compare it well with airplanes. You were really afraid of them then, and now they are one of the safest means of transport. The probability that I am involved in an accident in an autonomous vehicle is much lower than in a normal car, so I have no concerns.* *I am relatively sure that you can switch off the car in a controlled way. All you need is a manual button, like in a train where the car brakes directly and stops at the next corner. It seems more complicated than it actually is, I think. There are also autonomous metros, like in Paris.*
CB	*Legal and ethics is not an issue at all for me. If autonomous vehicles are permitted on German roads, then these problems should already be regulated. These are preconditions, so to speak.* *Privacy is another interesting point for me, what is done with my data. They can be distributed everywhere. I see this more critically. It's probably easy to gain control of the car, but from a terrorist perspective it's certainly a good idea to cause one or two accidents.*
CC	*Basically, I believe that in our current traffic situation the problem is always the human being. So if you let computers drive together, a lot less happens than with people. That's why I have no concerns at all about safety and reliability.* *The one problem for me is the ethical problem. Maybe you simply have to solve it differently. You give pedestrians more space because the traffic routes are better used, because they can follow much closer behind because they know exactly what the car in front of them is doing. Then there are runways for the bikes, pedestrians and vehicles, for example.* *What worries me more is data protection. These are issues, especially in German democracy, we find it more difficult to deal with because we have to follow these democratic principles. That is why I believe that it will take much longer in Germany or Europe than in China or America.*
e.	Would you consider leaving the city? Why or why not?
CA	*We associate moving out of the city with moving into boring life, then it's not automatically boring, but moving into a quiet and green area.*
CB	*That would be a factor, but not a decisive factor.*
CC	*As previously mentioned, I don't think that there are any factors associated with SAVs that would make me want to leave the city.*
f.	When do you think shared autonomous vehicles are going to be introduced?

CA	*We can't say. But my father already told me when I was very young that my children don't have to get a driving license anymore.*
CB	*I completely lack the expertise.*
CC	*Let's see if I am going to experience it, before I die.*
g. Do you think that autonomous/self driving vehicles will be redefining where we live in the future?	
CA	*--Question not covered in this interview--*
CB	*--Question not covered in this interview--*
CC	*I think so, because many move to the country because the city is supposedly not worth living in. In my opinion, autonomous driving should reduce traffic. This would allow more people to move back into the city. I live in the middle of the city and don't have the feeling that I am missing anything. I think it depends on the city. I think there are cities where I might not want to stay, I could imagine moving out. In Munich you don't have any insane disadvantages if the traffic decreases. You can actually see that very well with Corona.*
3. Open Discussion	
a. Is there anything else we haven't mentioned, or do you want to add something to a point?	
CA	*This is actually a topic that we could talk hours about.*
CB	*I believe that especially the car manufacturers in Germany have to change. They may have to change their business model.*
CC	*I basically have a problem with the proliferation of mobility. A major problem of our time is unlimited mobility. Everybody has to go somewhere in the world. That can't really be true. I think you have to step back a bit. Especially when flying, that can have a big impact on the environment. These are the questions that our society must solve. Is all this really necessary?* *I believe that the e-mobility that is so highly acclaimed is an environmental catastrophe. It reminds me a lot of the nuclear power issue we had 30 years ago. There are too many unanswered questions.* *For me the alternative is synthetic fuels, diesel, kerosene, hydrogen and the other is algae.*