A Work Project, presented as part of the requirements for the Award of a Master's degree in Management from the Nova School of Business and Economics.

Evaluation of the contribution of ACES Trends to the urban mobility transformation in Germany until 2040

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Field Lab project title

Exploration of the development of urban mobility in Germany until 2040 through the criteria of efficiency, sustainability and accessibility

Abstract

This working project is an analysis of the development of future urban mobility in Germany until 2040. The three stakeholder perspectives of the *public sector*, *private companies* and *consumers* are investigated in detail, to understand their roles in the process. Ultimately, the three factors *efficiency*, *sustainability* and *accessibility* of urban human mobility were identified to be the areas for necessary improvement of the mobility sector. As a result of the paper, an evaluation model was developed to help public sector officials decide on different mobility initiatives, focusing on the three areas of improvement and their respective inclusion by the initiative.

Keywords: Mobility, public sector, German urban mobility development, efficiency, sustainability, accessibility, public transport

Individual title

Evaluation of the contribution of ACES Trends to the urban mobility transformation in Germany until 2040

Abstract

This work, "Evaluation of the contribution of ACES Trends to the urban mobility transformation in Germany until 2040," contributes to outline the future development of urban mobility in Germany considering the role of the private sector. Through five semi-structured interviews for data collection and analysis, the potential impact of the trends: *autonomous driving*, *connectivity*, *electrification*, and *shared mobility* and the role of private companies are evaluated. It is found that private companies see themselves in the role of enablers and accelerators. Moreover, electrification is assessed as the greatest contributor towards sustainability, whereas shared mobility has the potential to increase efficiency.

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1 Introduction

1.1 Relevance of the topic and problem statement

The urban mobility ecosystem in German cities is currently characterized by inefficiencies, insufficient accessibility for users and a lack of contribution to the sustainability goals to which Germany has committed itself. The main problems lie for example in a massive consumption of fossil energy resources as traffic is responsible for about 33.5% of carbon emissions (European Environment Agency 2022). The utilization rates of public transport are low, especially in smaller and medium-sized cities, and create an enormous economic dependency on government subsidies. Furthermore, the traffic volume in Germany generates, on average, 40 hours of congestion in cities on an individual base per year (INRIX 2021). Many urban mobility problems can be traced back to the dominant use of private motorized transport. According to the Federal Motor Transport Authority, more than 48 million personal cars were registered in Germany in 2021, and the trend has been rising steadily for years (Federal motor vehicle authority 2021). However, personal cars not only have the worst carbon footprint compared with other means of transport but are also characterized by low utilization and usage rates (Federal Environmental Agency 2019). The global trend of rapid urbanization can also explain the growing relevance of this topic. For Germany, it is expected that 85% of the population will live in cities by 2050 (United Nations 2019). In the context of urban mobility ecosystem, three main stakeholder groups interact with each other. These are the public sector, private companies, and consumers. The common objective of these stakeholders is to develop a better urban mobility ecosystem, which can be achieved by reduced use of private motorized transport through the growing use of optimized public transportation systems, the creation of flexible, modern and more sustainable mobility offers by private companies in combination with improved accessibility and an attractive price-performance ratio from the consumer's point of view.

1.2 Objective of the work and outline

This dissertation aims to analyse the current status and the assumed development of urban mobility in Germany until 2040. Thereby, the interactions of the three identified stakeholder groups *public sector, private companies,* and *consumers* are considered. The transformation process is evaluated based on the indicators of *efficiency* in operational terms, *sustainability* reflected in a decreased carbon footprint, *and accessibility* related to consumer affordability and access.

The literature review first presents the megatrend urbanization and the development of mobility. Afterward, the three stakeholders, their interaction, and their roles are elaborated, which is defined as urban mobility ecosystem in the scope of this work. Furthermore, a comprehensive overview of Germany's current urban mobility situation and related challenges are given. Next, this work will present three main analyses focused on individual topics. In the third section, the public sector perspective on future urban mobility development is subject to exploration. Especially how the public sector develops public transportation toward being more sustainable, efficient and accessible. Furthermore, an investigation is conducted on how the public sector steers the general industry-overarching mobility market toward a more sustainable mobility approach. Chapter four covers the trends of *autonomous driving*, *connectivity, electrification* and *shared mobility* from now on, named ACES trends. Their respective disruptive potential and impact in the context of urban mobility are evaluated. Moreover, the private sector's role within the existing market environment is also elaborated because of its responsibility for research and industrialization of new technologies and innovations. Section five, covering the consumers' perspective, aims to understand how people in urban areas in Germany choose their means of transportation. In this context, the factors which influence consumers' mobility option selection and perceived advantages of personal car use or alternative mobility options use regarding these factors are analyzed. Finally, the

conditions under which consumer behavior and preferences regarding the various means of transportation may change in the future are outlined. After that, the findings of the individual analysis are brought together, and a conceptual model for qualitative analysis and comparison of mobility initiatives is introduced. Finally, the findings and gathered insights are brought together in the conclusion.

2 Literature Review

2.1 The global megatrend of urbanization

Urbanization and especially the continuous development of rapid urbanization, is considered one of the global megatrends that significantly impacts social cohabitation, political decisions, and economic development (PwC 2022a). Nevertheless, a uniform global definition of the terms ”urbanization”, “city”, “urban area,” or “rural area” has been lacking, and thereby, international comparability is limited. In the context of this thesis, the authors rely, regarding the term and process of “urbanization”, on the definition of Paul Knox: “Urbanization involves a complex set of economic, demographic, social, cultural, technological, and environmental processes that result in an increase in the proportion of the population of a territory that lives in towns and cities, an increased concentration of population in the larger settlements of the territory, and an increasing density of population within urban settlements” (Knox and McCarthy 2012). Regarding the differentiation of cities and settlements, the authors rely on the methodology degree of urbanization (DEGURBA) developed by the EU and OECD. The DEGURBA is defined as the proportion of the total population living in urban areas (European Commission 2012). This concept includes criteria for population density and the total population. It is computed using maps of built-up areas and population density obtained from satellite images and national censuses. Hereby it is differentiated between an *urban center*, which consists of contiguous grid cells with a density of at least 1.500 inhabitants per km² and a total population of at least 50.000 and an *urban cluster*, which consists of contiguous grid

cells with a density of at least 300 inhabitants per km² and a total population of at least 5.000 (European Commission 2022). Based on this methodology, 828 cities clustered by their respective urban center size were identified for Europe (European Commission 2012).

In addition, it is expected that the global population will grow from 7.98 billion to 9.6 billion inhabitants in 2050, which will predominantly lead to growing cities and is mainly due to strong growth rates in Asia and Africa. The share of the urban population, meaning the degree of urbanization, will continue to increase and rise from 55% in 2018 to 68% in 2050 (United Nations 2019). In the context of Europe, a stronger development of the urbanization rate to approximately 83,7% by 2050 (72% in 2015) is prognosticated; for Germany, a development to 84,3% is expected (United Nations 2019; Statista 2018a). Even if both the growth rates and the absolute number of inhabitants in European/German cities are significantly lower compared to other areas on a global level, the change towards an urbanized society is accompanied by similar challenges and opportunities. An enormous level of productivity characterizes cities, and urbanization is seen as a driving force in terms of increasing prosperity and general economic performance. This is reflected, for example, in the fact that 80% of the global GDP is generated in cities (World Bank 2022). At the same time, cities offer unique advantages and positive effects, such as the high concentration of economic activity, which reinforce and favor this development (PwC 2022a; Zhang 2015). Besides the positive economic effects, many challenges like sustainable infrastructure scaling, waste reduction, or rising informal housing and employment sector emerge through urbanization. Cities are responsible for consuming 75% of natural resources and cause 80% of carbon emissions (World Bank 2022). Based on the current development of the ongoing and emerging climate crises, cities will have a crucial role in tackling the issue and solving the problem towards less environmental pollution, resilience, and more efficient resource consumption (United Nations 2017). Furthermore, uncontrolled and rapid growth in some

areas leads to rising social problems though crime, income inequality, and housing unaffordability (Zhang 2015). However, another central challenge, as also dealt with in this thesis, is to cope with the growing demand for mobility and the expansion of the relevant infrastructure to meet the higher absolute number of inhabitants on the one hand and the general increasing demand for mobility. Current urban areas are characterized by unsustainability and inefficiency regarding their handling of mobility, which leads to high opportunity costs that are exemplary, reflected by 154 hours lost in traffic jams each year per person in 20 of the world´s most congested cities (Boston Consulting Group 2019).

2.2 Development of urban human mobility

Over the years, human mobility has changed drastically. Not only the means of locomotion have changed, but also the key factors of human mobility, namely convenience, environment, user experience and costs of mobility solutions have improved, driven by groundbreaking innovation (Rajat Dhawan 2019). Additionally, the access to even intercontinental mobility and especially to everyday commuting solutions became standard in many parts of the earth's regions. Consequently, the development of human mobility over time has not only changed the way of living, but also the international exchange in travel, trade and physical interaction.

This development is often seen as a continuous cycle of development with steady innovation and linear development over time. A famous quote of Henry Ford says "If I had asked people what they wanted, they would have said faster horses" (Rajat Dhawan 2019), showcasing the difference between vertical and horizontal innovation, being the source of this misperception. Continuous progress in the development of mobility solutions, such as advancing car models are horizontal innovations, as existing products got improved, but mobility was not fully reinvented in the sense of severely improving all four factors of mobility development (convenience, environment, user experience and cost). According to McKinsey, there have been two main inflection points, when mobility changed drastically (Rajat Dhawan 2019).

These inflection points describe phases with erratic development, followed by phases of vertical innovation such as product improvement, in the shape of a "S-curve" (Luo, et al. 2018). The first inflection point happened in 1908, when Henry Ford released the "Model T" – the first engine powered car that was accessible for the broader middle class. The "Model T" was the first real point of inflection through its innovative combination of reliability, innovation, and especially affordability, which enabled Ford to sell personalized and mechanized mobility to the masses (Rajat Dhawan 2019). The result was the first real car, satisfying people's needs regarding the factors of mobility innovation: lower transportation costs, greater comfort, and a better driving experience. Despite compromises, Ford's "Model T" and this first inflection point has been one of the greatest business success stories in history. Over time, mainly horizontal improvements took place and shaped today's mobility landscape, comprising not only (private-) cars, but also services and products building on the initial invention, such as taxis, busses, motorcycles, etc. (Rajat Dhawan 2019).

According to McKinsey, the second main inflection point is currently happening. Existing pain points with the traditional car are about to be resolved through new car generations that will seamlessly become part of a larger mobility network. These pain points comprise (fatal-) traffic accidents, traffic congestion, suboptimal infrastructure (solely focused on cars) and environmental burdens. With the new inflection point, connectivity, autonomy and electrification will moderate these pain points and lower their impact (Rajat Dhawan 2019).

Generally, cities and their infrastructures are heavily shaped by cars and road transport. Nevertheless, also other forms of urban human mobility emerged over time, such as railways and other public transport (Lazo 2021). Apart from technological development, also societal change in mobility usage emerged, disrupting the way consumers use mobility. Options such as car sharing services, less costly taxi substitutes such as Uber or Bolt and modern and convenient public transport options are driving consumers away from self-ownership of a car

to the more flexible and convenient service offerings (Deloitte 2022). Furthermore, cities in developed countries start to target strict emission reduction in urban traffic for the future. In order to realize these goals, many cities promote and support alternatives to cars, such as bicycles and walking. For this purpose, the German Federal Ministry for digital and transport has launched the special financial aid program "City and Country". A total of around 1.04 billion euros is now available for the period up to 2024, for cities to apply for (BMDV 2022).

All in all, technological advances, changes in use patterns of mobility by customers and governmental targets, such as carbon emission reduction, will continue to shape the future of mobility. Also, the reduction of pain points like air pollution, noise pollution and blocked streets will influence the development of new mobility solutions. Therefore, players from the private sector must comply with these indications and limitations to develop new and future proved mobility solutions. Furthermore, the state must increase the public's usage of public transport options, as it is a viable option that is sustainable, efficient and mostly pain point free (Federal Environmental Agency 2022c). In conclusion, consumers, the private sector and the public sector will define the future urban mobility through their interaction over time (McKinsey & Company 2020).

2.3 Stakeholder identification

As in any other market, the urban mobility market fundamentally comprises providers and customers (Bwl-lexikon 2022). Urban mobility encompasses a wide range of products and services. From products such as cars from OEMs like Volkswagen or bicycles from bike manufacturers like Cube, to individual mobility-as-a-service offerings like cabs, ride service providers like Uber and electric scooter providers like Bolt, to public transport offerings like subways, commuter trains and buses (Federal Ministry for Economic Development and Cooperation 2022). The target customers are usually private customers who make use of the offers. There are also customized offers for business customers who want to buy or lease car

fleets for their company, issue their employees mobility vouchers for public transport and cabs, or provide company cars or bicycles to their employees (Handelsblatt 2010). The German urban mobility market is thus designed as both a business-to-customer market and a business-to-business market.

However, the role of the public sector in this market is special. In this market, more than in almost any other, the public sector itself acts as a provider of mobility on a large scale, with over 10 million different passengers having used public transport services in 2019 alone (VDV 2020). As such, the public sector is a relevant player on the provider side.

Furthermore, the state, i.e. a part of the public sector, has a function as market regulator (Federal Agency for Civic Education 2022). In February 2010, the Federal Constitutional Court ruled that a minimum level of participation in social, cultural and political life is part of a humane standard of living. Mobility thus becomes a fundamental right that can best be guaranteed by the national public transport system (Westfälische Nachrichten 2017). Therefore, the public sector is obliged to keep its own mobility services, namely public transport, accessible and efficient, so that the citizens of Germany can make use of mobility services to a reasonable extent. Affordability of tickets and availability of stops in reasonable proximity to the place of residence are thus the basis of accessibility. To achieve adequate efficiency, the state must provide public transport connections that are as seamless and intelligently linked as possible.

In order to serve *sustainability* as the final factor, the public sector is on the one hand responsible for making its public transport services climate-friendly. On the other hand, the state must intervene in the private mobility market beyond the limits of its own services. In order to meet climate commitments such as the paris climate agreement, the public sector must realize major carbon emission reductions in the mobility sector and do so on the private market side as well. Thus, it must set the regulatory framework through taxation, bans and incentives

for private mobility providers, and thereby play an overall steering role.

All in all, there are three relevant main stakeholder groups interacting in the mobility development spectrum. In the following sections of this master thesis, these stakeholders and their interaction will be the subject of investigation.

2.4 Situation Germany

In the following part, key figures regarding Germany's demographics and mobility are presented.

2.4.1 Demographic situation in Germany and German cities

Germany is a country with 83.24 million inhabitants as of 2021. The annual growth rate over the past five years was 0.1 percent (Statista 2022g). The German federal statistical office does not expect the German population to neither grow nor shrink significantly within a time horizon until 2040 (Federal Statistical Office 2022 b). The demographical split counts 51.46m inhabitants in working age (between 20 and 66 years), while 15.41m people are younger than 20 years and 16.37m people are 67 years old or older (Statista 2022e). Unlike the absolute number of inhabitants, the proportion of German inhabitants in working age is expected to decrease by four to six million until 2035 (Federal Statistical Office 2019). The average age of German inhabitants is 44.6 years (Statista 2022f).

The situation in urban areas differs from the rest of the country. Growth in inhabitants and recent years can be observed for nearly every city and continued growth between 5 and 16 percent, depending on the city, is expected (City of Munich 2020; Citiy of Cologne 2018; Senate Department for Urban Development, Building and Housing 2021; Statistical Office for Hamburg and Schleswig-Holstein 2021; State Statistical Office of Hesse 2019). The average inhabitant's age is lower for most cities compared to the country-wide average (40.9 years in Frankfurt, 41.6 years in Munich, 42.1 years in Hamburg, 42.7 years in Berlin) (Statista

2022h). German cities are expected to domicile more young and old inhabitants in the future, leading to a situation similar to the overall German situation, in which the population in working age decreases in absolute and relative numbers (Statistical Office for Hamburg and Schleswig-Holstein 2021). Overall, we can expect a situation in which more people live within Germany's big cities and urban areas in general, leading to an increased need in mobility there.

2.4.2 Mobility situation in German cities

2.4.2.1 Need for mobility

Regardless of the place of residence, German residents leave their homes on a daily basis for similar reasons. Three occasions are the most common throughout every German city. The first is the way to an individual's workplace or educational institution, being accountable for around one third of the traffic volume. Almost another third is due to individual's mobility needs for grocery shopping or other private errands. A little under a third falls under leisure activities (Agora Verkehrswende 2020). Individuals that reside in Germany's urban areas cover an average distance of about 37 kilometres per day, without significant differences between big cities and metropolises. In contrast, looking at summative daily average travel times, people from metropolises (>500,000 residents) take on average 9 minutes longer than big cities (100,000<x<500,000 residents) residents and even 14 minutes more than residents from small cities (20,000<x<100,000 residents) to reach their destinations, while metropolitan residents use on average 92 minutes for their daily mobility (Agora Verkehrswende 2020).

2.4.2.2 Mobility differences between cities

While individuals have similar mobility needs within German metropolises and cities, big differences throughout the cities' current mobility situations can be detected. There are three main dimensions forming the mobility structure of each specific city, meaning how people meet their mobility needs in form of choosing a mobility option. The first dimension is the spatial structure of a specific city and its transportation offering. A city's spatial structure

highly influences and, in some cases, limits the spectrum of mobility options used by individuals within that city. The second dimension is a city's politics, planning, and implementation, which in some cases influences the mobility offering of for example public transportation services and might either facilitate or complicate private companies' operations. The third dimension is the residents' perceptions and orientations, as individuals are the consumers of products and services, in this case mobility options (Agora Verkehrswende 2020). So, while analysing and evaluating cities' mobility situations, we need to keep in mind that different cities deal with different prerequisites, such as a city's specific spatial structure, and therefore also have differing initial situations as starting points when looking into their future mobility structures.

2.4.2.3 Mobility structures

Figure 1 shows the average mobility split for metropolises, big cities, small cities and very small cities (<20,000 residents). The first learning from this illustration is that the smaller the city, the greater the proportion of the distances covered by car. Further, it is notable that with a declining number of a city's residents, the proportion of distances covered by public transportation decreases. This phenomenon can also be seen for distances covered by bike and on foot. In conclusion, it can be stated, that the dominance of car usage increases with a decreasing number of residents.

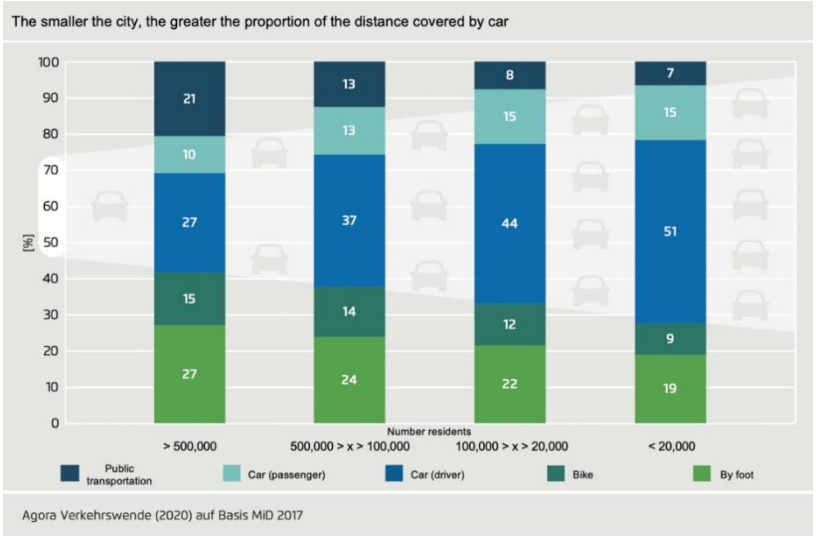

Figure 1 - Mobility structure and number of residents – translated from Agora Verkehrswende (2020)

2.4.2.4 Means of transportations

The following part serves as an overview of different means of transportation within German cities. Furthermore, the great differences between the cities are demonstrated.

Personal cars

Personal cars are the most used mobility option not only worldwide but also within the German society, being accountable for around 57 percent of the covered distances travelled (Federal Ministry of Transport and Digital Infrastructure 2019). Germany's policy makers are trying to initiate the desired shift in transportation, but the sobering truth is that on January 1st of 2022, more cars were registered in Germany than ever before, counting 48.5 million (Federal Statistical Office 2022a). This number increased from 41.7 million in 2010 by around 16 percent over the past twelve years (Berliner Zeitung 2021). In the beginning of 2021, 77 percent of German households owned at least one car, and of the 42 million existing German households, around 12 million or 29 percent owned more than one car (German Federal Environmental Agency 2022a). On average, a German household owns 1.14 cars (kfW Research 2022).

The degree of motorisation (meaning how many cars are registered per 1,000 residents) throughout Germany has increased from 532 private cars per 1,000 residents in 2000 to 580 cars in 2020. Since temporarily deregistered vehicles were added to the inventory up to 2007 only, the increase in the motorisation rate is even higher in practice (Federal Environmental Agency 2022a). As outlined in Figure 1 the proportion of an individual's distances covered by car increases with a decreasing number of a city's residents, indicating the relevance of a private car for daily tasks and errands. The proportions of different cities' households that do not own a private car as well as the degree of motorisation for different cities clearly confirm this observation. In German metropolises, on average 43 percent of households do not own a private car, while for big cities this value equals 33 percent, and for small cities only 23 percent

(Agora Verkehrswende 2020). These values are the arithmetic mean of the values of cities in the specific category, not weighted by number of inhabitants of such cities. In this regard Berlin can be highlighted, as every second household manages to get along without a personal car. The motorisation rate of the city is 335, being one of the lowest of all European metropolises, and way lower compared to other German metropolises (Hamburg: 436, Frankfurt: 449, Cologne: 453, Munich: 493) (Berliner Zeitung 2021; Agora Verkehrswende 2020).

To conclude, various numbers show a relatively low usage per resident of private cars in urban areas. On the other hand, this by no means mitigates the problems arising from the very high absolute private car usage in urban areas, and current trends do not show any signs of declining.

Public transportation

The proportion of distances covered by public transportation differs between cities and correlates positively with the size of the city in terms of number of residents. For metropolises, this proportion equals 21 percent, for big cities 13 percent, and for small cities and rural areal the proportion is below ten percent, as can be seen in Figure 1. Berlin shows the highest proportion with a share of 26 percent of the distances travelled. The highest usage for public transportation as a mobility choice can be detected for routes to work (40 percent) and educational institutions (28 percent) (Center Nahverkehr Berlin 2021).

Public transportation must play a key role in the desired transport turnaround in urban areas, which is currently not the case. For 94 percent of Germany's residents, the next public transportation stop is reachable within 400 meters, for metropolises this value is even higher in some cases (Federal Ministry of Transport and Digital Infrastructure 2019; Center Nahverkehr Berlin 2021), indicating an increased usage potential. Under certain conditions,

many Germans would be willing to use public transportation more often (Federal Ministry of Transport and Digital Infrastructure 2019). One problem might be long travel times, as these are between 1.94 and 2.24 times higher compared to car usage within German metropolises (Mobility Institute Berlin 2021). In metropolises such as Berlin and Hamburg, 40 respectively 38 percent of the residents over 18 have a monthly or annual pass, which shows the potential for an increase in usage rate of public transportation (Agora Verkehrswende 2020).

Carsharing

As of the beginning of 2022 around 3.4 million German people have registered on carsharing platforms, a number that increased by 18 percent within one year. 243 providers distributed over 30,000 car-sharing vehicles among 935 German cities (German Carsharing Association 2022). Large cities are better equipped with carsharing vehicles than small ones. Throughout metropolises there are also large differences in offer density, with a range from 0.21 to 2.1 carsharing vehicles per 1,000 inhabitants. Exeptional to this, the city with the highest density is Karlsruhe (around 313,000 inhabitants), with 3.2 vehicles per 1,000 inhabitants, followed by Munich with 2.1 vehicles per 1,000 inhabitants (Agora Verkehrswende 2020).

Carsharing vehicles emit on average 15 percent less carbon dioxide than the average new private vehicle in Germany, as the fleets are predominantly made up of small and medium-sized vehicles, making carsharing less environmentally harmful compared to the average German resident's private car. Moreover, car sharing relieves traffic congestion by leading to a reduction in the number of private vehicles needed. Each carsharing vehicle replaces between three and ten private vehicles, depending on local conditions. In densely populated areas of large cities, the replacement rate can even exceed 10 vehicles (Federal Environmental Agency 2022a).

(E-)Bikes and walking

As Figure 1 shows, the proportion of an individual's distances covered by (e-)bikes and on foot increases with an increasing number of a city's residents. In metropolises, around 42 percent of the distances are covered by bike (15 percent) or on foot (27 percent). The proportion of distances covered by (e-)bikes varies within the range of metropolises (from seven percent in Stuttgart to 24 percent in Bremen). The spatial structure of a specific city is a crucial determinant in this regard (Agora Verkehrswende 2020). In urban areas, an e-bike is on average the fastest mobility option to cover distances up to 7.5 kilometres. Since about 40 percent of the distances covered by car in urban areas are less than 5 kilometres, this holds extreme shift potential from cars to bikes (Federal Ministry of Transport and Digital Infrastructure, 2019). The proportion of journeys made on foot ranges from 23 to 33 percent and is similarly high throughout metropolises and big cities. Frankfurt records a high value of 33 percent, making it the strongest pedestrian city in Germany (Agora Verkehrswende 2020).

2.4.3 Current challenges Germany faces in urban mobility

In the context of the transformation of urban mobility, Germany as a whole is confronted with several challenges. These are problematic indicators that vary in severity from city to city or metropolitan region to metropolitan region but can be found throughout Germany.

First, there is a lack of investment in infrastructure in German cities. The total investment backlog for road and transport infrastructure is estimated at €39.6 billion (German Association of Cities and Municipalities 2022). This affects the entire mobility sector, including related infrastructure such as train stations. In addition, in the context of the expansion of urban infrastructure projects, there are massive delays as well as extreme increases in cost, which not only hinder the progress of the actual project but also have a negative impact on the implementation of other projects due to possible budget cuts that may result. A current example is the construction of the second S-Bahn main line in Munich, which is delayed by

at least 25 years compared to the original plan (2035 instead of planned 2010) and already exceeds the costs by a multiple (Deutsche Bahn AG 2022b).

Another challenge lies in securing the country's energy supply and transport infrastructure, which has become even more critical due to the changed geopolitical situation caused by the Russian invasion of Ukraine. In addition to the aspect of security of supply, this also resulted in massive price increases of more than 100% in some cases compared with the previous year in energy procurement (Destatis 2022). This had an impact on both the operating cost structure of the operators and the affordability for users. Even though Germany is in a continuous and growing expansion of renewable energies, the increasing electrification in the transport sector is creating a growing demand for electricity to ensure the security of supply in the long term and sustainably (Federal Environmental Agency 2022b).

The demographic development of the German population, which is already the second oldest population in the world with a median age of 47.8 years, is also becoming a challenge in the context of mobility (World Data 2022). Therefore, the administration and private companies must develop and implement appropriate concepts tailored to dynamically changing mobility behavior to enable a large number of older citizens to remain mobile into old age.

Another point to be mentioned is the economic efficiency of local public transportation. At the national level, ticket revenues of €10 billion are countered by expenditures of €13 billion to operate the transportation system, resulting in a subsidy requirement of €3.2 billion (Roland Berger 2019; Statista 2022i). Even though it is normal on an international level that public transport is subsidized on a large scale, Germany is faced with the challenge of reducing the current need for subsidies. However, the degree of coverage and the profitability of the respective transport company varies significantly between the individual cities and depends, among other things, on factors such as the size of the city (VDV 2021)

4 Individual Part II: Evaluation of the contribution of ACES Trends to the urban mobility transformation in Germany until 2040 – (Simon Schaub)

4.1 Introduction

4.1.1 Topic and Relevance

In their current design, urban mobility ecosystems in Germany are characterized by inefficiencies, a lack of comprehensive and affordable access to public transport, and an insufficient contribution to climate protection (ADAC 2021; Federal Environmental Agency 2021). In the context of this work, the ecosystem is defined as the interaction of the three stakeholder groups presented in the general introduction. Among other factors, individual motorized transport with internal combustion engine vehicles (ICE) is a central reason for the problems in German cities. This accounts, on average, about 35% of the modal split, which mainly reflects the most significant share per city (Infas Institute 2019). It primarily leads to adverse effects on efficiency, for example, due to congestion and high carbon emissions that oppose a threat to the climate (Federal Environmental Agency 2022a; Statista 2021b). Considering the trend of rapid urbanization, the rising mobility demand of society as well as the goals of Germany regarding carbon neutrality, it is necessary to find new mobility solutions and transform urban mobility (Federal Ministry for Digital and Transport 2022). It is not exclusively the public sector's responsibility but also an opportunity for private companies to create new business models within the framework of existing laws and given infrastructure. In the context of the general change in the mobility sector, the private sector can play a decisive role in research and development and the industrialization of new technologies or innovations. Particular attention should be paid to the development of the trends: *autonomous driving*, *connectivity*, *electrification*, and *shared mobility*, which are – to a small extent - already integrated into urban mobility systems and could lead to a shift away from traditional individual motorized transport with ICE. In some cases, the ACES trends are

already represented in new forms of mobility, such as car sharing or E-scooters. Nevertheless, mobility solutions based on the trends account only for a minimal share of the modal split of urban mobility. Given this fact, examining their future development and potential impact is essential.

4.1.2 Outline and objective

Much of the existing literature can be clustered into the analysis of the four trends' potential impact at the macro-level of the mobility sector on the one hand. On the other hand, there is a specific focus in research on the trends` relevance for specific industries like automotive manufacturers. However, a gap in the existing research is the analysis of the trends' influence on urban mobility. To assess the impact of the trends, it is first necessary to examine the market environment with a particular focus on the private sector, affecting both the development process and its speed. Private companies are responsible for the triad of development, industrialization, and distribution of new technologies or innovations. Hence, the first research question can be derived:

RQ 1: Which role can private companies fulfill in transforming urban mobility within the existing market environment?

Based on this informative fundament, the thesis aims to analyze the role and disruptive potential of the trends under consideration in the given time horizon in the context of urban mobility. The resulting second research question examined in this work is:

RQ 2: What impact can the ACES trends have in the context of the urban mobility transformation until 2040 – considering the indicators of efficiency and sustainability?

In order to capture the status quo and provide a consistent basis for understanding the respective trends, a literature review is carried out subsequently. The description of the methodology used follows this to analyze the research questions. Afterward, the key findings are discussed based on a qualitative evaluation of the conducted interviews by an inductive approach. Finally, the conclusion and limitations of the work are presented.

4.2 Literature Review

Autonomous Driving

Due to the different stages of development regarding the degree of automation, which can be divided into assisted, automated, and autonomous, there is currently no standardized definition for autonomous driving. However, the six defined levels of the Society of Automotive Engineers (SAE) are internationally acknowledged. Levels 0-5 differ in the distribution of tasks and responsibility between driver and vehicle (Table 1) and range from a fully responsible driver without assistance in level 0 to a fully autonomous driving vehicle in level 5 (SAE International 2021). The benefits of a widespread introduction of autonomous driving are anticipated to a safety improvement (Fagnant and Kockelman 2015), more efficient use of space in cities through fewer parking spaces required (Peters 2017), and broader accessibility to mobility since the ability to drive is not necessary (Burns 2013). In the U.S., the widespread rollout of autonomous driving is estimated to have a potential of $800 billion per year (McKinsey & Company 2021a). Besides estimated positive effects and economic potential, critical factors have been pointed to the unreadiness of technical infrastructure in urban areas or software failures, which could lead to a safety risk (Faisal, et al. 2019). Autonomous driving is assumed to have a high disruptive potential in the context of mobility transformation (Meyer, et al. 2017; Kassens-Noor, et al. 2020), but simultaneously the development progress or speed has been overestimated (SAE International 2020). Although research is being carried out with immense effort, the current area of application is at level 3, and industrial series use of levels 4 or 5 is not expected in the foreseeable future. (Zielpuls 2021). Due to its focus on the automotive sector, Germany strives to play a key role in developing autonomous vehicles. Additionally, the German government was the first country to enact a law enabling Level 4 vehicles to participate in public traffic to support the research process (Federal Ministery for Digital and Transport 2021).

Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Autonomous Driving**
Driver: fully responsible	Driver: ´primary responsibilities for tasks and environment	Driver: fall-back and environment	Driver: fall-back responsibility	Driver: optional fall-back responsibility	Driver: no responsibility (passive)
Vehicle: almost no support	Vehicle: some driver modes (e.g., acceleration)	Vehicle: assisting & dynamic driving modes	Vehicle: most driving modes	Vehicle: all driving modes	Vehicle: full responsibility for all modes

Table 1 - Classification of 6 automation levels (authors' illustration based on SAE International 2021)

Connectivity

Connectivity or connected vehicles (CVs) refer to the ability of vehicles to communicate and exchange information with their environment using technologies like 5G or short-range wireless technologies (McKinsey & Company 2014). Through internet access, it can exchange data with devices inside and outside the vehicle (Meola 2020). CVs are attributed to numerous advantages in the context of mobility. These include, first and foremost, the improvement of safety through a more decisive role for driver assistance systems and more assertive communication between the vehicle and its environment. This can be mapped in various dimensions, from more static vehicle-to-infrastructure [V2I] communication to dynamic vehicle-to-vehicle [V2V] communication and the development of a fully connected ecosystem vehicle-to-everything [V2X] (Aragón, Alonso-Zarate and Laya 2018; Olia, et al. 2014). Another advantage is a better customer experience, which can be derived, on the one hand, from an improved infotainment offering and, moreover, from stronger linking with personal devices such as cell phones (McKinsey & Company 2014). This trend, primarily based on data monetization, is attributed to an economic potential of $450-750 billion globally by 2030 (McKinsey & Company 2018). The potential of getting hacked or security vulnerabilities of CVs are named as the most considerable risk, which can lead to massive problems since many technical systems could be targeted (Koester, et al. 2022). In Germany, 19% of new vehicles

had Internet access in 2018 (Statista 2018b). According to the development and the associated economic potential, this area is expected to have substantial growth opportunities, especially in connection with autonomous driving.

Electrification / E-Mobility

In the context of mobility, electrification refers to using electrical energy, primarily stored in batteries, for propulsion. Hereby vehicles can be differentiated into purely electric vehicles and, e.g., hybrid cars (Wilberforce, et al. 2017). Compared to the other trends, this trend differs in two characteristics. On the one hand, electromobility has a long history, and the technology was invented and used at the end of the 19th century (Ajanovic 2015), on the other hand, the widespread and industrialized expansion of this trend is more likely and faster compared to the other trends due to its advanced development and the intense focus on the reduction of local carbon emissions during operational use. This can be justified both by the technical superiority in terms of efficient energy use of electric vehicles (Agora Verkehrswende 2020; Federal Ministry for the Environment 2021), and the fact that policymakers have enacted laws in important car markets such as Canada and the EU prohibiting new registrations of traditional internal combustion engines starting in a range from 2030 to 2040, which is steering the automotive industry (ICCT 2021a). Considering the entire life cycle, electric cars have a better environmental footprint than ICEs. They can be operated in a carbon-neutral manner by charging them with electricity generated from renewable energies (ICCT 2021b). In addition, they are significantly cheaper to maintain due to the reduced complexity and diversity of spare parts (Bansal 2005). From today's perspective, there are still economic disadvantages in production, which are currently covered through subsidies. However, these will be negated in the foreseeable future by a drastic reduction in battery costs (McKinsey & Company 2021c). The range of the vehicles, charging infrastructure, and batteries' longevity and disposal are currently seen as disadvantages (Ajanovic 2015; Bansal 2005). The strong

growth of electric vehicles is also reflected within the German market, considering both the absolute number of vehicles [2021: 309.000 / 2022: 757.000], as well as the relative share [2021: 0.64% / 2022: 1.3%] (Statista 2022a) (Statista 2022b). The role of electrification is also increasing in various other market segments like E-buses (PwC 2022b), E-Scooters (McKinsey & Company 2022) and E-bikes (Statista 2022c), which are closely related to urban mobility.

Shared Services

Shared Mobility is an on-demand, short- to medium-term active or passive use of transport means, detached from their ownership, as a service to meet mobility needs (Shaheen, et al. 2015). Shared mobility enables customers to temporarily book their means of transport (e-scooter, bike, car-sharing) or to be carried through ride-pooling or ride-hailing, depending on their demand, by using a corresponding provider application on their cell phone (Machado, et al. 2018). Each of these sub-categories, in turn, has its market environment and service providers, e.g., the sector of micro-mobility. In addition, the subtrend Mobility-as-a-Service (MaaS) can be derived from many offerings in which the supply side, including the collaborating providers, is displayed to the customer in a bundled form via one application. The most convenient form can thus be booked transparently (Becker, et al. 2020). In contrast to the other trends, shared mobility is not a disruptive technological evolution on a product level but rather a connective service offering between market participants. In principle, the benefits heavily depend on the individual users' mobility behavior. Shared mobility is also considered to have high economic potential, but at the same time, it is currently difficult for many companies to operate profitably in this market environment (McKinsey & Company 2021a; Kumar, Lahiri und Dogan 2018). In Germany, shared mobility is forecast to have a market volume of €53 billion in 2026. Overall, a more widely spread and higher usage is expected, reflected in a penetration rate of 109.8% in 2026 [2022: 90.2%] (Statista 2022d).

4.3 Research methodology and Analysis

Because there is hardly any research that explicitly analyses the potential of the ACES trends in the context of urban mobility, especially when it comes to the transformation in Germany until 2040, a qualitative research approach was adopted. This approach is considered most suitable for gaining new insights into a specific research topic (Lanka, et al. 2021). Interviews are classified as an efficient data collection method and are also widely used in qualitative research (Bogner 2009). Since private companies are primarily involved in research and development and especially the industrialization process of solutions based on the respective trends, representatives of private companies were interviewed. In total, five interviews were conducted between the 27th of October and the 24th of November 2022, ranging from 25 to 48 minutes. All experts interviewed are experienced and have great expertise in the mobility sector. The spectrum of experts provided holistic insights and diverse perspectives on the topic, ranging from start-up founders, consultants, and corporate employees to project managers at automotive manufacturers. A detailed overview of the interview partners can be found in the appendix (Appendix 4). By following a semi-structured guide with open-ended questions during the interviews, the conversations remained flexible to the interview partner's personal knowledge and insights while maintaining a thematic focus on the centric research questions and the supporting indicators (Appendix 5). The collected data was translated, anonymized, and transcribed with the help of transcription software to set a base for the analysis process (see Appendix 7). Afterward, a thematic analysis using an inductive approach, according to Braun and Clarke, was performed. In an iterative process, the data were coded, clustered, and categorized to assign them to suitable themes and subthemes, which were derived from the results (Braun und Clarke 2006). Following this approach of inductive category formatting, 5 main themes with 18 sub-themes were defined. The results table in Appendix 6 is used to answer the research questions.

4.4 Key Findings

The following section presents the findings and insights from the interviews to provide a base to answer the two research questions. First, the market environment of the urban mobility ecosystem is illustrated from a private company perspective because it heavily affects the role and behavior of private companies respectively. Then, building up on this, the role of private companies is outlined. Subsequently, the four ACES-trends' assessment findings are presented to illustrate the specific disruptive potential based on the interviewees´ evaluation. Since many interviewees have assigned a tremendous potential to the combined use of ACES trends within one mobility solution and referred to ride pooling executed by electric cars, the German start-up MOIA is introduced.

For a clear and better visualization of the urban mobility ecosystem as well as the interaction of the involved stakeholders, the following illustration was created to improve comprehensibility.

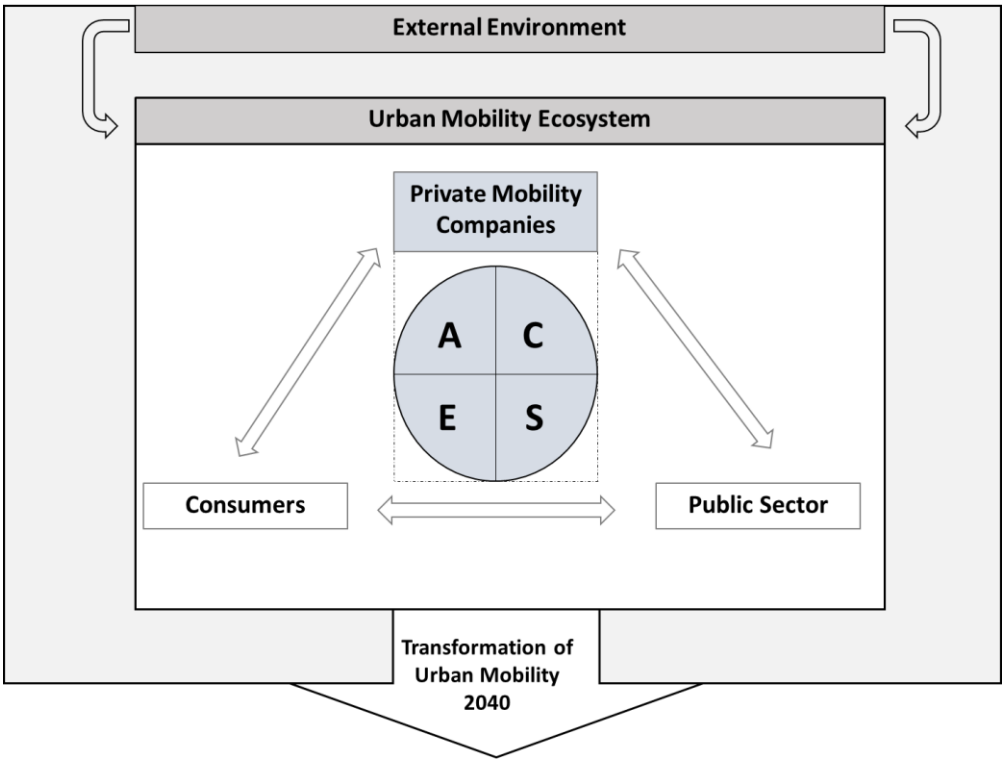

Figure 2 - Framework of an urban mobility ecosystem

4.4.1 Market Environment

Public Sector

The public sector is perceived as the most crucial stakeholder in the construct of the urban mobility ecosystem from the perspective of private companies concerning setting and defining the framework conditions: „*The Government must set an appropriate framework for what is possible and what is not*." (Appendix 6, I1) It is the responsibility of the public sector to steer the urban mobility transformation and to define the playground in which private companies should be able to operate freely and independently to develop, test, and implement new solutions (Appendix 6, I2). In order to exploit the scope for political action and define the framework, the public sector has instruments at its disposal, which can be divided into two main categories: Proactive promotion of new technologies or prohibition of the current status quo through restrictive laws (Appendix 6, I5). On the contrary, Germany's public sector represents part of the supply side since they provide the infrastructure and the service of public transport and can thus be classified as a direct competitor for private companies in some mobility segments (Appendix 6, I1; I3). This positioning leads to unequal competition due to a lack of subsidies for private companies and the absence of public companies striving for profit (Appendix 6, I1; I3). Regarding the German political system, federalism is found to be advantageous over a centralist system, as individual municipalities or cities have more substantial capabilities in operational implementation and collaboration (Appendix 6, I1). The current actions of politicians and the framework conditions that have been created are predominantly viewed rather critically. This is reflected in the perception of a lack of braveness, decisiveness, and consistency in defining the framework conditions to drive transformation. Nevertheless, the public sector faces many conflicting objectives, and it is not easy to satisfy all involved stakeholders equally (Appendix 6, I3; I4).

Consumers

"The consumer is first and foremost selfish. Price always comes first." (Appendix 6, I2)

From the private sector's perspective, consumers are primarily perceived as users of the available supply and consequently take on a passive role within the ecosystem (Appendix 6, I2). For most consumers, at the individual level, the economic factor, or the cost, comes first, as does the fulfillment of convenience and flexibility (Appendix 6, I2; I3; I5). Referring to the initially defined indicators, there is a higher interest in improving the efficiency and accessibility of urban mobility than in a positive contribution to sustainability. The consensus from the interviews is that consumers at the individual level need to be proactively persuaded by economic and operational efficiencies to achieve a natural shift in their behavior. Consumers have almost no intrinsic motivation to adjust their current behavior (Appendix 6; I2; I3). However, there is a consensus that the importance of ownership in general and possessing a private car, especially in urban areas, will decline (Appendix 6, I4; I5). Apart from their role as consumers, individuals can influence the development of urban mobility in their role as voters, thus indirectly influencing the speed and direction of the transformation (Appendix 6, I2; I5).

External Factors

Apart from the mentioned stakeholders interacting within the ecosystem, there are also external factors to consider those influence market participants and the speed of development in Germany. These include, among others, the changed geopolitical situation due to the Russian invasion of Ukraine. In addition to the fundamentally changed political orientation and alliance landscape, this has resulted in concrete economic cuts and changes regarding Germany's energy supply (Appendix 6, I1). The reduced availability and massive energy cost increase can negatively impact the pace of development and affect the achievement of objectives until 2040. Looking at the macroeconomic level, it is also conceivable that an

impending recession in the next two years will negatively impact market conditions and inhibit the innovation environment (Appendix 6, I2). On the other hand, positive factors can also influence the ecosystem. These include, for example, the availability of a well-educated workforce, which can contribute to the transformation process (Appendix 6, I1). Furthermore, some companies that do not directly belong to the mobility sector, e.g., energy providers, proactively promote initiatives like the construction of charging infrastructure in their responsibility to influence the ecosystem (Appendix 6; I4).

4.4.2 Role of private companies within the market environment

The private sector considers itself an essential part of the urban mobility ecosystem. At the same time, it perceives its role as an enabler and driver of innovations and technologies that can be transferred into new solutions and an expanded mobility offering (Appendix 6, I1; I4). Compared to the public sector, private companies can act faster, more agile, and more efficiently, which is attributed to the pursuit of profitability and success (Appendix 6, I3). "*I believe private companies can make the transformation faster and more efficient. For example, I do not think any government would have developed an electric car as Tesla did*" (Appendix 6, I1). Even though private companies mostly face themselves as competitors, cooperation and the bundling of forces are perceived by the majority as positive and an opportunity, as it accelerates the complex development process and makes it more efficient (Appendix 6, I3; I4; I5). Synergies can be created from which the entire ecosystem benefits.

The private sector does not force a close interaction with the public sector and prefers to work independently (Appendix 6, I2). To unfold their potential, private companies emphasize their dependence on the framework conditions set by the public sector. In its role, the government should define the guard rails that serve as a reference point for the private sector (Appendix 6, I1; I4). At the same time, it is also emphasized that too detailed guidelines lead to more complexity within the system, which also affects the scope of action of private companies. Since private companies are also dependent on the provision of public infrastructures such as

roads or railways, there is the expectation on the company side that an appropriate infrastructure will be provided to create new solutions (Appendix 6, I4). Furthermore, it was mentioned that the expectations of the public sector are partly exaggerated and that it is impossible to meet them. Especially since there are hardly any concessions on the part of politics and unequal competition due to subsidies for public offers (Appendix 6, I3).

Concerning consumer interaction, private companies strive to implement new offerings perceived as attractive and used by many consumers. At the same time, consumer opinion is taken into account during development to advance further helpful developments with a corresponding market potential (Appendix 6, I4).

4.4.3 Assessment of the disruptive potential of ACES trends

Considering the time horizon up to 2040, it is the overwhelming perception of the interviewees that the period should not be overestimated and that, for example, substantial changes to the infrastructure are not possible in the chosen time frame (Appendix 6, I2; I3).

On an individual level, including the technological aspect, *autonomous driving* is mainly seen as having the most outstanding revolutionary potential, as it would equate to the most remarkable technological progress (Appendix 6, I1; I2; I3; I4). Particularly in combined use with ride-sharing, the trend is seen as having numerous possibilities, such as better coverage by night, for decentralized districts or last-mile and higher active usage rates of the vehicles. Nevertheless, the use spectrum is classified as limited at an individual consumer level and as a substitute for owning a vehicle (Appendix 6, I2; I5). Considering the time aspect and the current state of technological maturity, including the speed of development until today, industrialized and widespread use by 2040 appears unrealistic from today's perspective (Appendix 6; I3; I4).

Although only positive effects are attributed to *connectivity*, these relate, on the one hand, to an improvement in safety and, on the other hand, to an improvement in the user experience and convenience in handling vehicles. Continuous development is expected, but this will be

driven primarily as a side effect and simultaneously with other trends. On an individual level, the trend is not assigned any revolutionary or disruptive potential in the indicators of efficiency, sustainability or accessibility (Appendix 6, I4).

Electrification is perceived as an irreversible trend and technically superior innovation compared to internal combustion engines. The penetration will be driven across all modes and means of transport in the coming years (Appendix 6, I1; I2; I5). Emission-free operational use, assuming that electricity is generated from renewable sources, creates a significant contribution to sustainability in the form of reduced noise, less particulate matter pollution, and no local carbon emissions. Furthermore, the efficiency of the ecosystem is improved by a less vulnerable and simpler technology (Appendix 6, I5). Critical in this context is the sufficient provision of charging infrastructure, supply of renewable energy as well as the speed of deployment considering the time horizon (Appendix 6, I4).

Shared mobility is seen as having very great potential at the macro level. However, the individual segments of the trend are assessed very differently. While micro-mobility is seen as having only additive potential to public transport, ride pooling and ride-sharing, in particular, are seen as having disruptive potential due to higher efficiency and significantly better usage rates (Appendix 6, I2; I3; I4). Besides, the subtrend Mobility-as-a-service, which positively influences user-friendliness and flexibility in the selection of transport means, is also seen as having supportive power (Appendix 6, I5). Above all, taking into account the more effective utilization at the vehicle level, which is not limited exclusively to road traffic, the possibility is seen to provide broader access to mobility and handle increasing volume more efficiently. Moreover, a positive contribution towards more sustainability can be achieved through the reduced presence of individual traffic and, consequently, vehicles on the street.

4.4 Example of cross-trend urban mobility operator in Germany – MOIA

The expert interviews revealed that the most significant disruptive potential is attributed to mobility solutions that combine more than one of the covered trends. For example, in one of the interviews, a desirable scenario was described as: "*I think it would be very innovative, sustainable, and efficient at the same time if I could order a connected autonomous vehicle, powered by electricity that I share with several passengers*" (Appendix 6; I1). The Hamburg-based start-up MOIA is a pioneer in offering a mobility solution, including some of the ACES trends. MOIA offers ride pooling in electric vehicles within a defined area of Hamburg. People share a vehicle whose starting point and destination are in a similar direction. Booking is made via an app, and the assignment between customer and vehicle is done via a dynamic pooling algorithm. The journey also follows a dynamic route, but the price is fixed and paid in advance. Based on published usage data, the company had 28.000 weekly users, accounting for 0.11% of Hamburg's modal split from June 2019 to October 2021 (MOIA GmbH 2022). An accompanying study, which examines the effectiveness, also shows a broad usage potential and several scenarios for making urban mobility in Hamburg more efficient and sustainable. It has been determined that up to 15 million vehicle kilometers per week can be saved through a combination of ride pooling and public transport. (TU Munich 2021). Based on the business model, MOIA primarily combines the trends of shared mobility and electrification, but also connectivity. In addition, research is already being conducted on a project with autonomous driving vehicles, which would be synonymous with combining the four ACES trends in one mobility solution.

4.5 Discussion

Based on the interviews, it was possible to evaluate the direction and speed of the urban mobility transformation in Germany until 2040 from the perspective of private companies. It was possible to gain insights into the role that private companies see themselves playing, how

they assess the market environment and how they evaluate the impact of the ACES trends. Regarding *Research Question 1* and the role of private companies, it can be stated that private companies see themselves as enablers and accelerators. Being driven by profits, in combination with a more agile and (cost-) efficient way of working, they take a key role in urban mobility. At the same time, however, it also became clear that the scope for action and the development potential depend massively on the framework conditions created by the public sector. About *Research question 2*, ACES trends will successively expand their influence on urban mobility by 2040. It became evident that the trends will be able to make a continuously growing contribution based on the indicators of sustainability and efficiency. Especially, electrification in terms of sustainability and shared mobility in terms of efficiency improvement can be decisive here. Furthermore, it became clear that the trends must be considered together rather than separately. On the other hand, the speed of the transformation was relativized, also due to the public sector, whose behavior is mainly perceived as too inconsistent. Autonomous driving is progressing much slower than initially anticipated. In addition, the shift to electrified vehicles will take time, considering that of a total volume of 48.5 million passenger cars, only a share of approx. 1.5% is purely electric now (Kraftfahrtbundesamt 2022). Nevertheless, the projected development, in combination with a different relation to ownership, will lead to a decrease in individual motorized mobility with ICE vehicles. Differentiation has emerged as a central factor at various levels during the interviews that must be considered. There will be no breakthrough of an identical mobility concept, defined by the same expression of the ACES-trends, at a city level, either in Germany or abroad. Instead, it is expected that different constellations of the four trends and different mobility mixes will emerge in a differentiated manner but with the same functionality (App. 6, I1; I4). The ecosystem will, besides the stakeholders, depend on indicators like topography, customer segments, and the city's character due to tourism or history (Appendix 6, I1; I4; I5).

4.6 Conclusion and limitations

This work aimed to review the current state of development of the trends *of autonomous driving, connectivity, electrification,* and *shared mobility* in the context of Germany and to evaluate their future potential for the transformation of urban mobility until 2040. In this regard, the qualitative research method enabled the author to collect and interpret information from representatives of private companies. By analyzing and clustering the information, it was possible to develop a framework that clarifies the interaction of the stakeholders within the ecosystem. Based on this, it was possible to outline the role of private companies and provide an outlook on which role ACES trends can play in the transformation of urban mobility. It was possible to highlight that companies can play an essential role in urban mobility, depending on the framework defined by the public sector. Furthermore, it was discovered that the ACES trends will influence the transformation and, in combination, can unleash greater disruptive potential. In conclusion, it can be stated that factor differentiation must be considered at several levels to achieve successful development. Regarding the time horizon, taking into account the current status quo, the experts expect a positive but too slow development to meet the carbon emission targets stated by the German government. Although this work has created new insights in the context of urban mobility transformation for Germany, limitations in the informative value must be acknowledged. The total number of five interviews can lead to a potential bias in the data collection. The informative value is reduced by considering Germany only and the period up to 2040. Even though international developments were covered during the interviews, e.g., megacities (population > 10 million), newly constructed cities from scratch, or cities in developing countries that face different challenges, were hardly considered. These topics offer further potential and are suitable for additional research. As it is an ongoing development, the author recommends further monitoring and investigating the progress of the German urban mobility transformation

6 Consolidated presentation of main findings and application of a conceptual model

6.1 Summary of the main findings

Based on the introductory part of the thesis and the analysis conducted on the various stakeholders, taking into account the respective perspectives and research questions, findings were obtained on the current status quo of urban mobility in Germany, the desired development, and the roles and behavior of the individual stakeholders. The central findings can be summarized under the following key aspects:

- Individual motorized transport with ICE takes up a substantial (depending on the city, the largest) share of the modal split of urban mobility in Germany. Therefore, it has a negative impact on both efficiency and sustainability.
- The public sector has recognized that it is necessary to modify its role and the framework conditions in order to be able to achieve the set objectives.
- Private companies see themselves in a position to contribute positively to urban mobility development, for example, by incorporating new trends and technologies. However, they depend on the framework conditions created by the public sector.
- Consumers take various factors into account when choosing their means of transportation. For many of the most essential factors, consumers see advantages for personal car use over the use of other mobility solutions and a natural shift towards a lower proportion of personal car use can only be expected as soon as alternative mobility options offer an increased perceived value for at least some of the critical factors.

The following can be deduced from the results: Both consumers and private companies see the public sector as primarily responsible for defining the framework conditions needed to drive the urban mobility transformation. The scope of action of private companies depends on the framework conditions created, and a change in consumers' habits towards increased use

of alternative mobility options can only be expected with an increasingly compelling offer. The task of the public sector can thus be differentiated into two essential core points. Firstly, the active provision of an efficient public transport system, in which the public sector represents the supply side and carries full responsibility. On the other hand, in the definition of the framework conditions in the form of the promotion of initiatives or the introduction of restrictive regulations and laws to steer both consumer behavior and the private sector in their respective actions. At the same time, however, the public sector also needs guidelines or indicators against which it can align the tasks mentioned above and serve as a guide. According to the governing parties' party programs and the international treaties to which Germany has committed itself, such as the Paris Climate Agreement, the strong indicators to be considered for the framework conditions are the parameters: *efficiency*, *sustainability*, and *accessibility*.

Consequently, the public sector needs tools or assistance in the decision-making process that adequately take into account the three parameters mentioned or disclose their impact in order to be able to evaluate initiatives. The factor *sustainability* is understood as a positive contribution to reducing carbon emissions, particulate matter pollution, or noise reduction. The efficiency factor is measured by the operational improvement of the urban mobility system, which is reflected, for example, in shorter travel times or higher utilization of the individual means of transport. Accessibility plays a role primarily for consumers and covers easier access to mobility, the degree of coverage of the mobility offer, and affordability in financial terms.

The evaluation of different alternatives is highly complex and requires the inclusion of a wide range of indicators, perspectives, and stakeholders due to the economic scope of the decisions. However, to enable a first evaluation and comparison of different initiatives in the mobility sector, a model was developed by the authors in the context of this work, which enables a

purely qualitative comparison in the early concept stage of an initiative in an efficient and fast way using a two-step approach. Based on the described role distribution as well as the perception of the individual stakeholders, this is a tool to be applied in the role or from the perspective of the public sector with a focus on the maximum improvement of the general welfare.

6.2 Scientific justification of the radar chart

Radar charts or network diagrams are often used to compare situations with a similar objective but with different characteristics. Frequent fields of application are the comparison of target/actual deviations or the evaluation of different initiatives based on their contribution to the achievement of the target based on previously defined qualitative or quantitative indicators (Porter und Niksiar 2018). The equal orientation must apply to all axes of the diagram, i.e., conversely to the selected criteria, which means that the better values recorded in the evaluation are either close to the center or decentralized at the edges.

The network diagram analysis is based on a previously created data table in which the determined values are assigned to each criterion (Porter und Niksiar 2018). Due to different-sized areas or distances to the central point, strengths and weaknesses can be easily visualized and systematically identified. The network analysis allows a quick graphical comparison of the previously determined criteria (Basu 2004). Deviations of the underlying bases can be derived directly from the diagram, and the weightings of the individual criteria can be considered.

6.3 Conception and structure of the model

The model design allows the operator, in this case, the public sector, to evaluate possible initiatives based on the defined three factors. Initiatives can be new mobility service solutions, such as extending a subway line by one stop or expanding the offering of car sharing to a new city district. Initiatives can be evaluated using a two-step approach in isolation or as bundles,

in which possible combinations of initiatives are reviewed. From here on, the term "initiatives" is used for single initiatives and bundles. When evaluating initiatives, it is assumed that consumers would use the corresponding offer if it targets their use. The factors *efficiency sustainability*, and *accessibility* are rated based on an upstream valuation model, including several subfactors per factor, and are transferred into a score for each possible initiative. Not every initiative must or will contribute to all three factors or all of the defined sub-factors. In both application steps, the results are illustrated with a radar chart.

At the beginning of the two-step approach, the initiative is evaluated along the twelve defined sub-factors. Each factor, *efficiency*, *sustainability* and *accessibility*, is assigned four sub-factors to ensure comparability. The evaluation is done on a qualitative level, using a scale of 0 to 5, whereby the same assessment principle applies to all factors. That is, the scale ranges from *0= has no positive impact* to *5= has an enormous positive impact*. The categories *efficiency*, *sustainability* and *accessibility* can achieve a score between a minimum of 0 and a maximum of 20 by evaluating the sub-categories. A score of 0 can occur in the case where the initiative does not contribute to any of the main factors via the sub-factors.

Efficiency is evaluated by the factors of *capacity per vehicle, average utilization per vehicle, space required per vehicle*, and *average travel time*. The *capacity per vehicle* is recorded to show an initiative's decisive impact on transport capacity. The *average utilization rate* refers to the utilization of the vehicle, whereby assumptions are made using utilization rates of comparable means of transport. The *space required* sub-factor is evaluated based on whether the initiative can be easily integrated into existing infrastructure and how it generally fits structurally within the context of the ecosystem, as well as how much space the implementation of an initiative requires in relation to how much mobility is offered in terms of the number of individuals transported and kilometers traveled by them. Finally, *average travel* time will be included to identify and evaluate time savings from deployments of the

initiatives examined.

Sustainability is evaluated through the categories of *carbon emission savings, energy consumption, air pollution,* and *noise pollution*. Concerning *carbon emission* savings, the goal is to measure emission savings per person transported to ensure comparability between alternatives. In the context of *energy consumption*, which energy source can be used to implement the initiative in an economically viable way is included. The *air pollution* factor is measured by the contribution to keeping the air clean and a positive or non-negative contribution to air quality. Finally, the factor *noise* is classified by the noise pollution caused by the imitative.

Accessibility is measured by the factors of *price per route per person, average distance* of the mobility alternative to the customer, *the temporal availability* of the offer measured based on a 24-hour day, and the *simplicity of use* or *accessibility to the offer*. The *price per route* factor assesses the service's affordability and assumes the extent to which the population has realistic financial access to the service. *Average distance* measures the proximity and spatial availability of the supply to the consumer. The *coverage period* of the initiative enables conclusions and an assessment of the temporal coverage of the offer within 24 hours per day. *Accessibility* includes the availability of the offer across social classes and the ease of use or booking of the initiative.

The following overview of the evaluation sheet is shown for schematic illustration. The illustration shows a pool of sub-factors for the three main factors. These serve as orientation, while further subfactors may exist for different initiatives, which can be designed and substituted by the model user.

Factor	Sub-Factor	Initiative 1	Initiative 2
Efficiency	Capacity per vehicle	3	4
	Average utilization per vehicle	2	4
	Space required per vehicle	4	3
	Average travel time	1	2
Sustainability	Carbon emission savings p.p. transported	4	3
	Energy consumption (cons. energy source)	3	2
	Air pollution	5	4
	Noise pollution	1	3
Accessibility	Price per use/ km traveled per customer	2	0
	Average distance to customers	3	0
	Time coverage of the offer	4	0
	Simplicity of use	1	0

Table 2 - Evaluation sheet of qualitative comparison tool

Based on the evaluation carried out at the sub-factor level, a score in the range from 0 to 20 is obtained by adding up the individual aspects, whereby here, too, it applies, analogously to the evaluation of the sub-factors, that the higher the value, the more significant the positive contribution to the respective main factor. All three main factors have the same weighting, so the overall assessment of the initiative is measured by how large the area is that is spanned between the three main factors. This form of presentation and evaluation enables an equal comparison of the main factors and illustrates the overall impact on the one hand and the contribution to the result at the level of the main factors.

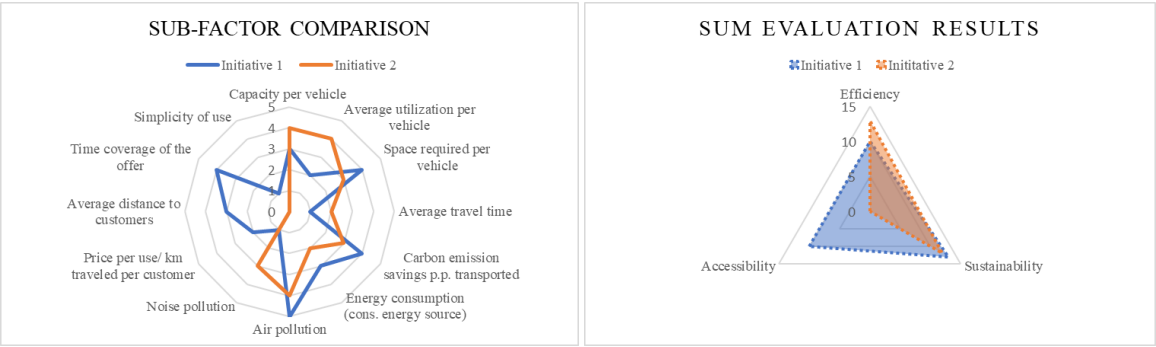

Figure 3 - Exemplary presentation of results of the evaluation steps 1 and 2

In addition, indirect effects, i.e., effects that result from the introduction of an initiative and are not intended but arise as an effect of the initiative, must be considered in the evaluation. While initiatives can be evaluated isolated, they also should be considered and evaluated in comparison with respective alternatives. Here the following aspects should be considered to

become a detailed overview of the respective initiatives:

(i) The objective sought to be achieved

(ii) The individuals or groups targeted by an initiative

(iii) Resources used

(iv) Time frame, duration until launch and initiative life cycle

6.4 Exemplary implementation of the model based on the comparison of two initiatives

The model has the potential to add real value to the decision-making process between two initiatives and is very straightforward. Applying the model, initiatives can be compared specifically in terms of the overarching goals of the public sector. To demonstrate the practical use of the model, two concrete initiatives are compared in the following.

One example scenario is that a city would like to connect a small suburb to the public transport network without any gaps. Two initiatives are available for this purpose. One would be to extend the existing subway by one station to the small suburb in order to meet the demand for mobility. The second possible initiative would be regular shuttle buses serving this route.

The first step is to analyze the two initiatives in terms of the sub-factors of the three categories *efficiency, sustainability and accessibility*.

Factor	Sub-Factor	Subway	Bus
Efficiency	Capacity per Vehicle	5	3
	Average utilization per vehicle	3	4
	Space required per vehicle	3	2
	Average travel time	4	2
Sustainability	CO2 Savings per person transported	4	2
	Energy consumption (cons. Energy source)	4	2
	Air pollution	5	3
	Noise pollution	2	1
Accessibility	Price per use/ km traveled per cust.	2	2
	Average Distance to customers	3	4
	Time coverage of the offer	4	3
	Feasibility & simplicity of use	2	1

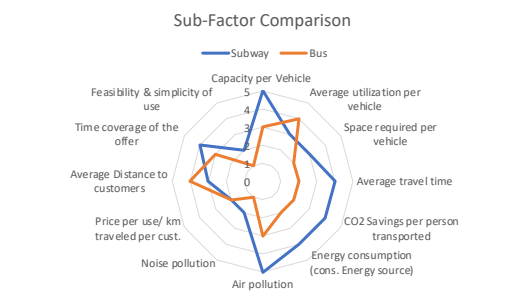

Figure 4 - Presentation of results of evaluation step 1 for the two initiatives

These results can now be summarized in the form of the network diagram, and it quickly becomes clear which of the two initiatives is the more useful in terms of the three goals of *efficiency, sustainability and accessibility*.

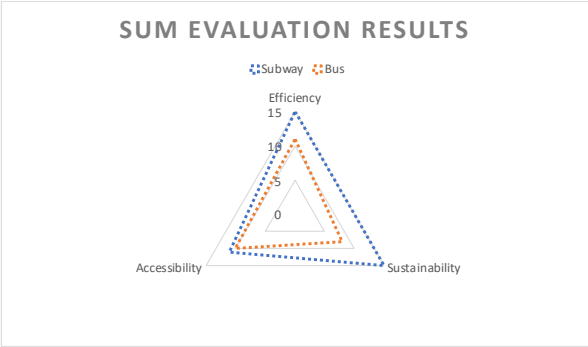

Figure 5 - Presentation of results of evaluation step 2 for the two initiatives

The model clearly shows that the subway is the better choice across all factors. On the sustainability scale, the subway scores almost twice as many points as the bus (15 to 8), it is clearly more efficient and at least marginally more accessible. Of course, the reliability of the model depends on how carefully and accurately the subfactors were evaluated.

Hence, in the next step, decision-makers would know that the subway contributes more to achieving their overall goals and is therefore the preferred option. Now the feasibility has to be checked with regard to other factors. For example, unavailable resources or a too long implementation time of the initiative could still overturn the decision as hard factors.

6.5 Benefits and limitations of the designed model

The developed model allows policymakers to assess initiatives at the individual level and by comparing different initiatives with each other. However, it is not an all-encompassing tool that allows all indicators to be fully included in the analysis and assessment. Instead, the model offers assistance in making a quick and comprehensive assessment by including key indicators in the context of efficiency, sustainability and accessibility and in evaluating the effectiveness of initiatives on a fundamental level.

The model's advantages include quick and simple handling, which is made possible by the qualitative indication of the individual initiatives or combinations of initiatives. This reveals a broad spectrum of applications, which also allows differentiated weighting about the contribution to efficiency, sustainability or accessibility depending on the focus of the respective initiative.

The limiting factors of the model include that not all indicators can be applied in full range to all potential initiatives, which means that some of the information may be incomplete. At the same time, even with a full scope of application, the informative value is primarily limited to a qualitative assessment of the degree of effectiveness. Imperatively, and to provide a fully comprehensive basis for decision-making, it is necessary to underpin this with quantitative factors and in-depth analyses. Especially for assessing the costs and the derived price-performance ratio, it is necessary to perform an in-depth analysis. Similarly, the time required to implement an initiative, which influences its efficiency, is given too little consideration.

7 Conclusion

This dissertation investigates future urban mobility in German cities and metropolises with the time horizon until 2040. Future urban mobility in Germany has to become more sustainable and efficient while ensuring the highest possible level of accessibility for consumers. The aim of this thesis was to gain a better understanding of the stakeholder groups and factors responsible for the further development of the mobility landscape, the creation of new solutions, and how these groups interact. In turn, these insights can be used to derive how future urban mobility in German cities and metropolises can become more sustainable and efficient. After an introduction to the topic, the relevance of the three stakeholder groups public sector, private companies, and consumers with regard to future urban mobility in Germany was elaborated and evaluated within three individual parts. Finally, the findings of the individual parts were combined, and a model was developed, which can support public sector officials in the evaluation of new potential projects and the comparison of alternatives in the future.

In the introduction, the relevance of the topic, as well as the selection of the stakeholder groups examined was explained. Furthermore, the status quo of urban mobility in German cities and metropolises was analyzed and the current challenges of Germany regarding urban mobility

were outlined.

The first individual part analyzed the role of the public sector in future urban mobility development. More specifically, the overarching goals of the German public sector, to achieve higher efficiency, sustainability and accessibility were examined. Furthermore, it was the target of this part to find out how and where the public sector steers the urban mobility development in German cities. Therefore, qualitative expert interviews were conducted with experts inside and outside the public sector, covering in their expertise various mobility related industries and knowledge areas, such as infrastructure, transportation and smart mobility.

The second individual part of the thesis examined the potential of ACES trends in the context of urban mobility transformation. Through a qualitative survey with representatives of private companies, insights were gained into the market environment, the role of private companies and the anticipated development through the impact of the trends until 2040.

In the third individual part, the factors as well as their relative importance according to which consumers in German cities and metropolises choose their means of transportation were examined. The results of the study provide insights into the conditions under which a natural shift towards a higher proportion in use of alternative means of transportation can be expected.

In the final part of the study, these findings were used to propose and conceptualize a model that can be used by public sector officials as a decision support tool for evaluating and prioritizing alternatives for new mobility concepts. Here, new mobility concepts are evaluated based on three factors: *efficiency*, *sustainability* and *accessibility*. These factors are composed of several sub-factors, which are evaluated individually and result in an overall score for each category. The results are ultimately presented within a radar chart, providing both visual and quantitative comparability of alternatives. The limitations of the model have been outlined in the corresponding section.

In summary, it can be stated that the model can be used as an initial indication for the

evaluation of projects and enables a quick assessment. The model acts as a tool for officials from the public sector, adding much value to educated decision making. In later steps, further factors should be included in the in-depth analyses when evaluating projects in detail.

The transferability of the findings and the application of the presented model is basically given for other markets in which the factors efficiency, sustainability and accessibility also play essential roles in the development of new mobility concepts. In this context it must be mentioned that in this thesis the interaction of the stakeholders in Germany was analyzed and for a possible application of the model for other markets the political and social situation must be considered.

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9 Appendix

Appendix 1: Individual Topic I - Overview conducted interviews

Overview interview partners			
Interview number	**Expertise**	**Role**	**Experience**
Interview 1 (I1) *10.11.2022 – 44 minutes*	Infrastructure	Strategy Consultant	- Various infrastructure projects in Germany, Europe and internationally
Interview 2 (I2) *18.11.2022 – 39 minutes*	Public Sector (External)	Project Manager	- Various strategy consulting projects with the German public sector
Interview 3 (I3) *22.11.2022 – 47 minutes*	Public Sector (Internal)	Public Sector Official	- Digitization of traffic and mobility - Project execution in future mobility topics in Hamburg
Interview 4 (I3) *18.11.2022 – 27 minutes*	Smart Mobility	Senior Expert	- Experience across mobility industries - Special insights into future mobility
Interview 5 (I5) *22.11.2022 – 31 minutes*	Transportation	Principal (Senior project leader)	- Experience across transportation industries - Special insights into public sector collaboration

Appendix 2: Individual Topic I – Semi-structured Interview Guide

Introduction	- Short introduction reviewing experience, sharing of information about the field lab and information procedure - Quick overview of the questionnaire - What do you think urban mobility will look like in German cities in 2040?
Section: German public sector	- How do you evaluate the efforts of the public sector towards improving efficiency, sustainability and accessibility of human urban mobility? - What extend of improvement per factor is realistic? - Do you see an increased responsibility of the public sector to act in these fields? - Will Germany meet their commitment to save further 42% of emissions in the public sector? - Do you wish for more public regulation and intervention or less? - How do you evaluate the German federal system regarding urban mobility development? - Which public interventions do you wish for? - Which cities do you see as future urban mobility leaders in Germany/worldwide?

Section: Contribution of technology trends	- Which of the mobility trends Autonomous Driving, Connectivity, Electrification, Shared Mobility has major impact on the improvement of the three factors? - How would you rank them according to their importance?
Section: Public sector collaboration with private companies and consumers	- In future urban mobility development: What is the role of the public sector? - … What is the role of the private sector? - … What is the role of the consumers? - Do you believe that car drivers will be willing to switch to public transport increasingly? - How can this be reached regarding public intervention (incentivization/regulation) - How can the collaboration with private companies be improved?

Appendix 3: Individual Topic I – Results from interview analysis and inductive coding process

Question	Interview quotes	Outcome/ Finding
What do you think urban mobility will look like in German cities in 2040?	- *"(…) we need to change the system to have fewer cars on the roads."* (I1) - *"I think it is relatively difficult to expand the public transport system. Most large German cities already have a super subway network which of course can be optimized at the expense of tax money and construction delays."* (I1) - *"There will be less car mobility, but public transport will increase in my view, as will pedestrian mobility and mobility by bicycle."* (I3) - *"I would say there can only be limited changes if no applications for approval have already taken place in 2022 to then carry out expansion measures and construction measures accordingly."* (I5)	- German cities already have a fairly good public transport network - Probably less car mobility and more walking, cycling and public transport - Big construction changes by 2040 in mobility planning take a long time and should be known already
How do you evaluate the efforts of the public sector towards improving efficiency, sustainability and accessibility of human urban mobility? **&** **What extend of**	- "*(…)almost all measures are focused on carbon savings or have that as their primary goal (…) but the public sector should act more strongly in this area."* (I2) - *"Regarding efficiency, there it comes to infrastructure and it's going to be hard to change that in a big way in the next 18 years, because those are long processes."* (I5) - *"The 49 euro ticket subsidizes public transport. Similarly, there are projects*	- Sustainability is the biggest focus area of the public sector - Physical infrastructure will hardly be revolutionized by 2040 - The 49€ ticket showcases the states commitment to accessible mobility - Physical access is also being worked on in city-internal initiatives

improvement per factor is realistic?	*of the city of Hamburg, where we have brought out an app that has calculated by AI the cheapest route with public transport to get from A to B. Here, all the efforts are made to reduce the number of cars."* (I3)	
Do you see an increased responsibility of the public sector to act in these fields? **&** **Will Germany meet their commitment to save further 42% of emissions in the public sector?**	- "*The public sector is responsible. However, I think it's important to focus on one thing at a time and to do it properly rather than trying to do everything a little bit at a time and it not working out well in the end."* (I1) - *"I see this one hundred percent the state's responsibility. I mean, it's a basic need that you have to be able to move around, and that's of course one of the central levers."* (I2) - *"I believe that we are working directly towards this goal. Still, I don't see the goal as realistic, honestly."* (I3)	- The public sector is more responsible than ever to deliver on its goals and commitments such as the paris climate agreement - The fulfillment of the emission reduction goal is unrealistic for Germany - The whole public sector tries to live up to the increased responsibility and to reduce emissions but change remains hard
Do you wish for more public regulation and intervention or less?	- "*I think yes, the state should intervene more (...) otherwise you won't get a grip on the number of cars. I am personally firmly convinced of that."* (I2) - "*I also think that the cities have to proceed how they envision it. That they create regulations that allow private sector business, which can also become more efficient."* (I4) - *"I think for the moment in the direction of carbon it is still too little regulated."* (I5)	- The public sector should regulate more, as this forces real change - Especially in the field of sustainability must be regulated more, as private companies and consumers do not care enough
How do you evaluate the German federal system regarding urban mobility development?	- "*From my point of view, it is a strength being able to implement something quickly and relatively. On the other hand, it makes it more difficult for new measures to be applied across the nation, since each municipality ultimately decides for itself."* (I1) - *"I believe that this is where we lose a great deal of synergy potential, and we have an enormous amount of resources that we have to put into this, because you have to develop your own solutions in 16 federal states. You can bundle much better if it is controlled centrally."* (I2) - *"What I am convinced of is that urban areas or metropolitan regions, which need joint planning, are no longer always located along state or national borders. City-states like Hamburg have a huge advantage as they can fully focus on urban mobility*	- The federal system holds the benefit for each state to remain flexible and focussed on the own needs - The federal system holds the disadvantage that resources cannot be bundled - Also, states might have very heterogenous rural to urban mobility conditions to serve

	solutions. All in all, federalism does not make too much sense." (I4) - *"The short answer is that federalism is totally bad in this respect."* (I5)	
Which public interventions do you wish for? **&** **Which cities do you see as future urban mobility leaders in Germany/worldwide?**	- "*(…) we have to consider whether to nationalize parts of the infrastructure again or subsidize them more or plan them better, across the nation."* (I1) - *"Hamburg is a kind of model city where a lot is being tried out and many pilot projects are being tested for eventual adoption throughout Germany and the entire EU."* (I3)	- The experts generally wish for more restrictive interventions of the public sector to initiate real change - Hamburg is a good model city to run pilot projects and gets much funding from German and EU means
Which of the mobility trends Autonomous Driving, Connectivity, Electrification, Shared Mobility has major impact on the improvement of the three factors? **&** **How would you rank them according to their importance?**	- *"Electrification is a big topic, but other fuels are also needed in parallel. I'm curious to see how, for example, hydrogen or HVO and so on will prevail."* (I2) - *"In itself, I honestly believe that all four aspects are important (…) In my view, autonomous driving will generally bring the most in terms of efficiency and progress."* (I3) - "*In my opinion, only autonomous driving and connectivity will bring relevant change as that's the only way to get all the cars out of the parking lots. I just think you have to be careful with autonomous driving that you don't just relate it to cars.*" (I5)	- In general, all 4 technology trends hold potential to reduce emissions and increase efficiency and accessibility - Autonomous driving is the most promising technology, according to the experts - With electrification, its also important to consider that other clean fuels are serving the same cause and should also be explored and produced
In future urban mobility development: **-What is the role of the public sector?** **-What is the role of the private sector?** **-What is the role of the consumers?**	- *"I think the public sector is the "guide rail provider" (…)the private sector should be the "mastermind", but at the moment, it's not quite like that yet, which means the private sector has a bit of an implementer role." (I2)* - *"(…) the customers are the ones who are moved afterwards. I don't think customers can be expected to think far enough ahead about the complexity of urban mobility to be strong idea generators."* (I4) - *"The public sector would be the "coordinator" and "implementer" for me. The private sector is for me the "vicarious agent" and the consumer is for me (…) a "conscious or an insightful participant"."* (I5)	- The public sector is seen to have the role of an coordinator and guard rail provider - With public transport, the public sector has also the role of implementer - the private sector must be the innovator of new technologies and ideas - The consumers have a receiving role as they simply decide on the usage of mobility options. They should be thoughtful and choose wise and sustainable, but they don't have an obligation
Do you believe that car drivers will be willing to switch to public transport increasingly?	- *"I think the consumer would go along with a lot of things as long as it is not more expensive and significantly more inconvenient than in the car. Then I think a lot of people will switch.*	- The public sector internal expert believes, that consumers might change their behaviour as soon as a better offer is made

& **How can this be reached regarding public intervention (incentivization/regulation)**	*Especially for commuters, these factors are rationally important." (I3)* - *"Often the mistake of assuming rational behaviour is made (…) usually, other considerations are involved. People have emotional bonds with their car or value social distance higher than low cost and flexible transfers with public transport"* (I4) - *"(…) they could somehow impose fines, not penalties, but a hindering tax for example, or decrease parking spaces, make roads more car unfriendly etc."* (I5)	- Public sector externally, the switch of consumers is seen as hard to realize as there are other factors than just rational decision making involved, such as emotional bonds with a car or the wish for social distance -The public sector must also actively try to make the personal car less attractive through regulations and make the use less comfortable
How can the collaboration with private companies be improved?	- *"There are many partnerships between state and companies. The state or the administration takes the companies with it and builds new solutions together, such as Moia or Ioki that are only possible through cooperation and not without."* (I3)	- The cooperation between public sector and private sector works quite well - There are a few successful joint ventures between state and Volkswagen for example, when cooperation worked out well - The state must take the companies with it and propose offerings

Appendix 4: Individual Topic II - Overview conducted interviews

Overview interview partners			
Interview number	**Company**	**Role**	**Experience**
Interview 1 (I1) *27.10.2022 – 29 minutes*	Service provider for micro mobility	Revenue manager – Germany / ACH / CEE / ME	- Development of revenue and commercial strategy for 12 countries in EU/ Middle East (>100 cities)
Interview 2 (I2) *04.11.2022 – 25 minutes*	Mobility start-up for car subscription	Co-Founder & Chief executive officer	- Development of revenue car-subscription platform - Expansion to two markets
Interview 3 (I3) *10.11.2022 – 48 minutes*	Car sharing services	Manager Strategy & Partnerships	- Strategy development for urban mobility offerings - Operational Business Development
Interview 4 (I4) *20.11.2022 – 32 minutes*	Consulting company	Consultant	- Business Development - Projects related to mobility transformation
Interview 5 (I5) *24.11.2022 – 39 minutes*	Premium car manufacturer	Project Lead Data Based Customer Support	- E-Mobility projects - Data-driven customer support support (after sales) - Corporate Strategy development

Appendix 5: Individual Topic II – Semi-structured Interview Guide

Introduction	- Short introduction reviewing experience, sharing of information about the field lab and information procedure - What do you think urban mobility will look like in German cities in 2040?
Situation in Germany / German Market	- How do you assess the current developments/efforts in German cities with regard to improving mobility services, taking the sustainability aspect into account? - Do you think Germany can reach its proclaimed targets of 40-42% greenhouse gas reduction in the transportation sector until 2030? If yes/no – Why or Why not? - How do you access the German market regarding the ease of "*Doing Business in Germany*"? - Which German city or metropolitan area, if any, as pioneer in urban mobility development?
Role of private companies	- What role do private companies play in the mobility transition on the German market? - How do you see interaction of private companies with each other under the aspect of achieving common (economic & socially relevant) goals?
Assessment of ACES Trends	- Which of the following trends: Autonomous Driving, Connectivity, Electrification, Shared Mobility has a key role in the development of urban mobility by 2040? - Which of the trends can have the greatest impact and disruptive potential in the context of urban mobility transformation?
Collaboration with other stakeholders – market environment	- How do you access the collaboration with other stakeholders in the urban mobility ecosystem? - How do you perceive the role of politics/ administration? - How do you see the role of the customer?

Appendix 6: Individual Topic II – Results from interview analysis and inductive coding process

Main Themes	Sub-Themes	Interview quotes	Outcome/ Finding
Trends Definition and Assessment of trends on an individual and combined level	Autonomous driving	- *"autonomous driving would certainly be the biggest revolution"* (I1) - *"I think autonomous driving will be the best feature since navigation. This will simply make the car as a product even better"* (I2)	- Autonomous Driving is, on an individual level, seen as the most outstanding technical revolution - Impact for urban mobility is limited,

		- *"What I don't believe in, however, is that autonomous driving will influence individual ownership of the vehicle"* (I2) - *"I think the topic of autonomous driving will become very relevant. It could be a game changer (...)"* (I3) - *"I think autonomous driving is a big area and a lot of research is being done. We are currently in the Level 3 development stage here, but I see even less potential here in Germany by 2040, especially in urban areas."* (I4) - "*I don't think it will be as relevant or disruptive for urban areas."* (I4) - "*I think autonomous driving is experiencing an extreme hype right now, which in my opinion will only be used to a limited extent."* (I5)	mainly due to slow development progress - Disruptive potential assumed in combination with other trends (esp. shared services)
	Connectivity	- "*I see connectivity as a side effect that increases convenience and has more tangible use cases for the user. Nevertheless, I see more of a parallel evolution of the trend here, rather than an individual pioneering role (...)."* (I4)	- Connectivity is an add-on to increase user experience and safety
	Electrification	- "From *an environmental perspective, electrification has great potential"* (I1) - "*I think a key challenge will be to reduce emissions at the vehicle level, but here I believe we are on a clear path and that the future lies in electromobility"* (I2) - "*I think that will be different in three to five years, and then we will only be using e-buses to reduce local emissions."* (I3) - "*I'm a big proponent of electromobility. It is not only locally emission-free, but because it has so many other advantages. E-mobility will therefore already be successful because it is much more comfortable, much cheaper, completely independent of any emissions issues*." (I5)	- Electrification is an irreversible trend and the superior technology compared to traditional internal combustion engines - Electrification will lead to a decrease in local emissions and positively contribute to sustainability
	Shared Mobility	- "*use vehicles more efficiently (...) I'm thinking here primarily of ridesharing and ride pooling, (...) MOIA, for example. The goal should be to increase the usage rate per vehicle."* (I2) - "*Shared Mobility has great potential to change mobility in cities."* (I4)	- Shared Mobility must be differentiated in its respective sectors - Shared mobility can improve efficiency
	Combined evaluation	- "*I think it will come down to a combination of the various trends"* (I1) - "*I think it would be very innovative, sustainable, and efficient at the same time if I could order a connected autonomous vehicle, powered by electricity that I share with several passengers."* (I1) - "*I think that autonomous driving will play an increasingly important role, especially in combination with ride pooling*" (I2) - "*And I think it's important that autonomous vehicles are used to transport more than one person. It's about*	- Combination of trends leads to higher impact and can improve the transformation and development process

		strengthening and expanding the idea of ride pooling." (I3) - "*I don't see these trends as alternative. Shared services, for example, make more sense if you use electric vehicles*." (I5)	
Market Environment Identification of stakeholders and factors that influence urban mobility ecosystem	Role of the public sector	- "*Politics must set an appropriate framework for what is possible and what is not. But within this framework, private companies can act as they want. "* (I1) - *"In the run-up to market entry, many things have to be discussed (...)."* (I1) - "*creation and implementation of incentives via malus or bonus systems*" (I2) - "*(...) and I think that politicians should stay in the background rather than supporting them. In my opinion, there should be less intervention."* (I2) - "*It is best if only the most rudimental framework is set and then the economy adjusts to it extremely quickly*" (I2) - *"However, they also have to make concessions to us, and so far, we have seen little movement in this regard."* (I3) - "*We see that the policy addresses it and takes measures, but it takes forever, and it is difficult to enforce something against the car lobby*." (I3) - "*On the one hand, the political intention is there, but implementation is only consistent in parts."* (I3) - "*Definitely, politics must set the appropriate framework conditions*." (I4) - "*However, politics is also confronted with a conflict of objectives here and is also not prepared to impose too many constraints on the manufacturers, since the industry also acts as a major employer and driver of prosperity"* (I4) - "*But the government will have to make a policy in the end that is still suitable for the majority. Otherwise, they won't be around after the next election.*" (I5) - "*The political instruments that exist here are proactive promotion or a ban on the opposite, in order to generate pressure and drive development forward."* (I5)	- Public Sector/ Government is crucial to define the framework and conditions - Private companies (mostly) do not have intrinsic motivation. Their behavior is steered through guidelines provided by the public sector - Public sector behaves inconsistent but also faces conflicts and has to consider many stakeholders at once
	Role of Consumer	- "*The price-performance ratio is crucial. The biggest point will always be the price*." (I1) - "*The consumer is first and foremost selfish. Price always comes first, followed by convenience and flexibility*." (I2) - "*In my opinion, it is the consumer who decides whether the solutions created will be adopted or not. It's super important that private companies understand what needs customers have depending on their region or age."* (I4) - "*As a voter in democratic systems, the customer influences the framework*	- Consumer influences up to three different areas (consumer, voter, workforce) - Consumers (mainly) focus on its own advantage - Efficiency and accessibility are more critical than sustainability

		conditions that politicians create for products and services." (I5)	
	Role of private companies	- "*I believe private companies can make the turnaround faster and more efficient."* (I1) - "*The private sector is the driver that can improve mobility concepts, not necessarily the individual municipalities, cities or the federal government in this respect*." (I4)	- Private companies act as accelerators and enablers
	Interaction Private Companies	- *"I do believe that direct competition is the driver for faster innovation"* (I1) - *"I think that cooperation definitely makes sense in order to leverage joint synergies. If you pool resources and capital here, you have the opportunity to work better on the technologies and that offers advantages in any case."* (I4) - *"However, it is a mandatory prerequisite that both sides always have the opportunity to profit from a partnership. For many manufacturers, it can be very expensive and unprofitable to develop their offerings alone."* (I4) - *"I am convinced that the benefits of cooperation will increase significantly, and that no one will be able to bring a solitary mobility service to the cities or onto the roads"* (I5)	- Collaboration can create benefits and increase development progress and its speed
	External Factors	- *"The changed geopolitical situation due to the war in Ukraine makes it impossible to achieve this goal"* (I1) - *"(...) also have to take into account that there are generally very good professionals in Germany"* (I1) - *"Of course, it will be exciting to see how this is viewed in the context of an impending recession in the next 1-2 years"* (I2) - *"At the same time, the energy producer ENBW, for example, has also been very active and committed to progress in providing an appropriate charging infrastructure in the city."* (I4)	- External factors can influence the ecosystem both in a positive and negative manner - External factors mainly influence the speed of development
	Competition	- *"(...) micro mobility market, (...), there are private providers as competitors on the one hand, but also partly state-owned or subsidized institutions."* (I1) - *"difference in the operators is that the private providers have to earn money, but the public transport does not"* (I1) - *"Basically, the private sector is simply not subsidized and is only subsidized in rare cases, which then makes it an uneven playing field and makes comparability difficult."* (I3)	- Competing with the public sector or public companies is unfair due to unequal preconditions (striving for profit, subsidies)
Evaluation of German development Assessment of the current situation and	Current situation/ Status-quo	- *"Congestion causes very high opportunity costs, which have an overall negative impact on efficiency (...)"* (I2) - *"In summary, I believe that we will not make it because we are simply not consistent enough and also not willing to be resolute against certain groups of*	- Current problems are congestion, lack of efficiency, and the dominant role of individual motorized transport with ICE

assumed future development in Germany		*voters"* (I3)	
	Time Horizon	- "*you would think that 2040 is still relatively far away, but it's not even 20 years and that's already very close*" (I2) - "*2040 sounds a long way off, but it will take much longer to build a really good rail network*" (I3)	- The time period is not very long to allow disruptive infrastructural changes
	Examples/ Leading Cities	- "*In this context, I would say that Germany provides quite good framework conditions, especially Berlin can be mentioned here"* (I1) - "*Stuttgart, for example, is a pioneer in electrification and has the most electric vehicles per capita in Germany. I see Munich as a hub for shared mobility. I also read that Leipzig is a pioneer in public transport."* (I4) - "*I can't think of any of the major cities that I could consciously highlight here. I think Berlin is doing quite a lot in terms of public transport and the attractiveness of public transport*" (I5)	- German cities are almost at the same level - In some areas, depending on local conditions, there are pioneers
	Political System	- *„the German federalist decentralized system makes it much easier to implement projects."* (I1) - *"but you can generally see the urge of the cities to make mobility available in the wider area as well"* (I3)	- German political system offers advantages in the operational implementation
	Role individual motorized traffic/use of ICE	- "*I think it can't stay the way it is right now, and I think that the accessibility of inner cities with your own car will become more and more difficult*." (I3) - "*There will be a shift away from owning your own vehicle to shared offerings or other mobility solutions*" (I4) - "*Taking into account the current vehicle fleet and amount of ICE, I do not consider such a large area-wide replacement to be realistic until 2040."* (I4) - "*I think that the private car ownership in cities will decrease significantly. There still will be cars, mainly in sharing or in the area of MaaS via ridehailing, but the private car ownership in the city will decrease significantly."*(I5) - "*However, it must also be said that the volume of ICE vehicles is currently very high and these will not be replaced overnight."* (I5)	- Ownership of cars will decrease driven by younger generations - Current Volume of ICE is high and shifting the fleet is another challenge
International Development Assessment of international development and identification of pioneering countries	International project examples	- *"(...) Masdar City in Abu Dhabi is a model city with a focus on the transportation system. They have developed a completely automated transport system from scratch (...)".* (I1) - *"The first is an example of a project in Saudi Arabia. As has already been publicly communicated, the city of "The Wall" is to be built there from the ground up with special requirements for mobility concepts."* (I4)	- Middle East is assessed as a pioneering area - Western countries face the same problems and are almost at the same level - New projects, even if they fail,

		- *"I believe that on a global level, we are already much further ahead than in Germany. In most cases, however, these are also countries that have different funding opportunities and provide different framework conditions"* (I4) - *"On the contrary, I even see here that you can find comparable city types worldwide in different countries but not that in one country the cities are comparable."*(I5)	could steer the development
Differentiators Factors that influence development, its speed, and characteristics of the urban mobility ecosystem	City Characteristics	- *"(...) take into account what the geographical situation is. Is it a historic city or not?* *Is there a lot of tourism there or not. You simply always have to take an extremely large number of factors into account (...)"* (I1). - *"(...) we have different consumers who differ, for example, in terms of their demographics and mobility behavior. (...) we have different players in the market that can serve different requirements. I think mobility is driven by consumer requirements. Then again, the whole area is also very dependent on the individual and given structures, which can be differentiated by rural, urban and urban periphery. (...) metropolitan regions in Germany, while not fundamentally different, will have different characteristics in comparison."* (I4) - "*I think we have to differentiate very strongly here, especially if we take into account the trends I mentioned earlier. I think it varies greatly from region to region which trends can play a dominant role."* (I4) - "*I believe that every city will have its own mix. Every city has very different requirements, for example climatic conditions topographical conditions, social conditions."* (I5) - "*It is important to distinguish between the classic European cities with their historical nucleus and the more area-oriented ones*." (I5)	- Cities are characterized through different indicators like topography, tourism, design (etc.), which affect the urban mobility ecosystem - Differently characterized systems with comparable functionality will emerge - Different customer segments with different needs will emerge

Appendix 7: Interview transcripts – Individual Topic I & Individual Topic II:

See additional upload - (Part 2)
2022-23_Fall_ 48275_Simon Schaub_49510_David_Immisch_Part 2_Appendix 7

Appendix 8: Questionnaire part 5 (consumers) – translated version

Part 1 – sociodemographic profile

1. What is your gender?

a) Female

b) Male

c) Non-binary

d) Prefer not to say

2. How old are you?

a) < 18

b) 18 – 25

c) 26 – 35

d) 36 - 45

e) 46 - 55

f) 56 – 65

g) > 65

h) Prefer not to say

3. What is your educational background (completed or currently completing)?

a) No degree

b) High school

c) Apprenticeship

d) Bachelor's degree

e) Master's degree

f) State examination

g) Doctorate degree

h) Prefer not to say

4. What is your current occupation?

a) Student

b) Self-employed

c) Employed

d) Unemployed

e) Other

5. What is your annual (household) income?

a) < €20,000

b) €20,000 to €30,000

c) €30,000 to €50,000

d) €50,000 to €70,000

e) €70,000 to €100,000

f) €100,000 to €150,000

g) > €150,000

h) Prefer not to say

Part 2 – mobility situation

6. What is the number of habitants of the city you live in?

a) Less than 100,000

b) Between 100,000 and 500,000

c) Between 500,000 and 1,000,000

d) More than 1,000,000

7. How far is the next public transportation station from your home?

a) Less than 500 meters

b) Between 500 meters and one kilometer

c) Between 1 and 3 kilometers

d) More than 3 kilometers

8. What is your primary type of transportation?

a) On foot

b) Bicycle

c) Public transportation

d) Car

e) Shared services (car sharing, scooters,...)

9. Do you use more than one type of transportation?

a) Yes

b) Sometimes

c) No

10. Do you have a driving license?

a) Yes

b) No

11. Do you have access to a car?

a) Yes

b) No

Part 3 – Mobility option selection and factors

12. Please rank the following factors regarding their importance in your mobility selection (please drag and drop)

1.	Reliability
2.	Total travel time (door to door)
3.	Sustainability
4.	Costs
5.	Flexibility
6.	Comfort and privacy

7.	Accessibility of destinations
8.	Perceived price-performance-ratio
9.	Ease of use
10.	Plannability of costs

13. To what extent do you agree with the following statements?

Statement	I strongly disagree	I somewhat disagree	I do not agree nor disagree	I somewhat agree	I strongly agree
"I would consider using mobility options other than a personal car in urban areas"					
"Alternative mobility options are inferior to a personal car in urban areas"					
"I would be willing to use alternative mobility options if the offering would be better"					

14. Please indicate how you perceive the following factors regarding personal car use vs. alternative mobility options use in urban areas

Factor	Alternative mobility options are far superior	Alternative mobility options are somewhat superior	None of the options is better than the other	A personal car is somewhat superior	A personal car is far superior
Reliability					
Total travel time (door to door)					

Sustainability (eco-friendliness)					
Costs					
Flexibility					
Comfort and privacy					
Accessibility of destinations					
Perceived price-performance-ratio					
Ease of use					
Plannability of costs					
Reliability					

Appendix 9: Perceived advantages of mobility options regarding important factors – personal car group