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Acceptable Automobility through Automated Driving. Insights into the Requirements for Different Mobility Configurations and an Evaluation of Suitable Use Cases

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Abstract: It is hoped that Automated Driving (AD) will make alternatives to the private car more attractive and facilitate the transition to sustainable transport. However, this expectation may underestimate both the resistance of private automobility and the unintended consequences of automated driving. Whether AD will contribute to sustainable mobility depends largely on its implementation and how its risks are prevented. This paper provides empirical insights into the design of acceptable forms of AD by investigating specific use cases with respect to the requirements of different *mobility configurations*. We pay special attention to people who travel with children. Our use cases comprise three probable types, covering the spectrum from demand-responsive transport (DRT) to private vehicles. Our results include the identification of mobility configurations and an analysis of AD use cases considering several empirically derived criteria: improved accessibility, ease of daily life and well-being, and improvement of the traffic situation and the transport system. Our analysis is based on a qualitative study in the Berlin area, Germany. The discussion focuses on the usefulness of AD against the background of different user perspectives, sustainability, and societal requirements, as well as an evaluation of AD in terms of its acceptability. We conclude that automated mobility use cases should meet the requirements of different mobility configurations to promote the transformation from private to shared automobility and, eventually, less automobility overall.

Keywords: automated driving; acceptance; acceptability; mobility configurations; use cases; automobility; qualitative research

1. Introduction

Mobility in Germany and elsewhere continues to be dominated by individualized motorized transport, leading to congestion, air pollution, road deaths, accessibility issues, and other adverse impacts on various types of road users and city dwellers. The transition towards sustainable mobility is, therefore, a part of the political agenda. There is hope that transport technology innovations like automated driving (AD) will make alternatives to the private car more attractive and help push the transition to sustainable mobility.

According to the most common classification by SAE [1], six (from 0 to 5) automation levels can be distinguished depending on which driving tasks are taken over by the driver or the system. The classification reflects the idea of incremental automation; by level 4 and 5, the vehicle is self-driving or fully automated, and the human occupant is freed from any driving or monitoring task, allowing the occupant to sleep or do something else. Full automation is usually meant when talking about the transformation potential of vehicle automation. This is also the case in this article.

High expectations are associated with the emerging sector of mobility as a service (MaaS) or mobility on demand (MOD), which might be driven by AD [2,3]. In particular, sharing rides and vehicles could bundle traffic demands by increasing the occupancy and usage rate of cars and reducing the volume of motorized traffic [4,5]. Moreover, there is an ongoing discussion that trends like digitization, connectivity, and automation might revolutionize mobility and blur the classic distinction between individualized and collective transportation—in other words, between the private car and public transportation [6]. As a consequence, the private car might become obsolete or at least lose its dominant position and be replaced by shared (auto-)mobility services.

However, this expectation might underestimate the resistance of private automobility [7]. Indeed, the car continues to be attractive. In many regions and for many people, a private car plays a crucial role in individual mobility. Over the decades, private cars have become the standard means of transport in developed countries, thereby shaping societal expectations and standards of time use and distances. This kind of path dependence has been described as "car dependence" [8,9], drawing on the difficulties of changing what Urry calls the "system of automobility" [8]. This is also reflected in political approaches to sustainable transport, where the car is still the focus of attention. Given this resistance, mobility researchers, too, conclude that the car should be considered and integrated in future mobility concepts [7,10].

From a modern theoretical perspective, future mobility concepts will hardly make the private car obsolete, as the car considered to be particularly suited to the modern individualization of lifestyles and flexibility [7,10]. Under the "mobile risk society" of "reflexive modernization" [2,11], attention is paid to "dealing with the risks, insecurities, uncertainties, and unintended side effects that are induced by the technological and organizational modernization of mobility and transportation" [12]. The associated risks and visible negative effects of automobility are mainly intended to be solved by technological improvements—for example, in the form of electric drive systems or, in the future, with automated vehicles. This strategy of a "technological fix" remains controversial because this "fix" is likely to lead to further negative effects because it covers only part of the problem [9,13]. For example, the aspects of equality, road space consumption, and traffic are not addressed by alternative drives or automation. On the contrary, new risks can arise, and some effects might even be worsened.

It is widely agreed that the chances and AD risks are at least equal to each other; see for an overview e.g., [3,14]. In terms of risks, the implementation of AD could worsen classic risks of automobility and also create fundamentally new ones. In particular, AD might lead to major increases in traffic volume, road space consumption, and barriers for active means of transportation and public transportation. New risks, for example, arise from the use of algorithmic systems or the challenging distribution of actions between human and the technological actors. Consider, for example, the Uber incident in 2018: As Stilgoe asked, "who killed Elaine Herzberg," the car or the person behind the wheel [15]? While modeling studies on impacts have produced especially optimistic results regarding the ability of AD to foster sustainable transport, other empirical studies have found that a variety of preconditions are needed to realize these possibilities. In particular, reduced car traffic or shared mobility—automated or not—go beyond vehicle availability, cost/time benefits, and technical feasibility but depend on various conditions, such as attitudes, sociodemographic characteristics, and travel needs [16,17]. Moreover, several authors have pointed out that governance is crucial to steer the development paths in more desirable directions. For example, Fagnant and Kockelman [5] advised cities and the federal government on how to prepare for the introduction of automated vehicles and discussed their potential positive and negative impacts. Cohen and Cavoli [18] analyzed the possible adverse long-term effects on congestion and accessibility of a laissez-faire scenario. They argued for a government that takes anticipatory action instead of leaving the development and introduction of automated vehicles to the market. Fraedrich and Heinrichs [19] analyzed the possible effects and implications of automated driving on urban planning. The authors ultimately provided a recommendation to pay more attention to the design of AD use cases. In a similar vein, Stark and Gade [20], taking public transport (PT) as an example, showed how the introduction of automated vehicles could either strengthen or weaken PT

depending on their use cases and integration level into the overall transport system. The authors also discussed how the interests between potentials users and non-users, municipalities, and PT providers could be aligned and identified as more or less favorable use cases.

Thus, as automobility continues to be attractive, and its automated version comes with additional risks but also the potential to tackle classic negative effects, are there versions of automated driving that consider and mitigate known risks? Furthermore, would those versions be acceptable?

As several authors have pointed out, the success of AD, its design, and how it will be implemented in our transportation systems (also in accordance with sustainability goals) depends on acceptance [21–24]. Apart from conceptual particularities, technology acceptance research is primarily concerned with investigating how individuals evaluate an acceptance object, e.g., an automated vehicle, in terms of its intended or actual use [25]. Today, technology acceptance research, despite being multidisciplinary, is strongly influenced by psychological approaches that focus on the individual level [26]. In this context, acceptance research has been criticized for its narrow conception of the human being and concentration on the individual—in particular, reducing individuals to their willingness to pay or consume [27]. In a similar vein, authors have pointed out how mobility and mobility changes are embedded in broader social practices and reach beyond the individual sphere [28,29]. Moreover, there are blind spots in the broad spectrum of travel needs among different social groups and how these needs should be considered when evaluating the usefulness of mobility innovations. This applies in particular to gender-related differences [30]. These differences include space–time fixities due to complex timetables, with many different tasks occurring at different places and times [31]. This problem is not limited to women but affects them more often [32,33]. For example, escorting one's children and picking them up are a relevant part of the daily activities of a parent [34]. Thus, to identify chances for more sustainable forms of automobility, it is relevant to examine what people need given their specific life configurations and not only to ask about isolated preferences. At the same time, the spectrum of AD risks should be considered, and opportunities should be taken to mitigate those risks proactively. The bridge between these two requirements can be captured with the term *acceptability*. This concept has its roots in the domain of technical risk assessment and has been used to emphasize a normative dimension of technology acceptance based on quality criteria for beneficial technologies [35–37]. Drawing on this, *acceptable* forms of AD would consider both mobility related needs for diverse life configurations and risk mitigation. *Acceptability* could be used to evaluate more or less favorable forms of automobility or, in this case, AD.

In this paper, we use the evaluative character of the acceptability concept and operationalize it via empirically drawn criteria. The question revolves around what form of automated driving is acceptable given the needs of different mobility configurations and given the chance to mitigate the associated risks, such as increased levels of car traffic. In the following, we present an analysis of different mobility groups and their needs and requirements for likely applications or *use cases* of AD. In the discussion, we evaluate the acceptability of these use cases and conclude with recommendations regarding the introduction of AD.

2. Materials and Procedure

This paper builds on an exploratory study on user acceptance and requirements regarding automated driving that we conducted in 2018/2019 in Berlin and Brandenburg, Germany. We investigated different user groups that we formed based on sociodemographic and spatial characteristics (see below). In a prior step, we identified these group characteristics as blind spots related to prior work and the literature. Thus, the selection of these characteristics was led by empirically drawn hypotheses. Moreover, we identified three types of use cases that appeared to be relevant to the debate on automated driving, covering the spectrum from public to private use, The procedure and methodology are presented in the following section.

We applied a qualitative study design using semi-structured group discussions and additional single interviews in Berlin and the surroundings of Berlin. For pragmatic reasons, the individual

interviews were conducted with members of one of the user groups (recipients with high income), as we were unable to arrange a joint appointment. The discussions and interviews were guided by the same questions with small modifications based on the specificities of each user group. We combined inductive code (re-)development and deductive code application. The guideline questions reflected findings from the academic literature and our own prior research work. We audio- and video-recorded the focus groups, with the latter recorded only to better assign a voice to the person.

The survey participants were presented with three different possible use cases of automated driving (see below). The survey participants were then asked to imagine that these three future mobility services, i.e., use cases, were already available for their current regular trips to evaluate how the availability of these services might change their mobility behavior. For each future mobility service (i.e., use case), the participants were asked to think of their usual daily trips (e.g., to work) and to elaborate upon whether the mobility service in question constituted an attractive alternative compared to their current means of transport. We moderated the discussion in a loose way and generally allowed the participants to express their thoughts and opinions. However, we made sure that the discussion touched upon relevant topics, such as tolerable ticket/vehicle prices, attitudes towards sharing vehicles with strangers, opinions on waiting times and additional driving times due to dynamic route planning, etc. Eventually, all interview recordings were transcribed and analyzed sequentially. The analysis was conducted complementarily and iteratively by two researchers following the method of content analysis [30]. We combined inductive code (re-)development and deductive code application. The emerging code system was discussed in regular intervals and consolidated via computer software (MAXQDA). The analysis showed a strong focus on aspects related to the term "usefulness" and the compliance of innovative mobility concepts with today's mobility needs and practices. Following this thread, we summarized these aspects and formed the key categories that comprised the concept of acceptability. In this paper, we concentrate on this thread in the analysis and present our findings regarding the acceptability of AD, where the key categories serve as the evaluation criteria. The categories will be presented in the results section.

2.1. Sample and Spatial Types

Our sampling strategy for the formation of group discussions was based on the distinction of five user groups that we formed based on the following criteria: travel company (individual traveler/traveling with children), income (low/high), area of residence (urban/suburban/non-urban), and gender. We decided on these group characteristics by considering the blind spots and further research questions identified in our prior work on AD.

To select the participants of each user group and spatial type, and to keep track of the sample composition, we prepared a screening questionnaire that was distributed via diverse channels, networks, and target group-oriented multipliers, such as libraries and social institutions.

For the spatial typology, we applied a rough heuristic based on centrality versus periphery. We concentrated our digital and analogue recruitment activities in two different areas to increase our chances of recruiting participants with the desired spatial settings. For the rural or "non-urban" setting (as we simplified it in our study), we chose a middle-sized town in Brandenburg and additionally tried to attract people from the surrounding villages. For the urban setting, we chose Berlin and addressed dwellers from urban areas, as well as those from the outskirts and suburban areas. Thus, the group discussions were mainly non-homogenous with respect to spatial type. For the analysis, however, we assigned each focus group participant to their own respective spatial type.

Eventually, we conducted six group discussions and three individual interviews that were homogenous in user group criteria and mostly heterogeneous in spatial type. For the "travelers with high-income," we decided to conduct interviews with individuals because it was generally difficult to recruit members of this group and even more difficult to compel them to attend a group discussion. However, the content and process were identical to those in the group discussions. Table 1 provides an overview of the sample characteristics. After responding to the first insights over the course of the

survey and then during the analysis, the focus shifted from our initial user groups to what we then called mobility groups. These groups were created based on only two grouping dimensions, as we found that the characteristics of gender and income were less relevant compared to spatial type and family situation. Therefore, the second group discussion in the non-urban/suburban setting involved a mix of low income and individual travelers.

Table 1. Overview of the survey sample.

Group Discussions						Interviews
Individual travelers		Travelers with children		Travelers with low income/individual travelers		Travelers with high income
Urban/ suburban areas		Urban/sub -urban areas	Non-urban/ suburban areas	Urban/sub- urban areas	Non-urban/ suburban areas	Urban/ suburban areas
Men	Women	Men and women		Men and women	Men and women	Men and women
4 partici-pants	4 partici-pants	4 partici-pants (3 men, 1 woman)	5 partici-pants (3 men, 2 women)	3 partici-pants (all men)	3 participants (2 men, 1 woman)	3 men

2.2. Use Cases

Table 2 outlines the selected use cases we presented to the survey participants, representing three general types of likely use cases that are relevant in the debate on automated driving and cover the spectrum from public to exclusive use (i.e., from demand-responsive transport (DRT) to private automated cars). We call these types *public door-to-door*, for a demand-responsive service that functions (almost) door-to-door like a taxi service but shared with other passengers; *public transport feeder*, for a DRT service covering the first or last mile of a trip conducted by public transport; and *private door-to-door*, for a privately possessed automated vehicle that drives its owner from door to door. To illustrate the use cases to the survey participants, we provided only basic details and only drew sketches of each use case to prevent priming effects as much as possible (see Table 2).

We assumed that from the viewpoint of a customer, there would be no essential difference between public demand-responsive transport with and without automation, apart from higher availability, extended operating times, and lower costs through reduced operating expenses. To address the waiting times and costs, we used relative values and rough approximations. The following table presents the use cases and characteristics.

2.3. Limitations

Our investigation considered a future scenario after the introduction of fully automated vehicles. Like all studies on future technologies and innovations, our study was subject to major uncertainties regarding the exact conditions and dynamics of its development. The respondents in our study were asked to picture a small excerpt of a likely future and respond on the basis of their present-day experiences. This is why we emphasized the actual needs and requirements in daily life and mobility, while keeping the actual technology of automated driving in the background, assuming that the needs and requirements are relatively stable and less dependent on actual technological implementation. The analysis, therefore, explored potential improvements and beneficial effects based on future assumptions of transport and the stability of mobility-related needs and requirements. Another limitation in the Berlin sample corresponds to the self-selection issue of "mobility interested and aware people." Although we broadly distributed the announcement of the workshops, contacted

different social institutions, and used various analogue and digital communication channels to attract participants, we obtained an overrepresentation of Twitter users and cyclists.

Table 2. Selected use cases of Automated Driving.

	Public Door-to-Door (Public D2D)	Public Transport Feeder (Feeder)	Private Door-to-Door (Private D2D)
Routing	No fixed stops or routes, demand-responsive	Semi-fixed stops or routes demand-responsive with regard to a mass transit hub	No fixed stops or routes demand-responsive
Connectivity	Direct connections, no transfers necessary (door-to-door)	Transfers required, only first/last mile connection	Direct relations, no transfers necessary (door-to-door)
Operations times	Demand-responsive operating times (active calling/booking required)	Demand-responsive operating times (active calling/booking required)	Demand-responsive operating times (active calling required)
Waiting time	Need for a certain *moderate* waiting time after booking (specified as about 5 to 20 min) in case the service is booked in advance	Need for a certain *moderate* waiting time after booking (specified as about 5 to 20 min) in case the service is booked in real-time (if not booked in advance)	No waiting time and no booking required exclusive availability on demand
Sharing option	Shared use: fellow passengers might be on board; there could be a dynamic ridesharing opportunity, i.e., routes and arrival times could be adapted to incoming calls (the dynamic ridesharing feature was put up for discussion)	Shared use: fellow passengers might be on board; there could be a dynamic ridesharing opportunity, i.e., the routes and arrival times could be adapted to incoming calls (the dynamic ridesharing feature was put up for discussion)	Private use: no other passengers are on board or have access to the vehicle (only if offered)
Costs	Significantly less expensive than a taxi (between taxi and public transport) more expensive than the feeder	• About as expensive as public transport or even integrated into the tariff system	About as expensive as a new regular car, maintenance and repair must be paid for

3. Results

Our results section is divided into three subsections and comprises the general empirically derived *acceptability conditions* for future mobility, as well as findings on the selected use cases of AD with regard to the acceptability conditions of the related *mobility configurations*.

This section is structured as follows: First, we present the conditions for acceptability; second, we present a description of our mobility configurations; and, finally, we outline our findings for the compliance of the selected use cases of AD with respect to the acceptability conditions for each mobility configuration.

3.1. Conditions for Acceptable Future Mobility

In order to understand what might become relevant for future mobility technologies that, like AD, cannot be used today, we asked the participants about current needs, limitations, and desires. In this section, we present categorized present-day mobility deficits, as well as the conditions that future mobility is expected to fulfill (Table 3). These categories form the basis for the following sections on the question of how the selected use cases meet the needs of the various mobility groups and how they could fulfill the desires for future mobility. In particular, we use the categorization of future mobility desires as the criteria for acceptable AV implementations, while the deficits illustrate what needs to be changed.

Table 3. Acceptable future mobility: Deficits to address and conditions to fulfill.

Deficits of Today's Mobility	Conditions of Acceptable Future Mobility
Poor or lacking infrastructure, car dependency, and insufficient public transport supply	Improved accessibility
Time fixities and lack of autonomy	Ease of daily life and well-being
Road safety issues and car traffic volume	Improving the traffic situation and existing transport system

With regard to the deficits of present-day mobility, poor or missing infrastructure for cycling and a lack of road safety, especially for unaccompanied children, have a particular impact. Driving and parking car traffic and the accompanying strain on road space are seen as a hindrance to carefree mobility. In the suburbs and the countryside, dependence on the car and an insufficient supply of public transport are other pressing problems. In particular, adequate feeder services, as well as bicycle or e-scooter services that run every half hour and first/last mile services better than those of a bus are called for. Other problems include parents' time fixities and children's lack of self-determination. Parents often have to accompany or chauffeur their children to leisure activities and are, therefore, time fixated. Likewise, children and teenagers suffer from dependence on their parents to drive or accompany them.

In view of these deficits, we next explore what future mobility services should provide. We summarize our results into three categories. The first category relates to improving accessibility. This category mainly concerns the people and geographical areas that currently suffer from poor access or reduced mobility, such as those in the countryside and people without a car. The associated potential of AD is a reduction of car dependence and the chance to become more independent from other people who are able to drive. The second category relates to making daily life easier and thus increasing one's well-being. Particularly complex chains of journeys and time fixities caused by escort trips or trips to carry and pick up children are considered a burden. In some cases, the time saved by using travel time to work or organize things is also seen as an opportunity. Increased comfort is another aspect in this category. The delegation of tiresome tasks, such as parking, to a machine or a service provider is as much a part of this category as the flexibility to take advantage of a driving service in bad weather or at night. The last category of conditions for future mobility refers to improvements of the current traffic situation and transportation system, which are seen as a burden and annoyance in daily commuting or traveling. In particular, there is a need to reduce parking and traffic volume. To this end, it is considered necessary, among other things, to regulate the allocation of automated vehicles and make them available, especially in areas that are particularly dependent on cars. AD technology is not necessary for improvement in this area but could facilitate it. This particularly affects public transport. Here, there is a need to expand the timetables and areas of operation of buses and trains and to facilitate ticketing and navigation, especially for inter-provider travel, as well as enable or facilitate intermodal travel chains, e.g., through real-time data exchange between connecting buses and trains. A second key area of improvement is cycling. Here, increased traffic safety for cyclists and a fairer distribution of road space are called for. A prerequisite for realizing this improvement is that the introduction of AD must lead to less traffic, e.g., through more attractive vehicles and car-sharing services, thus yielding an effective bundling of transport demand.

In summary, improvements in accessibility, people's daily lives and well-being, and the existing traffic system are relevant categories and criteria for acceptable forms of automated driving.

In the following sections, we examine different mobility groups and analyze how different AD use cases correspond to these categories or the acceptability criteria.

3.2. Mobility Configurations

As mentioned in the methods section, we reduced our initial user groups and shifted them toward mobility configurations. These configurations include the mobility group, which consists only of the type of space (urban, suburban, or non-urban), and the mobility mode. The mode distinguishes whether a person travels individually or with children. These pictorial dimensions were particularly useful in systematizing the differences between the respondents. The resulting six mobility configurations are heterogeneous in terms of both income (low and high income) and gender (male and female) (see Table 4).

Table 4. Mobility configurations.

Mobility Group			
Mobility Mode	Urban	Suburban	Non-Urban
With children	Urban travelers (traveling) with children	Suburban travelers (traveling) with children	Non-urban travelers (traveling) with children
Individual	Urban travelers individual mode	Suburban travelers individual mode	Non-urban travelers individual mode

As can be seen from the table, we removed the feature dimensions of the income. The differences between the user group of low earners and the other groups proved to be irrelevant for our research questions. For example, the willingness to pay extra for a mobility service varied between the groups in a similar way to the provision of transport. Moreover, even in the group of high-income earners, there was no sign of carelessness when dealing with money; rather, it was shown that such earners economically organized their mobility in the same way as the other respondents. We also rejected the differentiation of gender-specific user groups because they showed no relevance compared to differentiation according to the type of space or mobility. A feeling of security is an example often cited to highlight a large difference between women and men. For illustration purposes, we take this example and roughly present some results.

Both in the user group of *women traveling alone* and among the women in the other user groups, safety issues related to the fear of entering a shared vehicle were never raised by the women themselves. When asked about possible feelings of insecurity at night caused by strangers or drunk people, they answered similarly to the male respondents, as follows: Most people are accustomed to confrontations with strangers and also have experience with threatening encounters. Individual events can be unpleasant, but, in general, these experiences are not an obstacle to visiting public places or, in this case, using a shared vehicle. Rather, the opposite was highlighted. A mobility service that takes someone home at night—for example, from the train station—is seen as conducive to a feeling of security compared to walking alone through sparsely populated areas.

3.3. Acceptability of AD Use Cases per Mobility Configuration

In the following section, we present the analysis results for the acceptability of different use cases in relation to the mobility configurations. The previously presented acceptability criteria (*improved accessibility, ease of daily life and well-being*, and *improving the traffic situation)* structure the presentation. We concentrate here on the main results and differences between the mobility groups. Since there are greater differences between the groups in the "individual traveling" mode, we present these differences individually, whereas the differences between the groups in the "traveling with children" mode are less significant, so we present them together. For the use cases, we only distinguish between public transport feeder and public door-to-door (public) cases where relevant; when they are not relevant, we speak of *DRT*.

3.3.1. Urban Travelers Individual Mode

We will begin by discussing urban travelers in the individual mobility mode. Urban individual travelers already have a wide range of mobility options in their areas. For example, grocery shopping can be done on foot or by bicycle, and stations and stops for light rail, metro, and bus services are close by. The durations of daily trips and the purposes of travel vary, but there is usually no need for a private car. Sometimes a car is used to transport heavy things, such as music equipment, or a car is rented for a few hours or a day. Cycling and public transport are the predominant means of transport to work or university, as well as for visiting friends and engaging in leisure activities. Only a small percentage of this group owns a car, and some do not have a driver's license. In the following, we relate the findings in this group to the three acceptability criteria.

- Improved Accessibility

Generally, there is little demand for additional services but rather for an improvement of the existing mobility supply. Urban travelers are satisfied with the available means of transport, but the conditions for walking and cycling are viewed critically. Such travelers call for an improvement in traffic safety and greater comfort. Accessibility deficiencies do not play a significant role in this group.

With regard to the use cases presented, there is a general reluctance and low demand for additional mobility services. When comparing the use cases with each other, however, the two demand-oriented transport services (DRTs) are assessed more positively overall, with fewer negative effects on traffic volume also noted. The private door-to-door option was rejected.

- Ease of Daily Life and Well-Being

There are two relevant aspects for the second criterion. The first aspect can be summed up as follows: Existing alternatives are too attractive to accept the extra effort. With regard to the use of DRT use cases for daily trips, the routes are considered too short, so calling and booking a DRT seems to be too much effort. Furthermore, the waiting time, even if only five minutes, is considered a waste of time compared to the alternative of walking to the next public transport stop within the same time. In addition, the forms of transport already used—especially bicycles or regular public transport—are estimated based on their advantages that would not be present in AD use cases, e.g., independence, physical activity, and low to no costs.

The second aspect relates to the observation that a productive use of travel time is not necessarily demanded. Travel time is not necessarily seen as a waste of time but rather as pleasure or a contribution to increasing well-being, e.g., as free time to reflect upon or experience the outside world. Cycling in particular is often seen as more than just moving from point A to B; it is also about the trip and the time spent on the bike. For some people, working on the road is already a habit (working on the train, for example). Thus, the idea of having enough space and facilities for mobile work seems attractive to them. Only the public door-to-door (d2d) use case is taken into consideration here, as the travel time in the feeder is considered too short and interrupted to be able to start work in a meaningful way. However, the results are not consistent: A further increase in time efficiency is also viewed critically, as it could lead to more work. Work done while driving could be added to one's regular working time, and the possibility of working while on the move could lead to more work overall rather than time savings.

- Improving the traffic situation and existing transport system

For the improvement of the traffic situation and the existing transport system, this groups indicated little potential. Generally, it is expected that DRT will be used occasionally for reasons of convenience and that a modal shift from active modes of transport to motorized transport (in the form of DRT) will take place. Urban individual travelers considered both variants of DRT—as a feeder and as a door-to-door service—as an option for occasional and extraordinary trips. Such occasions include,

e.g., a longer distance and poor PT supply at the destination or in cases where cycling is not an option, e.g., due to the time needed, due to bad weather, or for special appointments with a certain dress code. Thus, the main trip purposes of DRT are linked to convenience. Another occasion where DRT would help is trips beyond the urban center, e.g., to special recreation areas, as these trips would entail additional motorized traffic and would change from active modes or regular PT e.g., (busses, trains, or light rail, as well as mass transit).

The use case private door-to-door vehicles was largely not considered attractive among the urban individual travelers. Car use in general was viewed critically. However, the potential to occasionally use an automobile without the requirement of a driver's license was positively evaluated by those without a license.

3.3.2. Non-Urban Travelers Individual Mode

The non-urban traveler groups in both mobility modes had a poor PT supply and high car dependence. This means that the distances to the activity locations in typically scattered settlement structures were often too great to walk or cycle. School transport was often the main or only public transport service providing connections between neighboring villages and towns.

- Improved Accessibility

Given the conditions described, an isolated additional service like the DRT would not be sufficient to make the car obsolete due to spatial expansion and scattered demand. However, the public door-to-door service is regarded as relatively useful compared to the public feeder service on some occasions. Children or senior citizens, i.e., those who are currently dependent on a driver, need to transport themselves to places of activity, such as the grocery store or a friend's house. Thus, there is a need for internal mobility within and between villages and towns, rather than the need to travel to the nearest railway station.

- Ease of Daily Life and Well-Being

This aspect can be summarized as follows: Private d2d is attractive, and the DRT use cases would require a non-urban compatibility update. Compared to the urban and suburban mobility groups, the non-urban travelers find the private door-to-door use case the most attractive, even for those who currently do not use a car or try to keep their car use to a minimum for sustainability reasons. The elimination of the need to drive (by oneself) is seen as an advantage or as a relief. Part of this relates to the possibility to work or read while traveling. However, there is general openness to the idea of sharing a vehicle under certain conditions. In particular, the presented use cases would need to be made compatible with non-urban conditions. In view of the logistical challenges of coordinating dispersed source locations economically, adjustments of the presented DRT use cases are proposed—advanced booking, for example, or a hub-to-hub variant, described as collection points close to home (not at the door) and at relevant activity locations. The real-time booking option was seen as hardly attractive or even undesirable. In contrast to the urban mobility group, the understanding of demand-responsive mobility here does not imply short-notice and spontaneity but rather planning to ensure the availability of a vehicle when needed. Planning is, therefore, crucial to the goal of making private cars obsolete in non-urban areas in the face of non-existent alternatives, such as public transport.

A further aspect related to the specificity of non-urban areas is the frequent practice to form informal supply and mobility networks, for which the sharp distinction between private and public does not fit. The long distances to care or medical facilities and leisure and cultural facilities, as well as the poor supply of public transport necessitate informal organization. Individuals with a car take senior citizens or carless individuals from the neighborhood or the village, drive their children to events, activities with friends, or sports clubs, and then pick them up. One participant, who takes the train as often as possible, mentioned that his regular practice at night after the last train has passed is to call across the platform to determine if anyone needs a ride home. The experiences that form

informal networks of this kind should be taken as an asset and considered when implementing mobility services for the countryside. Suitable use cases that were suggested include a car-sharing-like concept organized in a limited community with a higher degree of exclusivity and availability. The community might be comprised of neighbors or of customers of a certain vehicle brand, thereby forming a vehicle pool that fellow customers can access.

- Improving the Traffic Situation and Existing Transport System

Firstly, drivers appreciate the idea of DRT for transit-dependent individuals, but not for themselves. Although the non-urban mobility group principally welcomes the idea of a *public D2D*, such individuals do not consider it a serious alternative for themselves. They doubt that the presented DRT use cases could work in the countryside under acceptable conditions. The fleets would need to be massive to ensure the presence of vehicles in the dispersed settlement structure and heavily subsidized or unaffordable for daily commutes and travel. Compared to that, a private car ensures reliability and availability. DRTs might provide an improvement for those dependent on a driver or PT, such as seniors and teenagers, and thus provide a significant relief for those driving, but, due to a lack of availability and reliability, DRTs are not considered appropriate for the daily commute.

3.3.3. Suburban Travelers Individual Mode

The suburban traveler group lies in-between the urban and non-urban mobility groups. Nevertheless, they present some specific traits. For example, such individuals often own a private car and travel or commute to the city on a daily or regular basis. For this group, there is usually some supply available to cover the first or last mile with PT, such as a bus, but often this is not sufficient in terms of operating times or frequency. Likewise, in suburban areas, there is usually a lack of safe cycling infrastructure.

- Improved Accessibility

At the center of the suburban mobility group is the first or last mile problem for connecting services into the next city to go to work or go shopping. There are several areas in which this problem arises, such as commutes. Those willing to take PT might use park and ride facilities, but these services are often congested. Thus, a private car might be used for the entire distance into the city, but in many cities, parking and driving in rush hour traffic is stressful and time-consuming. To sum up, for the suburban mobility group, there is a need to solve the first/last mile problem in a way that facilitates the use of PT in the city.

- Ease of Daily Life and Well-Being

With regard to ease and well-being, AD might offer greater security and comfort for suburban travelers. In particular, at night, on the way home from the train station, a DRT service might address the issue of not feeling comfortable or secure in unpopulated streets and other areas. A further aspect is the need to carry heavy objects such as luggage. In many cases, walking is acceptable, but walking becomes an unpleasant challenge when carrying objects.

- Improving the Traffic Situation and Existing Transport System

In this category, two aspects are relevant: first, the *public feeder* is considered the most attractive and useable option for daily trips. It provides convenient access to more reliable and frequent mass transit and constitutes an attractive option for a car trip. The *public d2d* use case can be useful depending on the degree to which the suburban area provides relevant social infrastructure, such as medical and leisure facilities and grocery stores. Unlike in the urban and non-urban mobility group, the public transport feeder could be used for regular trips to work or to run errands. The potential to reduce private car trips or even replace a car, however, depends on the time/cost ratio of the private car

compared to using the feeder and PT mass transit on a daily basis. The second aspect relates to the fact that alternatives like micro mobility might offer the same benefits but with fewer costs. The first/last mile problem could also be solved by improving conditions for active modes such as cycling, and there were some suggestions in this regard. One suggestion was, e.g., to use an electric scooter, which was not yet been permitted in Germany at the time of the survey.

3.3.4. Travelers (Traveling) with Children in All Mobility Groups

Several aspects that emerged from the spatial specifics described for the individual mobility configurations also apply to mobility configurations for traveling with children. To avoid repetition, the focus of this section is on the mode-specific aspects, that is, the potential benefits for those traveling with children under each use case.

To understand the potential of the AD use cases for this mobility mode, we must clarify that there are two facets of this mode: Firstly, there are travelers with children. This means people that have care-related obligations. Secondly, there are travelers actually traveling with children. For the first facet, it has already been mentioned that trips only for escorting or picking someone up are time consuming. These trips lead to time fixities in already complex daily schedules. The matter of escort trips mostly affects parents, but it might also impact carless neighbors or relatives. In terms of the second facet, when traveling with children, AD use cases require help with problems such as tired children or transporting daytime equipment. In addition to this clarification, the objects of potentially delegated escort trips, especially children and teenagers, are important. We did not interview children directly, but their parents introduced their children's perspectives and made assumptions about the effects of AD use cases for them. Against this background, we present our results for both facets and also consider the implicit group of children and teenagers dependent on escort trips.

Improved accessibility for children and teenagers and automated mobility services—both public and private—would improve children's accessibility and extend their autonomy to engage in activities, allowing them to become less dependent on their parents. In urban areas, younger children would especially benefit. In the urban environment, elementary schools and kindergartens are usually located within walking distance, like their friends' houses. Here, the lack of road safety related to car traffic is the main reason not to let younger children go out alone. When children are old enough to deal with traffic situations, it is easier for them to move independently, especially with PT. In the non-urban and suburban groups, teenagers would especially benefit from additional services, as they would have better access to extracurricular activities or leisure activities not covered by the school bus's operating hours and further away from their living areas. Younger children that are not yet self-dependent would also benefit from a service that transports them independently from their parents.

- Ease of Daily Life and Well-Being

For parents, or travelers with children, AD might provide relief via escort trips—this is the most notable potential for additional services in all mobility groups. As noted previously, for urban travelers, escort trips are usually limited to smaller children, while teenagers can move around on their own. To replace escort trips for young children, an automated mobility service would, however, have to meet certain security and accessibility requirements, such as guaranteed and tracked arrival at the door and/or communication interfaces for the children to obtain help if needed, as well as registered personal information about the other passengers. The presence of other passengers is considered a benefit, not a danger. Children traveling on their own or with other children could be risky since the children could bully each other or miss their stop. As a substitute for passengers, an entertainment system or Wi-Fi access was suggested as a distraction.

For the purpose of escorting children, the public transport feeder is not suitable, as it is considered too complicated for a child to transfer to mass transit in between. More important is a public door-to-door service that could take children to school or leisure activities. Like in the individual mode, the urban mobility group in the traveling with children mode predominantly rejects the need

for, and the usefulness of, private vehicles and supports the shared public variant. For non-urban travelers, the demand for escort trips or trips to drop off and pick up children is created not only by the younger children but also by the teenage children. Given that, the public transport feeder does not match the needs and requirements of this mobility configuration. A better match is public d2d and private d2d if the parents can afford it for their children. For travelers traveling with children, improvements are expected in terms of offering greater flexibility and less planning effort.

Of course, parents also travel with their children for the purpose of spending time together, going on trips, taking them to the doctor, or running errands. After a long day, children become tired and walk more slowly. In addition, there is often the need to carry various types equipment for the child. A taxi is often not prepared for transporting younger children (like car-sharing, even if, in principle, there is a car-sharing service in the required area) and would face the same constraints for child seats. In this configuration, the first/last mile problem also affects the mobility groups and impacts their mode choice. For the urban travelers in particular, the option to flexibly adapt one's mode choice to upcoming events is vital. At the beginning of the day when planning a trip, cycling or using public transport might be the best choice. However, on the way home, the weather might be poor, or the children might become tired and irritable. To date, the kind of flexibility and spontaneity to change one's means of transport during the day for people traveling with children is not available. It is strenuous to load a trailer, bike, children, and (often) various kinds of equipment onto train, underground, or light rail services. Similarly, car sharing is often not an option since there are few child seats. The consequence of this is that, due to the anticipated stress, cycling or public transport is never chosen. An additional service like public d2d or, in the case of the urban and suburban groups, a public transport feeder, could provide greater flexibility over the course of the day, assuming sufficient space to carry bikes and luggage. Here, at least a minivan-sized and child-seat equipped public shuttle would be required to carry parents, children, and the day's equipment home when walking is too strenuous.

- Improving the Traffic Situation and Existing Transport System

The possible effects of AD use cases on traffic are ambivalent. On one hand, parents in urban areas demand a mobility service to transport their children safely. This shows that the parents consider the current traffic situation to be unsuitable for children. An additional (motorized) mobility service will not change this fact unless, firstly, automated vehicles are confirmed to increase road safety and, secondly, automated vehicles displace manual vehicles. Moreover, greater independence of parents from their children's daily schedules suggests the chance of additional traffic. On the other hand, a public transport system would become more family-friendly and attractive if additional, more flexible services were integrated to meet traditional family needs. As a result, people with children could feel less dependent on their private cars.

4. Discussion

With this study, we sought to add an empirical socio-technical contribution to the knowledge base on the acceptance of automated driving by discussing the usefulness of AD and the criteria for acceptable new mobility services in light of different user perspectives, sustainability, and societal requirements. We examined the configurations of mobility groups and analyzed the needs and requirements in relation to concrete use cases, as well as in relation to our empirically derived acceptability criteria. This also included an analysis of useful alternatives and additions to automated driving, such as an improvement of public transportation and bicycle infrastructure. In this respect, our study does not present uncritical technological optimism that places all hope in a new technology and ignores the risks. At the same time, we also avoided technological pessimism and contributed a constructive investigation of possible useful areas of application for AD. In the beginning, we introduced our research question: What kind of automated driving is acceptable given both the needs of different mobility configurations and the chance to mitigate the associated risks, such as increased levels of car traffic? In the following section, we provide conclusions from our findings in this regard and refer to

our acceptability criteria. Moreover, we discuss the possible courses of action to achieve acceptable AD. Before that, we discuss the implications of our research for sustainable automobility in the *mobile risk society*.

4.1. Implications of Acceptable Automated Automobility

For the mobile risk society, what are the implications of investigating acceptable automated automobility? From our perspective, the concept of acceptability provides a framework for relating the many factors that play a role in establishing and evaluating mobility innovations. Our approach, which systematically considers individual acceptance alongside social and sustainability requirements, is innovative in the field of technical acceptability research. While acceptance research tends to be technology-optimistic, sociological contributions to the topic seem to focus largely on the risks alone. In contrast, our contribution aims to provide constructive, criteria-based, and empirically sound indications as to which forms of AD research are appropriate. The criteria we used in this paper included an assessment of the possible impacts on the mobility-oriented needs of people in certain life configurations and on sustainability goals, as well as the transport system. These needs were (1) an improvement of accessibility, (2) an increase in the ease of daily life and well-being, and (3) improvements of the traffic situation and the existing transport system.

There are parallels here to the motility approach Kaufmann et al. introduced [38]. Motility, consisting of the dimensions access, competence, and appropriation, represents the "link between spatial and social mobility" [38] and offers a second dimension to mobility besides (actual) movement. Similarly, we also considered potential mobility. Since our research object was future mobility technology, however, this potentiality is inevitable. More importantly, we also recognized the social interwovenness of mobility and did not stop with an analysis of the spatial aspects of mobility, such as ways to get from A to B. We looked at the configurations of needs and daily practices together with spatial settings.

Despite the parallels, one major difference to motility is that motility is a methodological or epistemological concept, unlike our evaluation-oriented acceptability concept. Our research interest entails the evaluation of the prospective effects of possible applications of AD on mobility configurations—i.e., what is useful and what does no harm or even mitigates negative automobility effects. For the second dimension of acceptability, more ease in one's daily life and well-being, we focused on the usefulness of mobility innovations in a person's life. Thus, a given mobility innovation might be accessible for all kinds of people and might even be better accessible than alternative options; however, if it is not able to improve a person's life, it is not useful enough. In a similar vein, several authors have linked motility and/or daily mobility to well-being or quality of life, e.g., [39–43]. Nordbakke (2013), for example, examined the differences among the mobility of older women, considering their different mobility opportunities. She found that, in addition to spatial resources and restrictions, individual strategies for coping with, e.g., physical barriers can extend these opportunities. Even more interestingly, her findings also show that different conditions enable these women to develop strategies to promote well-being; these conditions can include an urban environment, a good quality public transport system, appropriate places for activities nearby, and a social network [42]. It can thus be concluded that the usefulness of any mobility offer, innovative or not, depends on its potential to improve mobility/mobility in practice in such a way that well-being is also improved.

In addition, the degree of facilitation in one's daily life and well-being is contrasted with a focus on cost or time efficiency, which is particularly common in transport research (dominated by psychology and engineering). Innovations in the field of automobility, as in the case of AD, may increase efficiency, but this does not mean that they improve well-being. We return to this aspect in the following Section 4.2.

For the third dimension, improvements of the traffic situation and existing transport system, we refer to the possible impacts of AD on the sustainable transformation of the transport system, focusing on a reduction of private automobility as a core aspect.

Mobility concepts based on automated automobility certainly correlate with existing mobility routines and social expectations, at least in the beginning. For this assumption, we follow the contributions of other authors e.g., [7,10,44]. This factor particularly concerns what is considered reasonable availability, waiting and travel times, and costs. Thus, we do not assume that mobility will change overnight but that the most likely scenario will involve a gradual withdrawal from private automobility with the help of AD. In our results, there are both more and less acceptable use cases of AD. Overall, public and, therefore, shared use cases are more acceptable than private automated cars. However, a private automated car is basically a continuation of the very successful and change-resistant regular car. Therefore, the private car's attractiveness will likely remain in the age of automation if no proactive measures are taken. This is not merely a call for restrictive regulations. Rather, AD also creates opportunities for public transport. The classic weaknesses of public transport, which are often identical with the classic strengths of the private car, could be addressed by AD, such as baggage and child transport, high availability, and coverage of the first and last mile. If suitable forms of AD are available—suitable in terms of their compliance with different mobility configuration requirements—automobility might become more sustainable through automation. This, of course, does not mean that we put all our hopes into this technology. As Kaufmann reminds us, technology is ambivalent, and "it is not very good at using it for ambitious, positive societal projects that increase wellbeing, reduce inequalities and better respect the environment" [44]. Kaufmann also comes to the conclusion, however, that "autonomous vehicles are only socially beneficial if they are shared and integrated into the public transportation system" [44].

In other words, there is the need and potential to steer mobility innovations, such as AD, toward sustainable directions. There is a growing body of evidence available to help decision makers understand what risks to avoid, what applications to promote, and what mobility futures to pursue, e.g., [3,5,18,20,44]. This paper aims to add to that list.

Mobility innovations are desired and being continuingly developed, despite their risks for society's future living conditions. With AD, there is an opportunity to push transformative dynamics into the mobility sector, especially for making public and shared transportation more attractive. However, if no action is taken, AD faces a great risk of worsening automobility-associated and -induced negative effects by making them as available, less annoying, and more accessible than regular automobility. Rather than treating mobility innovations such as AD as a panacea, risks must not only be weighed against their benefits but also against alternatives. In particular, without additional and costly technology, mobility could be improved in many low-tech ways, such as by installing cycling paths, restricting car traffic in the neighborhood, and reducing car dependence. Furthermore, in suburban and non-urban areas, the acceptability of AD depends on its integration into a functioning overall transport system. AD should, therefore, not be considered in isolation.

4.2. Acceptable Forms of Automated Driving

In the following section, we discuss our results for the research question of acceptable forms of AD, based on the criteria we developed for acceptability. In this way, we explore how our investigated use cases perform in terms of improved accessibility, increased ease in people's daily lives and well-being, and improving the traffic situation compared to the existing transport system.

4.2.1. Improved Accessibility

Depending on the use case and the mobility group, there is the potential to improve accessibility. We operationalized accessibility by referring to availability, usability, and usefulness drawing upon different approaches in this area [45,46]. According to a common understanding, accessibility refers to both spatial and individual aspects, such as whether, and to what extent, mobility offers and

transport infrastructures are made available, as well as whether a person is able to make use of these offers, given their individual abilities, needs, and constraints [46]. Drawing on this, there are certain requirements for AD use cases to improve accessibility. Such offers must be physically available, available in rural areas, and practically useable/useful for a person. This means that mobility offers should be affordable, and their usage should be both easy to understand and physically accessible. Beyond that, they need to be temporally accessible, e.g., based on a person's or a family's space–time organization [45]. In addition, security aspects play a role in practical accessibility. Feelings of insecurity in a means of transportation and the surrounding environment, as well as exposure to discrimination or threats, constrain accessibility; conversely, accessibility might be increased if insecurity issues are reduced. Usefulness is especially important. Usefulness has a similar meaning to appropriateness or appropriation as it is used, e.g., in the motility concept [38]. In our study, mobility offers and use cases were evaluated according to their appropriateness for different uses and mobility configurations. Individuals traveling with children have other requirements that today's intermodal and innovative mobility offers regularly do not meet. The second aspect we want to discuss in terms of accessibility improvement is security. In our study, we found evidence that feelings of security and, therefore, accessibility could increase through DRT use cases. Remarkably, this finding contrasts with common opinions (e.g., opinions given after conference talks) and also studies showing that DRT would be a source of insecurity, especially for females at night. As we already reported in the results section, for both the user group of women traveling alone and among the women in the other user groups, security issues related to the fear of entering a shared vehicle were never raised by the women themselves. Instead, the opposite was true. A service that takes one home, especially at night, was considered attractive and security supporting. Sarriera et al. (2017) reviewed various studies on sharing and included differences between men and women. The authors stated that "contrary to assumptions that women may be less likely to rideshare because of fear of strangers or physical harm, many studies have found that women are more likely to carpool than men" [47]. However, their own survey results suggest that women tend to feel less safe in ride sharing services than men. Similarly, a study on "in-vehicle security" found that men assessed their in-vehicle security better than women [48]. While these studies used standardized questionnaires, possibly with priming formulations, we were careful to prevent this kind of priming.

Further research with different methods is needed to understand the possible differences in this area regard and to determine if insecure feelings really prevent males or females from using DRT. For now, based on our results, the hypothesis that DRT engenders special fears or feelings of insecurity compared to regular public transportation modes among women still lacks empirical evidence. Presumably, however, there might be differences between regular public transportation riders and car driving enthusiasts. The former are more accustomed to strangers and the sometimes strange behavior of their fellow citizens, but they ride anyway, so there is no reason to believe that this behavior would fundamentally change if the vehicles were smaller or demand-responsive.

In terms of usefulness, we also explored the demand for additional services. In general, the need for improvement is largely a matter for non-urban and the suburban groups. In the non-urban mobility group, the DRT use cases were considered useful for providing access to places and activities and increasing independence for those without access to a car, such as seniors and teenagers. This might also be true in the private door-to-door use case, when owners privately share their vehicles with their neighbors and children. Considering the children and teenagers currently in need of an escort in all spatial settings, DRT services and private services might help provide more autonomy of movement. An additional service alone would not improve the mobility supply in non-urban areas where more fundamental changes, such as comprehensive public transport, are required.

Urban individual travelers, on the other hand, already face a great variety of mobility options and do not suffer from car dependence. In suburban areas, there is a great chance for the public feeder use case to improve the mobility supply by helping with the first/last mile problem, both for individual travelers and for travelers accompanied by children, thereby strengthening the public transport system

and reducing car dependence. In the urban context, on the other hand, there is no need to improve the supply, but there is a risk of cannibalizing the active modes and regular PT [3,20]. The importance of both a well-developed public transport system and car independence for accessibility and mobility has been stressed by several authors e.g., [45,49,50]. Beyond that, our results paint a different picture of how accessibility could be improved for certain mobility configurations with the help of concrete use cases, as well as where there is no need for improvement.

4.2.2. Ease of Daily Life and Well-Being

Due to the expected availability and costs, the demand-responsive use cases of AD are not considered a means of transport for daily use or longer distances. Occasional or unusual trips are more likely to be undertaken using this service than regular ones. Apart from limited availability, this also applies to the urban and suburban mobility groups. AD-based DRT services are expected to provide greater comfort when traveling and make some of the challenges of timetable coordination more manageable. In particular, there is hope that AD could relieve parents of some journeys and provide greater flexibility when traveling with children. In addition, travel time could be used for work or other productive activities, while also saving time for later. Therefore, this use case supports ease of life and well-being in different mobility configurations. Several studies have examined this aspect under the concept of *travel time savings* or changed *value of time* under AD [51–55]. However, significant travel time savings are expected to occur in private rather than public automated vehicles and over longer distances while commuting, rather than over short distances, such as within a city [54,55]. Other studies have found that people would rather rest than work [22,56], suggesting that the potential for travel time savings is overestimated [55]. Furthermore, given the unintended effects and sociotechnical dynamics, time gains are likely to be consumed by additional tasks [57]. In our study, it was uncertain whether a time efficiency increase is necessarily positive. The time savings of working on the way to work could easily lead to more work in total. A similar conclusion was drawn in the study of Pudāne and Rataj [58], who conducted focus groups with commuters in the Netherlands on the impact of AD on travel activities. Thus, if working while traveling became feasible for everyone (not only for PT riders), it could lead to an overall expectation to work while traveling and thereby increase the overall workload.

4.2.3. Traffic Situation

The flip side to an increase in well-being and comfort due to more convenient trips and extended accessibility as a result of DRT is an increase in traffic volume. Thus, the traffic situation might actually worsen due to AD, instead of improving. This ambivalence regarding the beneficial inclusion of new user groups in independent mobility and the negative effects of traffic increases reflects the literature [51,59]. However, the risk of an increase in traffic depends on the use case and the reference scenario, e.g., whether a person changes from a private vehicle to a DRT service. In any case, private door-to-door traffic carries the highest risk of a traffic increase due to the possibility of unlimited availability and empty trips. Likely, automated vehicles will be used more intensively than manual vehicles that stay where their driver has parked them. In addition, a private automated vehicle could become attractive for those who do not currently use a car because they are repelled by the annoying tasks of parking or driving in heavy traffic. How attractive a private automated vehicle could become depends on the purchase price and such annoyances being maintained by regulatory measures, such as the pricing of empty trips. In peripheral areas, it is unlikely that public sharing services alone will replace private vehicles. Given the lack of suitable alternative forms of mobility e.g., (public transport) that could be used if necessary, rural people depend on the guaranteed availability of a vehicle. Regarding the potential of MaaS to substitute for private cars, Storme et al. suggested "that MaaS should be regarded as a complement—rather than a substitution—of private car use in the near future." If places and activities are not accessible for a person without a private car, that person will not be satisfied with MaaS. Chauffeuring (i.e., escorting) and leisure trips are especially difficult to

replace [16]. Indeed, an interesting point that was not addressed is that MaaS needs to be designed and integrated into the transport system in such a way that it could be used, for example, to perform the task of escorting. Our paper aimed at providing suggestions in this direction. From our point of view, such services are likely to be developed in such a way that they are tailored to the needs of different mobility configurations as soon as there are appropriate political guidelines and as soon as such mobility options are recognized.

5. Conclusions

We provided insights into an acceptable implementation of AD by analyzing specific use cases of AD with respect to different mobility configurations. We applied a new concept that combined evaluation and acceptance research with theoretical methodology to investigate the useful applications of AD beyond the binary of technological optimism and pessimism. There are many technical and economic risk assessments in the form of e.g., impact assessments, but the needs of users of new technologies are often neglected. Our consideration of acceptance from the users' point of view could also help highlight risks not foreseen by researchers and/or minimize those risks from the outset during technological development/market introduction. We found it useful to examine mobility configurations instead of e.g., individuals from sociodemographic user groups. The general idea of studying configurations or constellations is known in practice theory (see [60–62] and [63] in the context of AD) and considers the interconnectedness of practices and technologies (e.g., car use), in contrast to linear explanatory models based on individual attitudes or preferences [63]. In a similar manner, we emphasized the interconnectedness of technology (AD) with spatial characteristics and selected frequent practices of traveling—particularly, those related to the practice of traveling with and without children. As our study indicates, mobility-relevant actions are not limited to individual preferences or needs. Rather, they encompass other peoples' needs (like those of children) and are connected to the *mode* in which a person is situated at a given time of the day or week. Given the future-orientation of our research and its evaluative motivation, practices of automated driving have not yet been developed. However, considering today's mobility configurations with their associated needs and requirements is one way to provide recommendations for the design and shape of future mobility offers. We found that people's needs and, accordingly, the respective usefulness of mobility innovations vary significantly. Therefore, studies on the acceptance of innovations should consider more than the stereotype of an average user, i.e., an unaccompanied urban traveler. This type of user is not the majority but only one of several possible mobility groups. Other important groups that often continuously use motorized private transportation include both non-urban dwellers and travelers with children.

Against this background, what needs to be done to achieve acceptable automated automobility? First, further thought should be given to the question of how car dependence can be reduced through automated mobility services. One suggestion is to focus investments in modernizing the public transport system for rural areas and then integrating complementary and additional demand-responsive services where they are useful. Above all, such developments should do no harm in terms of accessibility, well-being, or traffic situations. In addition, measures should be undertaken to increase overall road safety so that children can walk and cycle independently and relieve their parents from the need to escort them. Finally, we should consider improving regular public transport services together with the development of innovative services, such as the DRT use cases presented herein. However, given the resistance of automobility, automated mobility concepts should respond to the requirements of different types of mobility configurations and especially to those in non-urban regions. A spectrum of shared AD use cases is conceivable, ranging from almost private to completely public. In this sense, "requirement-responsive" use cases, i.e., those adapted to different requirements, could promote the transformation from private to shared automobility and, ultimately, to less automobility overall. The car with its versality, especially in areas without alternative mobility offers, would also have a place in (near) future mobilities, as Canzler suggests [7,10], and its most harmful effects, resulting from

overuse and mass use, could be constrained. Furthermore, some of its benefits would be transferred to public transport and thus make such transport more attractive.

Drawing on this, suitable use cases that attend to the specifics of non-urban areas and non-urban travelers are still required. Besides the spatial setting, the differences in mobility needs between people traveling alone versus those with children are significant. These needs go beyond a transport capacity for strollers (although they also include this factor). Escort trips in a car-dependent or traffic-polluted environment could be especially reduced and bundled. There is great potential for reducing private automobility in the parent group, but there are also risks involved. Further traffic could be produced by sending each child individually and at any time to any place of activity. To date, the time budgets of parents have been the limiting factor in this area; if this limit were eliminated, completely new dynamics of leisure-time mobility could emerge.

To conclude, the acceptability of each use case, including public door-to-door, feeder, and private options, highly depends on the right balance of mobility improvements and traffic increase prevention. Generally, the acceptability of public DRT services is better than that of private vehicles, and the acceptability of a DRT service might be improved when it is introduced in a non-urban or suburban setting. Moreover, the prevailing task should be to reduce car dependence and prevent motorized transport from becoming too attractive compared to regular PT and active modes. Proactive governance is crucial to support relevant desirable effects and prevent the risks. Some recommendations are as follows: First, the conditions of accessibility should be met by providing attractive and locally modified mobility services for all kinds of spatial settings. Secondly, differences in mobility configurations should be recognized. Mobility needs go beyond the needs of individual city travelers. In particular, people traveling with children and those with complex daily coordination tasks, as well as suburban and extra-urban travelers, should be considered and recognized as target groups for mobility innovations.

Further research is needed to systematically assess acceptable AD from the perspective of further mobility configurations and how conflicting acceptability conditions might be weighed and aligned. In addition, as we showed in this paper, there are fundamental differences between residents of urban areas, suburban areas, and non-urban areas. There is thus a need for further research on the specificities of a given area and on area-specific use cases and operational models, especially for suburban and rural areas. Research should not address this topic from a primarily economic or technical point of view, as these services will not be economically viable in rural areas. Rather, this topic should be considered from the perspective of the potential for people in a community to be mobile without private cars or with fewer cars. The focus should be on better understanding this potential so that requirement-responsive mobility concepts for rural areas can be tested locally in concrete projects.

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