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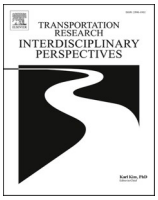

Keeping older people mobile: Autonomous transport services in rural areas

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ABSTRACT

Rural areas are characterized by limited access to public transportation. In the absence of alternatives, many older people continue to drive private cars. This imposes risks on society and older people, as traffic risks increase with declining mental and physical health. As opportunities to remain mobile have key relevance for quality of life, this paper investigates attitudes of older people to autonomous transport services (ATS), based on a sample of n = 2,349 respondents living in rural and urban areas in Freiburg, Germany. ATS are not currently available, though they are expected to follow the introduction of automated driving, thus representing a future to alternative to public transport and private car travel. Results show an openness to the use of autonomous transport services for a majority of >65 year olds, though interest declines with age. Neither willingness-to-pay nor waiting times to ATS arrival are likely barriers to adoption. The study concludes that an introduction of ATS that targets older people in rural areas is promising, and will generate social and economic benefits for individuals and society. The transition from private cars to ATS can be supported by mandatory license renewal (fitness) tests. These are welcomed by a large majority of respondents, but not currently required in Germany.

1. Introduction

The car is an essential transport mode for older people in rural areas, who rely on transport for a wide range of activities including shopping, visits to friends and relatives, participation in cultural and religious life, as well as access to health care services (e.g. Banister and Bowling, 2004; Schwanen and Páez, 2010; Szeto et al., 2017). In addressing these transport needs, the car is closely linked to quality of life (Graham et al., 2018). Car reliance is often higher in rural areas (Cutler and Coward, 1992), also because public transport may be unavailable or difficult to access, with infrequent departure times (Hjorthol, 2012). The only transport alternative, taxis or other individual transport services, may be considered unaffordable or inconvenient. In many industrialized countries, older people thus express preferences for using their cars until high age. This is also problematic, as traffic risks increase with age (Croston et al., 2009; Dobbs and Carr, 2005, EC, 2021; Haghzare et al., 2022). Age affects driving abilities, and as collision statistics suggest, older drivers constitute a risk for themselves and other traffic participants, while also being more vulnerable in collision situations (Abou-Raya and ElMeguid, 2009; CDC, 2020).

While a share of older people drives more infrequently with high age, or stops driving altogether, few appear to plan for driving cessation, even when more serious health issues are known (Adler, 2010). This has prompted some authors to call for interventions beyond self-regulation in the transition to transport alternatives (Ang et al., 2019). While this problem is acknowledged in the transport literature in principle, it has been difficult to devise solutions for reasons of car-attachment, cost, 'aging in place' preferences (Wood et al., 2016). In Germany, driving license renewal "fitness" tests, a standard in most countries, are politically taboo. Against this background, automated transport services (ATS) represent an opportunity to support the transition to driving cessation. As autonomous cars and ATS move closer to market introduction, this paper investigates rural transport patterns, the attractiveness of autonomous, individualized mobility services, as well as the socio-cultural, health and cost-related barriers to the use of such services.

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2. Theoretical background

2.1. Mobility patterns of older people

Mobility patterns depend on age, gender, cultural or geographical context (Gilbert and Perl, 2008). Lower population densities, greater travel distances, and more limited public transport options create *structural* car dependence in rural areas (Roberts et al., 1999; see also Jones, 2011; Wretstrand et al., 2009). Older people have, in general terms, more limited and flexible transportation needs, as they do not have to commute to work. To purchase groceries and to do other shopping, social visits (friends, relatives), health care, leisure activities, as well voluntary work will characterize daily trips (e.g. Hjorthol et al., 2010). Mobility is thus central to quality of life for older people, also to avoid social exclusion and isolation (Golden et al., 2009; Graham et al., 2018; Hyde et al., 2003; Mollenkopf et al., 1997). Mobility in later life should therefore not only be considered under a utilitarian perspective (Mokhtarian and Salomon, 2001) – i.e. as a derived demand – but also as a mediator for health and well-being and as an instrument of freedom in later life stages (OECD, 2020; Pantelaki et al., 2020). Transport-on-demand services are a theoretically effective strategy to address this situation (Preston and Rajé, 2007). A potential barrier is that older citizens associate the loss of the car with the loss of independence, and perceive the cessation of driving as a signifier of old age (Eisenhandler, 1990). A large share of the old population in industrialized countries is reluctant to give up driving, relying on cars until high age (Dickerson et al., 2007; Glasgow and Blakely, 2000; Hjorthol et al., 2010). This is a potential concern, as drivers aged 70 and older are more often involved in road traffic collisions (Abou-Raya and ElMeguid, 2009; CDC, 2020; DaCoTA, 2012; Kenntner-Mabiala et al., 2016; Li et al., 2012).

Even though many countries have driving license renewal procedures for older drivers, few older people plan driving cessation (Adler, 2010). Evidence suggests that this is a slow process (Dickerson et al., 2007) even where safety concerns are imminent, as in the case of dementia (Croston et al., 2009). Foley et al. (2002) conclude that men are likely to live seven years, and women ten years beyond their ability to drive safely. They also find that in most European countries, anxieties related to becoming too old to drive are significant. Productive engagement related to work and volunteering, as well as the maintaining of social ties is negatively affected by driving cessation (Curl et al., 2014). Particularly in rural contexts, non-availability of a car affects quality of life, and perceptions of still being "able-bodied" to drive encourage continued car-ownership (Marin-Lamellet and Haustein, 2015). Even though there is evidence that automobility does decline with age (Burns, 1999; Edwards et al., 2010), a considerable share of older people will not voluntarily give up their private cars.

2.3. Autonomous mobility acceptance

Fully autonomous cars have been tested on public roads for years, and expectations have been voiced that manufacturers will release the first autonomous vehicles in 2024/2025 (Ondruš et al., 2020). While it is currently unclear when autonomous cars will become available, i.e. vehicles that can navigate without a driver, it has been suggested that such technological progress would make a significant contribution to road safety (Ye and Yamamoto, 2019). Research suggests that attitudes towards fully automated cars are positive (Payre et al., 2014), even though there are some concerns about software hacking, legal issues, and safety (Kyriakidis et al., 2015). As drivers become passengers, automated vehicles may dissolve driver-car bonds (Gössling, 2017), and induce a shift from owned vehicles to hailing services, also on a ride-share basis (also pooled). Becker and Axhausen (2017), in a review of studies, conclude that younger people in urban contexts are more positive to automated forms of mobility, and men are more positive than women. The overall attitude is thus expectant of ATS, though it remains currently unclear if people would predominantly want to own autonomous vehicles, or be satisfied to use these as a service. Here, Yuen et al. (2020) suggest that relative advantage, compatability, complexity, trialability and observability interact with acceptance and perceived value, which again is linked to trust in the technology. These, as well as other aspects, may have relevance for targeting older people to adopt autonomous mobility services.

Perceptions of autonomous mobility among older drivers have so far only been studied in a limited number of contexts. Hassan et al. (2021) studied perceptions of older Canadians in Southern Ontario, i.e. a rural context. The stated preference survey found that injury and liability dominated concerns, though older people welcomed driving assistance features of semi-autonomous cars. Bird et al. (2017) found, in a study in the USA, that ride sharing programs were a suitable mobility service alternative attractive specifically to female users (77%) belonging to the "young older" aged 65–74 years (82%). Yet another study in the USA (Kadylak et al., 2021) suggests that only a small share (19%) of older people (>75 years) is willing to use automated vehicles: acceptance appears to decline with age, and male respondents are more interested (21%) than female respondents (16%). Kadylak et al. (2021) nevertheless highlight that age differences are not statistically significant. Qualitative research has so far established that older people have concerns in regard to safety, cost, and difficulties to use automated vehicles, while they also fear a lack of interaction with a human driver (Zandieh and Acheampong, 2021).

2.4. Car ownership in Germany

Germany is a country with 83.2 million residents, of which 49.3% are male and 50.7% female (Destatis, 2021). Some 22% of Germans are 65 years and older, with a significant share of very old people (80 years and older, corresponding to 7% of the population). Over the next two decades, Germany will see a growing share of older people, as the baby boom generation is reaching retirement age (Destatis, 2021). National statistics on car ownership and modal split of the German population show that, in 2017, 83% of 60+ Germans owned a car (Bundesministerium für Verkehr und digitale Infrastruktur, 2018). Based on modal split data, a decreasing use of the car over life stages is evident: Younger seniors (60–69) use a car for 49% of the trips, with an average of 33 km actively driven per day. For 70 to 79 year olds, the car is used for 40% of trips, while the average distance driven declines to 22 km per day. For the highest age group, 80 years and older, car use declines to 32% of trips, with a driving range of just 6 km per day. Half of this age group (50%) does no longer own a car as a result of poor health, indicating that a large group of old people recognizes impairments and voluntarily gives up on driving or drives less. A large share continues to drive, also because 'for life' driving license policies increase driver age (Edwards et al., 2010).

3. Research design and methods

"Old adults" comprises a considerable range of age groups from early retirement to very high age. Alsnih and Hensher (2003) concluded that it is meaningful to distinguish young (65–75) and "old" old people (over 75 years), as mobility needs change. Others have identified lifestyle clusters (Hildebrand, 2003) to derive transport needs of older population groups, or segments describing heterogenous mobility types (Haustein, 2012; Haustein and Siren, 2015). This study includes all age groups, with the intention to show how perceptions and needs change with age.

The approach relies on self-reports and stated preferences of drivers. Self-reports and stated preference approaches have known disadvantages. For example, self-reports may be biased because of recall inaccuracy or expectations of social desirability (Lange and Dewitte, 2019). In the context of this paper, such effects are likely less relevant, as data was collected on the basis of printed questionnaires, allowing

respondents to reflect on their answers in their own time, and in anonymized form.

The empirical data was collected between 18 July and 30 September 2020. Printed questionnaires were distributed to 18,000 households in Freiburg, Germany, and surrounding communities. Household members 18 years and older were invited to participate in the survey by returning the printed questionnaire, or by entering data online in an online survey instrument. In total, 1,979 printed questionnaires were returned by post, and 454 responses received online.

The Freiburg region includes the city of Freiburg district (230,940 inhabitants in 2020) and the surrounding districts of Breisgau-Hochschwarzwald and Emmendingen (with a total of 431,729 inhabitants). These latter municipalities have population sizes ranging from 500 to over 20,000 (Statistisches Landesamt Baden-Württemberg, 2021). While the city district of Freiburg can be identified as a predominantly urban environment, the surrounding districts are shaped by a mix of rural, small town and suburban structures. The public transport system is well developed, except for some smaller and more isolated settlements in the surrounding districts of Freiburg. Statistically, the population 65 years and older is lower in Freiburg (21.2%) than in surrounding districts (26.8%) (in 2020; Statistisches Landesamt Baden-Württemberg, 2021).

The data used for the analysis consists of 1,179 questionnaires for the Freiburg city district and 1,170 questionnaires for the surrounding municipalities. The remaining 84 questionnaires were excluded from the sample because the respondents' place of residence was outside the Freiburg region or it could not be identified. To provide a common understanding of "automated transport services", the following text was presented to respondents:

No car is available in your household. There however exists an autonomous transport service, i.e. a vehicle that picks you up at your doorstep and takes you to your destination. To order transport, you press a button on your mobile phone. A vehicle arrives within 10 min. There is no driver, but you can tell the car the destination and you will be driven there. You return using the same service. Transport is as expensive as driving your own car, the trip is automatically paid for, and you don't have to worry about anything. The pick-up service is easy to use, guaranteed collision-free and comfortable.

For the purpose of analysis, findings distinguish two groups of older people: People up to 65 years who will usually still work and thus have different transport patterns than those older than 65, for whom commuting to work becomes redundant. As studies highlight a growing propensity for people 75 years and older to become involved in traffic risks, the analysis also considers the specific characteristics of this age group. Socio-demographic characteristics of the sample (n = 2349) are shown in Table 1.

Table 1
Sample characteristics, percentages (n = 2349).

Gender	male	44.3
	female	55.4
	diverse	0.3
Age	below 30	12.8
	30–49	30.7
	50–64	30.4
	65–74	14.9
	75 and older	11.2
Employment	yes, full-time	41.3
	yes, part-time	25.9
	no	32.8
Place of residence	rural area	49.8
	urban area	50.2
Household size	one	10.2
	two	50.7
	three	16.1
	four	16.4
	five and more	6.6

4. Results

4.1. Rural-urban comparison of transport patterns

Table 2 compares rural and urban areas, illustrating that the rural population in the sample is characterized by a higher share of old people, with 31.7% of rural respondents being 65 and older, in comparison to 20.4% of the urban population. Both rural and urban respondents report a high degree of driving licensure, at 97.7% and 95.0%, respectively. The most significant difference between the two samples is car ownership, as 83.5% of the rural and 58.2% of the urban sample reported to own a car. The survey also found multiple car ownership, car numbers per household, as well as motorization to be higher in rural areas. This translates into differences in transport demand, which is much higher in rural areas, where respondents drive an average of 186 km per week, plus another 61 km per week as a passenger. In urban areas, the corresponding values are 122 km as driver and 29 km as passenger. Rural populations thus cover 64% more kilometers (96 km/week) than their urban counterparts.

In regard to the main question of this study, results confirm a general openness to autonomous services (Table 3). In rural areas, 25.7% of the sample reported a "definite" interest to use such services, and another 47.7% suggested to "probably" use these. However, about one quarter, 26.6%, would "definitely not" rely on autonomous transport services. Corresponding figures for urban areas are similar, at 25.5% (definitely), 45.8% (probably) and 28.8% (definitely not). This indicates that the countryside is slightly more open to the use of autonomous transport services, as may be expected given the more limited alternatives. Respondents in rural areas also reported to be more often physically limited, specifically to feel insecure when walking (6.4%, in comparison to 4% in the urban sample). Yet, for the overall sample, the data only shows a small difference between respondents with physical limitations in (not using) autonomous services (definitely not: 28.8%) in comparison to those not physically limited (definitely not: 27.6%).

Data also shows that men are more open to the use of autonomous services (definitely yes: 29.9%, compared to 22.0% of the women; overall sample), perhaps because they place more trust in technology innovations. Equally relevant is that exclusive services are not necessarily demanded or a precondition for use (2.7 in rural and 2.6 in urban areas; 5-scale Likert) (Table 2). This suggests that pooled versions of ATS are attractive to a share of the prospective users. Given the considerable length in stated acceptable waiting times for ATS to arrive, at 27 min in rural and 22 min in urban areas, there appears to be a potential for the introduction of shared services even from a technical feasibility/acceptance point of view. Willingness-to-pay (WTP) for autonomous transport services is also high, at around 1 Euro per km in both rural and urban areas. Given the cost of private vehicle ownership in Germany, at 0.45 to 0.86 Euro per km for small/large popular car models (Gössling et al., 2022), WTP likely exceeds the cost of autonomous transport services.

As a measure of perceptions of policies forcing older people to consider transport alternatives, the questionnaire also explored attitudes towards limiting car ownership. Findings suggest that support of controlling driving capabilities is high in both rural and urban areas, with a respective support of 79.6% and 83.2% of regular fitness tests. For the overall sample, the age at which such tests should begin was given at 71.2 years (rural areas) and 69.5 years (in cities). While rural populations are slightly more guarded regarding license renewal tests, there is a clear majority in support of such tests at an age that is below the critical threshold for growing injury numbers. Confronted with a scenario in which driving becomes impossible, a majority of respondents would have to rely on public transport (78.5% in rural and 80% in urban

Table 2
Rural vs. urban area.

		rural area	urban area	Chi-square (or *t*-test)
n		1170	1179	
Gender	male	47.6	41.1	10.537***
	female	52.2	58.6	
	diverse	0.2	0.3	
Age	below 30	6.6	19.0	103.100***
	30–49	29.4	32.0	
	50–64	32.3	28.5	
	65–74	17.6	12.1	
	75 and older	14.1	8.3	
Do you have a driving licence	Yes	97.7	95.0	13.842***
	No	1.8	3.2	
	No, but someone in household	0.5	1.9	
Do you have a car	Yes	83.5	58.2	204.008***
	No	8.6	30.6	
	No, but someone in household	8.0	11.2	
Would you use an autonomous pick-up service?	definitely not	26.6	28.8	1.400
	probably	47.7	45.8	
	definitely yes	25.7	25.5	
Regular driving test	no	20.4	16.8	5.041**
	yes	79.6	83.2	
If you drive a car now, what will you use when you cannot drive anymore?	taxi	22.1	24.0	1.123
(multiple answers)	public transport	78.5	80.0	0.857
	family and friends	46.6	33.5	41.683***
	don't know	15.1	11.3	7.503***
Do you engage in voluntary work?	yes	49.9	43.5	9.681***
	no	50.1	56.5	
Are you employed?	yes, full-time	40.2	42.5	4.635*
	yes, part-time	24.9	26.8	
	no	34.9	30.7	
Do you have a mobile phone?	yes	95.1	97.0	5.458**
	no	4.9	3.0	
Are you physically limited in your mobility?	no	88.7	91.7	2.658
(multiple answers)	yes, I am insecure when walking	6.4	4.0	7.032***
	yes, a rolling walker	1.0	1.0	0.000
	yes, a wheelchair	0.6	0.8	0.508
	yes, I need help getting in and out of the car	0.7	0.6	0.076
	yes, other	5.7	3.4	7.382***
		rural area	urban area	*t*-test
If you would use an autonomous pick-up service, what would be important?	Exclusive service without other guests (rating)	2.7	2.6	0.997
	Acceptable waiting time in minutes	27.1	21.8	6.714***
	Maximum cost per km in EUR	1.0	1.1	−0.191
If you have a car, how many cars do you have?	average	1.2	1.1	2.659***
How many cars do you have in your household?	average	1.6	1.3	6.932***
PS main own car	average	139.0	131.1	2.037**
Average km per week by	car (self driver)	186.35	122.12	2.491**
	car (passenger)	61.36	29.29	5.55***
	train	77.10	132.79	−2.283**
	bus or streetcar	28.65	24.89	0.874
	bike	42.59	46.71	−1.271
	e-bike	40.75	22.48	5.529***
	taxi	2.02	0.81	1.631
Regular driving test	if yes, age	71.2	69.5	3.549***
Household size	average	2.57	2.52	1.015
Financial situation in household	averag rating (1–5)	3.67	3.7	−0.779
BMI	average	24.7	23.6	5.586***

Notes. *p <.10; **p <.05; ***p <. 01

contexts), with family structures in rural areas constituting an alternative (46.6%, compared to 33.5% in cities), followed by taxi services (22.1% versus 24.0%). These findings suggest that the use of ATS might become more attractive through the introduction of driving license renewal policies.

4.2. Views of old age groups

Further insights can be derived from the specific evaluation of the data for the highest age group that poses the greatest traffic risk and that is also the most vulnerable in collision situations. As data in Table 3 shows, the interest in autonomous transport services declines with age, and negative attitudes are more significant in rural than in urban areas. Of the rural respondents for whom ATS would provide the greatest benefits (the 75+ year age group), 38% would "definitely not" use such services (Table 4). However, 19% state "definitely yes", and a majority (43%) is open to the use of ATS in principle. Given the reliance on the car in rural areas, as also expressed in higher levels of car ownership, this shows that in particular those groups for whom ATS would resolve problems in regard to independence appear cautiously interested. Views on fitness tests appear to have a limited influence on views, but people who are physically impaired are more interested than the average sample. Men are also more interested in ATS than women. Differences are small, however.

Furthermore, a binary logistic regression was conducted (Table 5). Specifically, this concerned the question under which conditions older people would use automated mobility services, i.e. the dependent variable is "I would definitely use automated mobility services". A significant positive relationship was found with two statements, i.e. an expectation to use taxi services when becoming unfit to drive, as well as gender (coefficient for male). A negative significant relationship was found for not being employed anymore. No significant relationship was established for urban/rural, age, driving licensure, owning a car, the number of persons in the household, financial situation, mobile phone, or BMI.

In order to allow for asymmetric behavior of different groups, a statistical decision tree for "I would definitely use automated mobility services" was developed in a consecutive step (Fig. 1). Decision trees are commonly used in machine learning for classification tasks (Alpaydin, 2020), and have the advantage of high interpretability (Nuzzo, 2014; Wasserstein & Lazar, 2016). The decision tree, here based on n = 1441 valid cases, supports that planned taxi use is a predictor of ATS acceptance. This is not a surprise, as taxis represent a mobility services, and hence may be considered a step in-between private car and ATS. The tree also confirms that male drivers are more open to the use of ATS. Female acceptance of ATS is higher among those physically impaired, while for men, employment has a positive effect on ATS. Overall, the decision tree confirms the significant variables derived thorugh the logistic

Table 3
Rural – urban comparison of ATS acceptance.

Would you use an ATS? **All:**							
	below 30	30 to 49	50 to 64	65 to 74	75 and older	total	Chi-square
definitely not	26.9%	23.9%	27.6%	32.1%	35.4%	27.9%	24.49***
probably	53.7%	46.9%	45.7%	43.5%	44.0%	46.6%	
definitely yes	19.4%	29.2%	26.7%	24.4%	20.6%	25.5%	
total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
Would you use an ATS? **Rural area only:**							
	below 30	30 to 49	50 to 64	65 to 74	75 and older	total	Chi-square
definitely not	17.3%	20.9%	26.4%	32.0%	39.0%	26.8%	26.125***
probably	58.7%	50.4%	46.5%	45.2%	42.2%	47.7%	
definitely yes	24.0%	28.7%	27.2%	22.8%	18.8%	25.5%	
total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
Would you use an ATS? **Urban area only:**							
	below 30	30 to 49	50 to 64	65 to 74	75 and older	total	Chi-square
definitely not	30.1%	26.7%	28.9%	32.4%	29.2%	28.9%	12.218
probably	52.1%	43.6%	44.9%	41.0%	47.2%	45.6%	
definitely yes	17.8%	29.7%	26.2%	26.6%	23.6%	25.5%	
total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Notes. *p < 0.10; **p < 0.05; ***p < 0. 01

Table 4
ATS acceptance by subgroup (75 + year olds, rural areas).

Would you use an ATS? Gender**:**				
Gender	female	male	total	Chi-square
definitely not	47.8%	33.7%	38.0%	2.782
probably	34.8%	46.2%	42.7%	
definitely yes	17.4%	20.2%	19.3%	
total	100.0%	100.0%	100.0%	
Would you use an ATS? License renewal**:**				
License renewal	yes	no	total	Chi-square
definitely not	37.5%	38.9%	38.0%	0.664
probably	44.8%	38.9%	42.7%	
definitely yes	17.7%	22.2%	19.3%	
total	100.0%	100.0%	100.0%	
Would you use an ATS? Physically impaired**:**				
Physically impaired	yes	no	total	Chi-square
definitely not	37.8%	38.1%	38.0%	0.385
probably	40.0%	43.8%	42.7%	
definitely yes	22.2%	18.1%	19.3%	
total	100.0%	100.0%	100.0%	

Notes. *p < 0.10; **p < 0.05; ***p < 0. 01

Table 5
Significance of interrelationships with "I would definitely use automated mobility services".

	I would defenitely use an autonomous pick-up service	
Variable	Coefficient (S. E.)	Wald (Sig.)
I will use a taxi when I cannot drive anymore	0.463 (0.128)	13.150 (<0.001***)
Not employed anymore	−0.138 (0.066)	4.381 (0.036**)
Gender (male)	0.350 (0.112)	9.848 (0.002***)
Constant	−1.030 (0.224)	21.097 (<0.001***)
Chi-Square		29.373 ***
Cox & Snell R^2		0.020
Nagelkerkes R^2		0.028

Estimated parameters in binary logistic regression models.
* (**, ***) indicates that the coefficient is distinct from zero at the 0.1, 0.05 and 0.01 significance level.

regression, but adds a role of being physically impaired for women.

4. Discussion

There is a general consensus that transport planning must address the mobility needs of older people in rural areas, offering diversified transport options, within wider frameworks of infrastructure planning and policies (Cui et al., 2016). This does not necessarily only include motorized forms of transportation, as active transport will benefit health and sociality of older people (Age UK, 2015). Transport offers provided for older people will also benefit those with disabilities as well as younger people (Dickerson et al., 2007). In the current situation, transport needs are met by public transport systems relying on specific departure times and locations, which may often be inconvenient for users. ATS, when these become available, have the potential to make public transport systems redundant.

As a general conclusion of this research, ATS will benefit rural populations, and have socio-economic advantages for older people and society. An ATS scenario makes it possible for older people to become less dependent on transport provided by others or available public transport: a dependency that is perceived as a burden and undesirability (Schwanen et al., 2012). ATS are individual services at a cost comparable to or below private car ownership, with survey results indicating a WTP that exceeds private automobility costs. ATS also resolve the first and last-mile problem of public transport services (Shaheen and Chan, 2016; Yap et al., 2016) and reduce waiting times in inconvenient locations such as bus stops next to major roads. Older Germans perceive public transport as specifically negative in regard to cost, comfort (ticket purchase prodcedures, orientation), physical barriers (opening doors, climbing stairs), safety, waiting times, and the availability of toilets (Engeln and Schlag, 2002). While ATS can address several of these issues, they also represent a solution to the problems of self-driving, as old people report negative experiences with private vehicle travel that reflect on growing insecurity in traffic.

A major secondary benefit of ATS is that these can be pooled: loneliness is a key issue for older people, who may profit socially from opportunities to share transport. Pooled transport will also be cheaper, providing an added financial incentive. While this is optional for users to decide, research in Germany has identified "material depreviation" as an issue for many households, with in particular those feeling to be forced to own cars also being at a higher risk of poverty (Mattioli, 2017). For low-income households, car ownership is a major cost item that is potentially on par with the cost of housing (Gössling et al., 2022). As

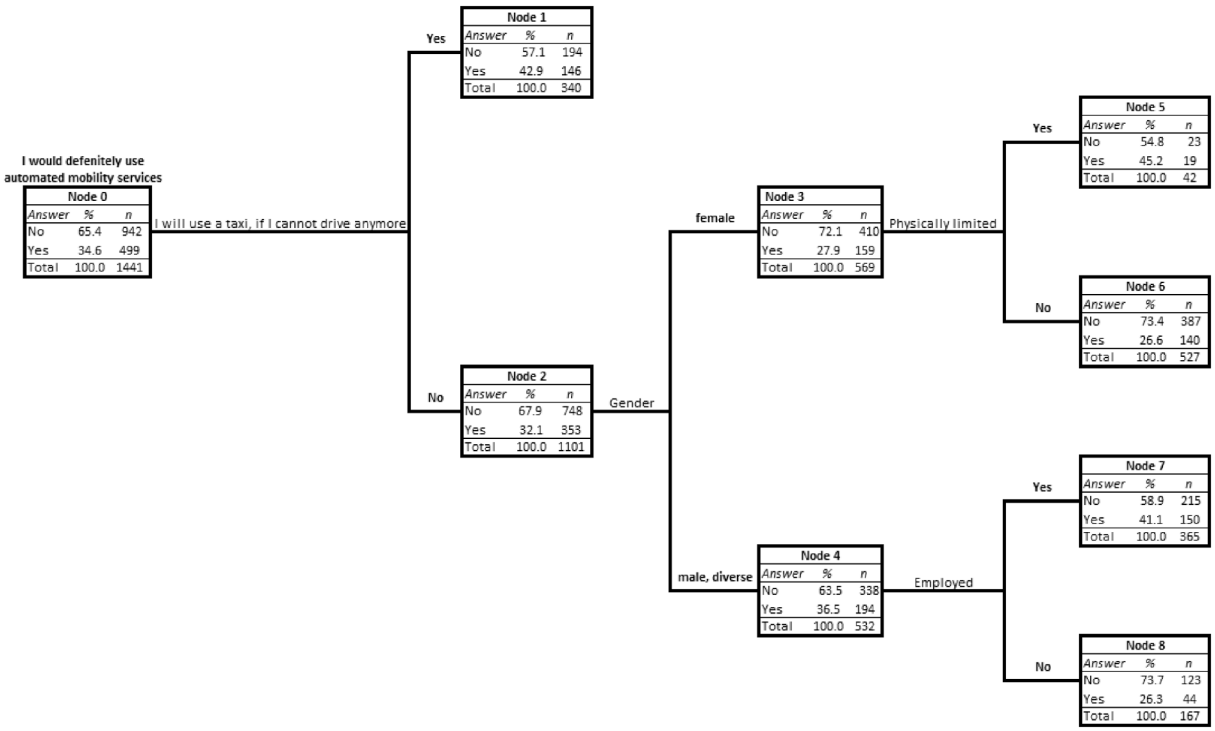

Fig. 1. Decision Tree for "I would definitely use automated mobility services".

ATS can potentially be offered at a lower cost, there are social and financial arguments for such services.

This positive outlook may be considered in light of various developments, such as recent digital innovations that make a share of trips redundant. For instance, opportunities for digital healthcare consultations (Nikou et al., 2020), social media platforms to maintain social networks (Liu et al., 2016), or delivery services for groceries or medicines (Brandt et al., 2019) can substitute trips. A potential barriers to the use of technology is that older people will be required to have a mobile phone as well as the mental capability to navigate applications. This will also be a precondition for using ATS. Research suggests that a large share of older people have access to the Internet, use mobile devices, and often apps, even though these are not usually designed for use by older people (Ani, 2020; Klimova, 2018). In this study, a large majority of older respondents was found to own a mobile phone, i.e. 93.3% of the 65–74 year olds, and 87.7% of the 75+ year olds. While further research is needed to understand interrelationships of age and ICT use, findings are basically encouraging for the ICT-based use of ATS. A general conclusion is that it will be easier to introduce ATS services in earlier life stages in order to create familiarity with the ordering of services.

Another barrier concerns potential difficulties for disabled people to use ATS, for instance because walking aids or wheelchairs need to be carried along. Taxi services will remain a better solution for impaired older people, as well as those suffering from dementia or Alzheimer, as drivers can ensure safe arrival at the destination. The survey also noted a far lower interest of women to use ATS. Though echoing other studies, this is unexpected, as other studies have shown that women over 70 years are more reliant on males to drive them (Li et al., 2012). Further research is needed to understand whether this is a result of men being more open to technology innovations in regard to vehicles. Of interest in this context is that ride-sharing programmes have been found to be more attractive to women (Bird et al., 2017). Whether concerns are technology or safety related thus deserves further study, because there is a general outlook for ATS to empower in particular older women without driving license. Perspectives on ATS may change when such services are introduced and prove to be reliable and safe: positive (as well as negative) experiences are likely to quickly spread in rural areas, where neighbourhood relations are often tighter.

While the overall prospect for the introduction of ATS is thus positive, a share of old people will be unwilling to give up their private cars (Kadylak et al., 2021), even when they are clearly no longer able to drive. This leads to a situation where a share of older people will only seize driving when they become involved in a near collision or collision, a situation calling for interventions (Rudman et al., 2006). Findings from this survey support that policies requiring fitness tests for older people can potentially encourage the use of ATS. Such mandatory license renewal systems are a norm in many countries. As this study also finds support among older people for such tests, there is no principal barrier to establish these in Germany. The availability of ATS in combination with fitness texts may be seen as a mechanism towards a reduction of car ownership among older people that has already been shown to have roles in the adoption of ride hailing services (Freund et al., 2020). Findings from this research confirm that employment, male gender and interest in taxi services can be used to identify target groups.

In practical terms, information on ATS might become a regular feature of fitness tests, and be directed at both those still eligible to drive, as well as those becoming too old to drive. Possibly, such strategies may include a cost argument (Mattioli, 2017). Affective and symbolic barriers, such as car-driver bonds and perceptions of losing independence, will likely remain. To address this, rational arguments may be combined with emotional communication strategies, highlighting, for instance, sociality in pooled versions of ATS. Such campaigns may be initially directed at men, and in contexts where taxi-services are already used. Health services, for instance, may suggest ATS instead of offering taxi rides.

5. Conclusions

This paper investigated older people's perspectives on automated transport services against a background of diverse transport needs and growing traffic risks in high-age groups. Findings confirm that such transport services are attractive to a significant share of older people. Three insights are of particular importance in this context: First, interest in ATS may increase once such service prove to be reliable and safe. The

share of older people "definitely" interested in the use of such services provided a sufficient basis for the trialling of such services. Second, results indicate that interventions such as license renewal tests would likely increase interest in ATS, as these provide a flexible alternative to the private car. Given that older people support the introduction of such tests, there is no principal barrier to enact such legislation. Last, there is an economic argument for the switch to ATS. As the distances driven decline with higher age, the fixed cost of car ownership (purchase of the car, insurance, maintance) increases in relation to the flexible cost (specifically fuel use). The switch to ATS will thus entail economic benefits for old people, while society and older people will profit from a decline in collisions and injuries.

To support changes in the transport system, and to make the benefits of ATS tangible, far-reaching changes in public policy and transport planning will become necessary. In Germany, this includes the acknowledgement that pro-automobility legislation has remained silent on the risks imposed by older drivers on other traffic participants and themselves, while supporting lifetime driving licensure without fitness tests. Public debate is required on the implications, as well as the potential benefits of ATS. Trial areas for ATS, once these are technically feasible, will have to be set up. Once ATS are safely functioning, their roll-out will require information campaigns and technology support, such as apps to order these services. New mobility-as-a-service companies will come into existence that need to be regulated, for instance in regard to insurance. Opposing groups, such as taxi drivers, will have to be involved early in the transition, possibly in connection with new employment opportunities, such as accompanied ATS to help disabled or impaired older people. Given the prospect of ATS availability in the near future, it is time for transport planners to begin engaging with these challenges.

CRediT authorship contribution statement

Stefan Gössling: Conceptualization, Project administration, Writing – original draft, Writing – review & editing. **Tim Freytag:** Methodology, Conceptualization, Data curation. **Andreas Humpe:** Data curation, Formal analysis, Project administration. **Anna Scuttari:** Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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