Swiss mobility transformation to sustainability – recommendations on niche developments

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One of the biggest challenges for mankind is the imminent climate crisis, if global warming exceeds two degrees by the end of this century. The transport sector is the main contributor to greenhouse gases in Switzerland and many countries in the globe. A transformation of the mobility sector to sustainability is thus coercive if we want to reduce the risks of climate change. Within this paper we provide recommendations on how to tackle this transformation by looking at possible factors increasing the uptake of sustainable mobility technologies using a series of stated-preference surveys and lifestyle analysis framed within the multi-level perspective. We focus on a variety of niche-developments in the mobility sector ranging from electric mobility to autonomous vehicles but also governance innovations like mobility management and tailored interventions. This report acts as a guideline on how these niches could be fostered and – as such – accelerate the sustainable transformation of the Swiss mobility system.

1 Introduction: Swiss mobility transformation process

Mobility is a core asset of modern lifestyle. In 1847, the first steam-train was established in Switzerland providing alternatives to the horse carriages (Blümli, 2020). Through the invention of the car and its consequent diffusion in the early 1920, it became the backbone on how society moves between different places. Soon followed the extensive adoption of electrified-trains. In 1960, Switzerland was the first country to have fully electrified all train tracks (Blümli, 2020). A further boost to mobility was given with the possibility of commercial air-travel with jet airplanes for long-range flights in 1960 of the then called Swissair air travel company ("Swissair," 2020). However, since the population is increasing and the private car still holds its place as the dominant transport regime in Switzerland, negative externalities like greenhouse gas emissions, noise and space consumption are increasingly recognized. Further, the transport sector is the highest contributor to Switzerland's CO_2 emissions (BAFU, 2020). As such, the aim of SCCER Mobility is in line with the Swiss Energy Strategy 2050 to reach net zero emissions by 2050 and transform the transport sector to more sustainability (B. für E. BFE, 2020). During the last decade, the gigatrend of digitalization gave rise to a plethora of new mobility technologies and services, which have the potential to accelerate the shift to a sustainable mobility system. In this report, we focus on the following six niche developments:

- Electric mobility
- Car- and ridesharing
- Mobility as a Service
- Autonomous vehicles
- Mobility management
- Tailored interventions based on lifestyle segmentation

Electric vehicles (EVs) fueled with renewable energies have substantially lower CO_2,noise and other pollutant emissions (Cox et al., 2020). Switzerland has favorable conditions for the adoption of EVs since the average distances driven per day are roughly 37 kilometers, a distance which is easily covered by small to mid-sized battery electric vehicles (BEVs)(BFS, 2020). Furthermore, only 2% of the electricity produced in Switzerland stem from fossil energy (BFE, 2020). While in 2019 the share of BEVs on new car registrations was below 5% it has recently risen to 6.8% in 2020 (Swiss Federal Office of Energy, 2020). Still a faster switch to BEVs is needed to substantially reduce CO_2 emission from transport.

Car- and ridesharing are promising developments to reduce vehicle ownership and car use (Ko et al., 2019; Nijland and van Meerkerk, 2017) given their integration and connection to the public transport system (Namazu and Dowlatabadi, 2015). Switzerland has a long history of carsharing and is often recognized to be the origin of the worlds' first carsharing initiative in 1948 (Shaheen et al., 1998). Since then, the now called company Mobility Carsharing (or in short, Mobility) covers whole Switzerland offering 3120 cars and 1530 stations. While mostly round trip station-based carsharing is offered by Mobility, they are increasingly enabling one-way trips and test freefloating carsharing in two major cities (Zurich and Basel). Yet, so far less than 5% of their fleet is electrified (Mobility, 2020).

Mobility as a Service (MaaS) aims to integrate various forms of transport services like public transport, carsharing, bikesharing or scootersharing into a single mobility service accessible on demand (MaaS Alliance, 2021). MaaS further provides the travel planning, reservation and payment through one single platform accessed through a website or a mobile app (Jittrapirom et al., 2017). It is thus supposed to increase the flexibility and attractiveness of public transport as well as provide alternatives to the private car. In Switzerland, several pilots like yumuv and ZüriMobil have been launched recently. Yumuv is a research project of the Verkehrsbetriebe Zürich (VBZ), Swiss Federal Railways (SBB), Bernmobil, the Basler Verkehrsbetrieben and the Swiss Federal Institute of Technology in Zürich (ETHZ) to test the acceptance of different MaaS subscription plans in various cities (Yumuv, 2021). Similarly, ZüriMobil, a project by VBZ and the Civil Engineering Department of Zürich also provides a MaaS platform for multimodal travel in the urban region of Zürich and further tests stations, at which the various different transport options are located closely together simplifying the changeover from one means of transport to the other (VBZ, 2021).

Autonomous vehicles (AVs) are no longer a distant dream, but start to enter our mobility system in many cities around the globe. Fully automated vehicles requiring no manual steering (SAE levels 4 and 5)(SAE International, 2021) could disrupt the transport sector since they are expected to make mobility cheaper (Bösch et al., 2018), more comfortable (Fraedrich and Lenz, 2014), safer and accessible for persons without a driving license (Anderson et al., 2014). However, this could also lead to higher demand increasing vehicle miles travelled if the cars are not consequently pooled (Meyer et al., 2017). Several small autonomous buses are being tested for the integration of AVs into the public transport network in Switzerland. As an example, the Geneva public transport authorities (TPG) and the University of Geneva test one of the worlds' first autonomous shuttle bus without a fixed route (Swissinfo, 2021).

Mobility management in companies or administrations gained momentum in Switzerland after the launch of the program "Mobilitätsmanagement in Unternehmen (MMU)" by EnergieSchweiz in 2008 (EnergieSchweiz, 2021). They further developed the mobility management tool 'Mobitool'[1], a comprehensive website collating various information and guidelines regarding mobility management as well as calculators for energy efficiency and environmental impact of mobility. Through an effective mobility management, mobility to and within the companies and administrations can be optimized by e.g. company carsharing, carpooling, safe pedestrian and bicycle paths, incentives for green mobility including electric vehicles or slow modes - to name a few. This not only has the potential to reduce negative impacts of commuting but also increase the satisfaction of the employees and stand out as an environmental-friendly company. Furthermore, homeoffice and teleworking are promising measures to reduce traffic peaks in the morning and

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[1] https://www.mobitool.ch/

evening rush-hours and reduce vehicle miles travelled in general. Companies increasingly accept working from home or during travel (e.g. in a train) breaking the usual travel patterns. Through the emergence of digital tools like teleconferencing, which received a strong boost in acceptance since the Covid-19 Pandemic, meetings are increasingly hold online, without the need of physical presence consequently reducing travel needs. With above 50% of occupied jobs in financing, insurance, administration and other service sectors, Switzerland has a high potential for homeoffice and teleworking (Swiss Federal Statistical Office, 2021).

Tailored interventions based on lifestyles are increasingly being acknowledged instead of the so called "one-size-fits-all" interventions - interventions targeting an average citizen – that are associated with limited potential to induce behavior change in the field of mobility and in general (Haustein and Hunecke, 2013). Instead, a tailored approach is suggested in order to sufficiently exploit target-group-specific potentials for behavior change and consequently increase the effectiveness of the interventions (Abrahamse et al., 2005; Abrahamse and Steg, 2013; Klöckner, 2015; Seidl et al., 2017; Whitmarsh and O'Neill, 2010). For the design of the so called "soft policy measures" (Möser and Bamberg, 2008), it has been argued that tailoring interventions based on lifestyles or mobility styles should be particularly effective (Haustein and Hunecke, 2013). In Switzerland, Ohnmacht et al. (2009) derived four leisure mobility styles in Swiss agglomerations by the means of a cluster. The leisure mobility styles were based on leisure preferences and mobility orientations collected by the means of the computer assisted telephone interviews of 823 test persons older than 18 years living in German- and French-speaking Swiss agglomerations. Ohnmacht et al. (2008) develop the segment-specific intervention strategies and evaluate the segment-specific potentials and expected acceptance of the selected measures. In contrast to Ohnmacht et al. (2009) and Ohnmacht et al. (2008), Schubert et al. (2020) apply a lifestyle-based segmentation approach with a priori defined lifestyles (Otte, 2004) and investigate the effect of this lifestyle typology on air travel. Based on the sample of over 5000 Swiss households from the Swiss Household Energy Demand Survey (SHEDS), they find that Otte lifestyles are helpful for differentiating between flyers and non-flyers and explaining short- and middle-distance air travel. However, Otte lifestyles were not successful in explaining long-distance air travel. They authors suggest to focus the tailored interventions to reduce short- and middle-distance air travel on reflexives and hedonists - groups with modern perspective and higher income levels.

2 Overview

Since the beginning of the digitalisation trend, a whole new set of mobility services and technologies emerged. Together with the trend of individualisation in mobility and the differing needs of various stakeholders in planning, policy, society and institutions, the mobility sector is growing as complex sector. How the current mobility system could be transformed to net zero emissions in 2050 is thus an interaction of many diverse stakeholders, technologies and policies, which is difficult to understand without the help of an overview. In order to provide an overview of the actions needed to reach this goal, we frame our work in the multi-level perspective (MLP) developed by Geels (2002). Therein, Geels describes three analytical levels in which a non-linear process of transition happens. The niches describing a place for radical innovations, the socio-technical regime representing established rules, habits and practices and last, the socio-technical landscape putting pressure on the regime by overarching megatrends, beliefs, societal values being beyond the control of individual actors. We adapted the MLP from Geels (2012) and focus on the private fossil-fuel driven car as the established and dominant mobility regime in Switzerland, which we want to transform into a connected, multimodal, electrified and sufficient mobility system meeting the needs of society and policy to reach net zero emissions in 2050 (see Figure 1). The three megatrends of digitalisation, lifestyle change and population growth put pressure on this regime and open up windows of opportunity for niche developments to enter the market and accelerate the transition process.

In this report, we describe two separate tracks of niche innovations and provide empirical insights into how these innovations can reach into the current private fossil fuel car dominated mobility regime of Switzerland and support the transformation to a sustainable transport system.

The first track encompasses mobility innovations such as, electric mobility, car- and ridesharing, mobility as a service (MaaS) and autonomous vehicles. The second track includes governance innovations like mobility management and tailored interventions based on lifestyle segmentations. For each of these mobility and governance innovations we provide empirical evidence on how to increase their uptake from studies conducted during the SCCER Mobility Phase 2 period (2017 - 2020). We will briefly describe each of the studies in the next section but recommend to read the respective papers to get a deeper insight into the applied methods and results.

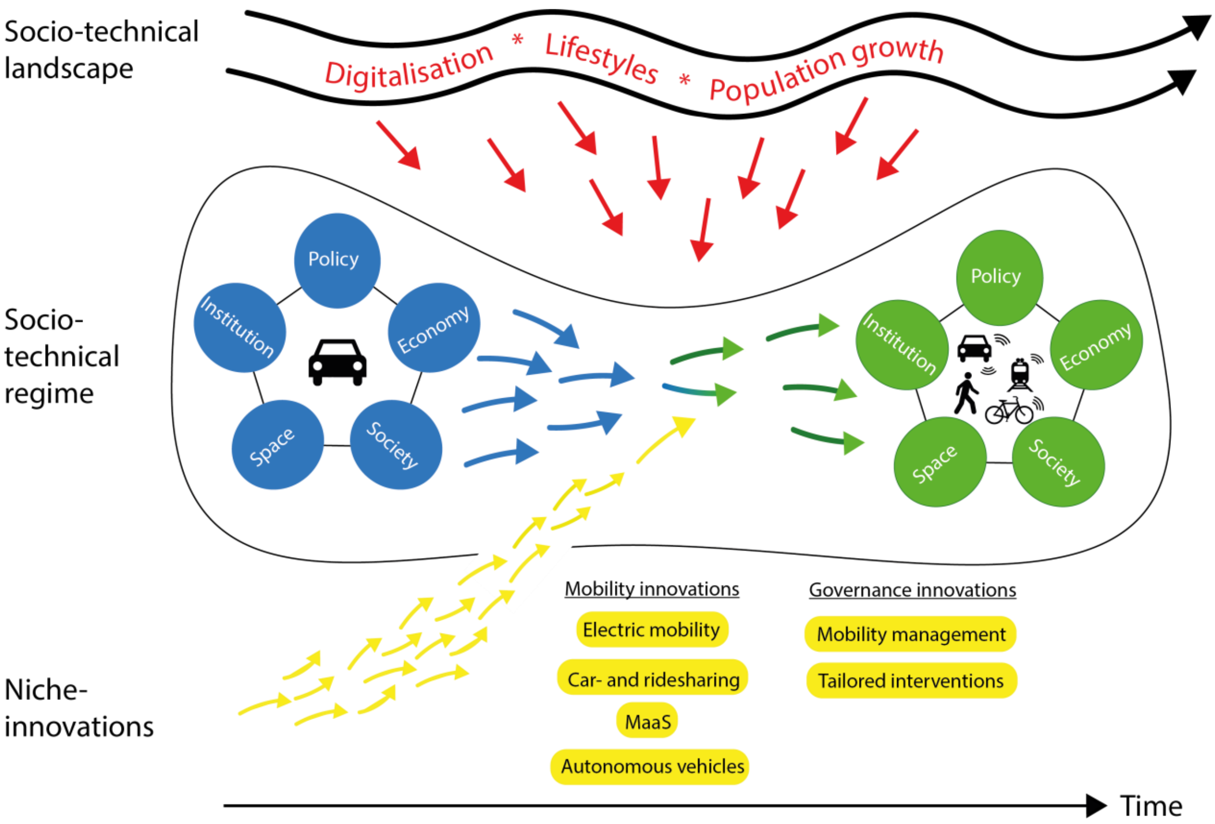


Figure 1: Overview of the three levels of the multi-level perspective, adapted from Geels (2002).

3 Studies included in this report

During the timeframe of SCCER-mobility Phase 2 from early 2017 until the end of 2020, we conducted eight studies, which are relevant for the aim of SCCER Mobility and the transformation of Swiss mobility to net zero emissions in 2050 in particular. The first two studies and study 7 were not financed by Innosuisse but are nonetheless worthwhile to be included in this report. The remaining five studies were all financed by Innosuisse. In Table 1, we give an overview of the studies and how they contribute to mobility innovation or governance innovation.

Table 1: Overview of studies included in this report and their contribution to the niche innovations.

Topic \ Study	1	2	3	4	5	6	7	8
Mobility Innovation								
Electric Mobility					X			
Car- and ridesharing	X	X	X	X	X	X		
MaaS	X			X				
Autonomous vehicles	X		X			X	X	
Governance Innovation								
Mobility Management	X							
Tailored interventions		X					X	X

1 (Hoerler et al., 2019), 2 (Hoerler and Hoppe, 2019), 3 (Stoiber et al., 2019), 4 (Raphael Hoerler et al., 2020), 5 (R. Hoerler et al., 2020a), 6 (Stoiber and Hoerler, 2020), 7 (R. Hoerler et al., 2020b), 8 (Tomic et al., 2019)

1. New solutions in sustainable commuting: the attitudes and experience of European stakeholders and experts in Switzerland

This study was conducted within the EU project Smart Commuting where we analysed through online surveys, expert interviews and expert workshops on how these various experts evaluate carsharing, mobility as a service or autonomous driving for commuting. The work further provides insights into best practices for company mobility management.

2. Commuter segmentation and openness to sharing services: a Swiss case study

Similar to the first study, we analyzed commuters in the region of Basel within the EU project Smart Commuting. We investigated the commuters' openness for car- and ridesharing through a logistic regression analysis and conducted a bottom-up segmentation analysis for better interpretability of the reasons of mode choice.

3. Will consumers prefer shared and pooled-use autonomous vehicles? A stated choice experiment with Swiss households

In this study, we conducted an online choice experiment with 709 participants of the Swiss Household Energy Demand Survey (SHEDS) 2018. The experiment tested the influence of 15 short-term and 13 long-term decision instruments to encourage the adoption of shared and pooled use of autonomous vehicles, like autonomous taxis and autonomous public transport.

4. What are the factors and needs promoting mobility-as-a-service? Findings from the Swiss Household Energy Demand Survey (SHEDS)

By means of an online survey conducted in Switzerland (SHEDS), we tried to understand potential user needs as well as factors that would motivate the use of MaaS. By comparing the openness to use MaaS for specific trip purposes like commuting and leisure activities, we further provide important differences between these trip purposes and related policy measures for the increased uptake of MaaS.

5. Are carsharing users more likely to buy a battery electric, plug-in hybrid electric or hybrid electric vehicle? Powertrain choice and shared mobility in Switzerland

We adopted a stated choice survey with 995 participants randomly drawn from the German and French-speaking population of Switzerland to test the drivetrain purchase preferences of users with and without carsharing experience.

6. Drivers for utilizing pooled-use automated vehicles — empirical insights from Switzerland.

We utilized the results of an online choice experiment involving 709 participants from Switzerland, which tested future mode choices considering automated cars, automated pooled-use taxis, and automated public transport shuttles, both for short and long-term mobility decisions. Exploratory regression analysis explains the experiment outcome with a broad set of underlying data predicting willingness to use.

7. The fear of urban sprawl through autonomous vehicles in commuting - a segmentation analysis of the Swiss population.

In this paper, we differentiated the Swiss car commuters through a cluster analysis and investigated the suitability of these groups to work in an AV by using the Swiss Mobility and Transport Microcensus, a nation-wide travel survey conducted every five years. The aim was to identify what part of the population may use travel time for working purposes and, ultimately, lead to urban sprawl through the acceptance of longer trips.

8. Mode choice for commuting and leisure: A matter of lifestyle?

In this study, we examine the effect of Otte lifestyles (Otte, 2004) on the mode choice for commuting and leisure based on the SHEDS data from the year 2016. We specify two multinomial logit models (for commuting and leisure respectively) and control for four main socio-demographic variables (age, gender, education and income) in addition to Otte lifestyle dummies.

4 Results

4.1 Mobility innovations

4.1.1 Electric mobility (study 5)

Electric mobility is seen as one of the core technologies to reduce CO_2 emissions in transport. We provide evidence on how to increase the uptake of electric vehicles by the general public through carsharing experience and other variables using an online-survey conducted in the Swiss Household Energy Demand Survey (SHEDS) 2018. Therein, we adopted a stated choice question regarding powertrain choice including battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), hybrid electric vehicles (HEV) and internal combustion engine vehicles (ICEV).

A few studies investigated the interaction of carsharing experience with EVs. Clewlow (2016), for example, investigated the differences in vehicle ownership characteristics between carsharing members and non-members in the San Francisco Bay Area utilizing a large household travel survey (n = 63'082). The findings suggest that carsharing members own significantly more EVs than non-members (18.3% in comparison to 10.2%, including hybrid, plug-in hybrid and battery electric vehicles). Whether this is an effect of subscribing to the carsharing service is unclear, however. Schlüter and Weyer (2019) adopted the technology acceptance model (TAM) to investigate the perceived usefulness and perceived ease of use of EVs among the users of a carsharing service in Germany. They find that carsharing experience leads to a significantly higher perceived usefulness of EVs, because people using carsharing services have a mobility mindset that is in line with EV characteristics, yet the effect size is small. Carsharing experience was not found to influence perceived ease of use of EVs. Schlüter and Weyer (2019) further asked the participants whether they would buy an EV as their next car finding that those who have experience with carsharing are more open to buy an EV as their next car compared to participants without carsharing experience. This effect was even higher for users of an EV carsharing service (although only significant on the p = 0.1 level). Similarly, Burghard and Dütschke (2019) report that those interested in carsharing are also more likely to own, have an intention to own and be interested in a BEV. They further suggest that carsharing users exhibit characteristics that are conducive to the acceptance of BEVs, such as less concern about dealing with limited range compared to ICEVs.

Figure 2 illustrates the most important findings of the study by applying a logistic regression analysis to test whether the following variables would significantly increase the likelihood of choosing an EV (either BEV, PHEV or HEV) instead of an ICEV as the next car or car replacement.

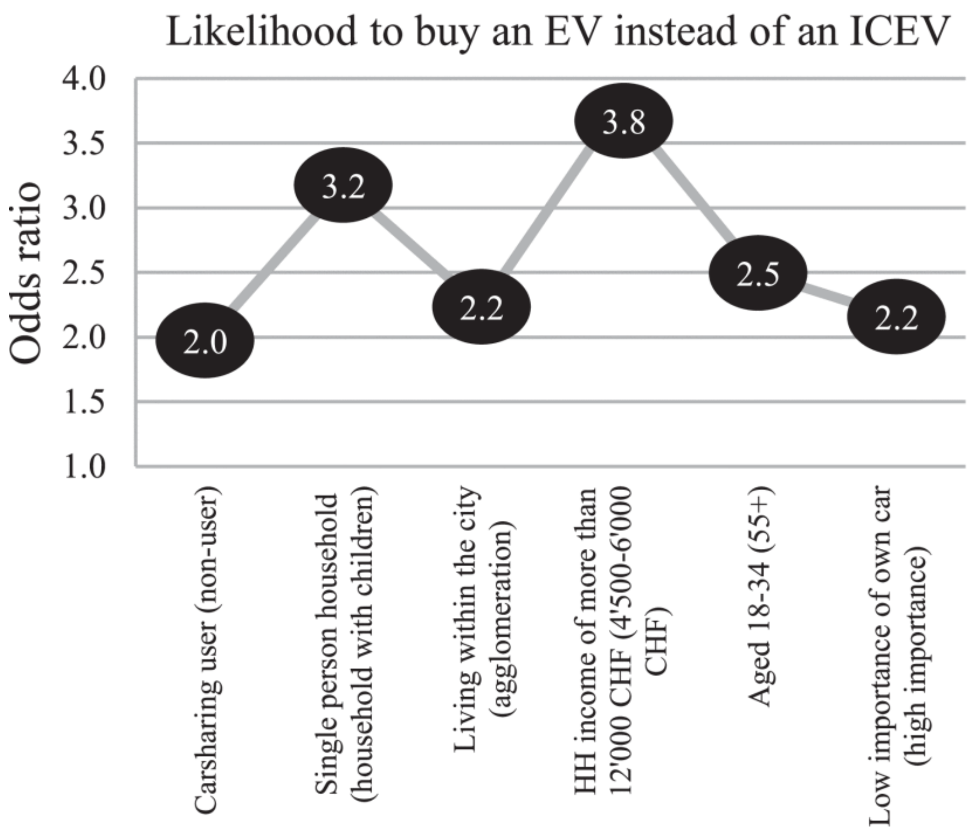


Figure 2: Odds ratio of variables significantly influencing the likelihood to choose an EV instead of an ICEV.

Most importantly, those participants who use carsharing are two times more likely to buy an EV (odds ratio of 2.0). In addition, participants who see low importance in owning a car are more likely to buy an EV. Further, HHs who have the following attributes are more likely to by an EV: being a single person household as opposed to households with children, living in cities instead of agglomerations, income of above 12'000 CHF per month compared to a medium income of 4'500-6'000 CHF and younger individuals. This result suggests that carsharing user exhibit characteristics that go beyond pro-environmental, socio-demographic and mobility characteristics influencing powertrain choice, as we have controlled for these effects in the model.

The findings suggest that when a situation arises where one considers buying or replacing a private car, carsharing users are in favour of EVs. If this behaviour is linked to the exposure to carsharing, the uptake of EVs might be expanded by the provision of carsharing services. However, if instead people attracted to carsharing are open to buying an EV in the first place, then this would distort our findings. We tried to account for these latent effects by including a variety of sociological and psychological variables. With 60% of variance explained in the regression model, we are confident that carsharing experience could indeed lead to an increased openness to EV. This result could provide important levers to decision-makers and transport planners as carsharing experience could foster a more sustainable mobility lifestyle. By supporting access to carsharing, the attitude of the population towards EVs might be changed positively. With further strategies, like information campaigns discussing the mutual relationship between carsharing and EVs, this lifestyle change could be accelerated. In terms of assessing the potential environmental benefits, which may be obtained through carsharing, the results raise another question: could experience with carsharing motivate to buy a car for HHs currently not owning a car and, as such, increase private car ownership? While we do not see such an effect in our study, other researcher argue that especially for car-savvy people, carsharing could act as a "gateway drug" (Giesel and Nobis, 2016). Within our study we see that those who use carsharing and see a high importance of owning a car, are mostly already owning at least one car. Only 3% do currently not own a car within this group, indicating that a shift from these 3% to car ownership would be negligible. The potential increase in alternative vehicles may even be fostered by encouraging those not using carsharing and exhibiting a low importance of an own car, to adopt carsharing. More than 60% of this group are car owners, who may in the future avoid buying a car thanks to carsharing (Martin et al., 2010) or replace the current car by an EV due to the increased openness shown in our study. This group is further characterized by the highest value in planning to reduce car use and strong biospheric values, signaling a large potential for the adoption of sustainable alternatives such as carsharing or small EVs, respectively.

Within this paper we elaborated the interplay between carsharing experience and powertrain choice through an online questionnaire. We demonstrate that carsharing users show a two times higher likelihood to purchase an EV instead of an ICEV compared to non-carsharing users. By controlling for a variety of sociological and psychological variables, we argue that carsharing experience might be a lever for increasing the diffusion of EVs. Still, for a better accountability of latent effects, further research including questions about motivations joining a carsharing system is required. Especially by focusing on a representative sample of heavy carsharing users, future studies could provide important additional insights to our results. Even though we did not see an increase in the decision to buy a car for carsharing users who currently own no car, such rebound effects need to be carefully considered when planning carsharing services. Moreover, further research into car size choice among carsharing users and non-users to provide better insight about the sustainability potential of conventional carsharing is also needed.

4.1.2 Car- and ridesharing (study 1 and 2)

In the EU-funded project Smart Commuting we investigated the openness of various stakeholder in the three case areas of Switzerland, Austria and Finland to support different sharing services like shared autonomous vehicles, carsharing and MaaS through a mix of online surveys, expert interviews and workshops.

The survey participants were asked to give their personal opinion on these innovations in commuting, i.e., whether they support, approve, or oppose these innovations. Figure 3 summarizes the share of answers to the online survey for each participating country and stakeholder regarding their openness to these sharing services.

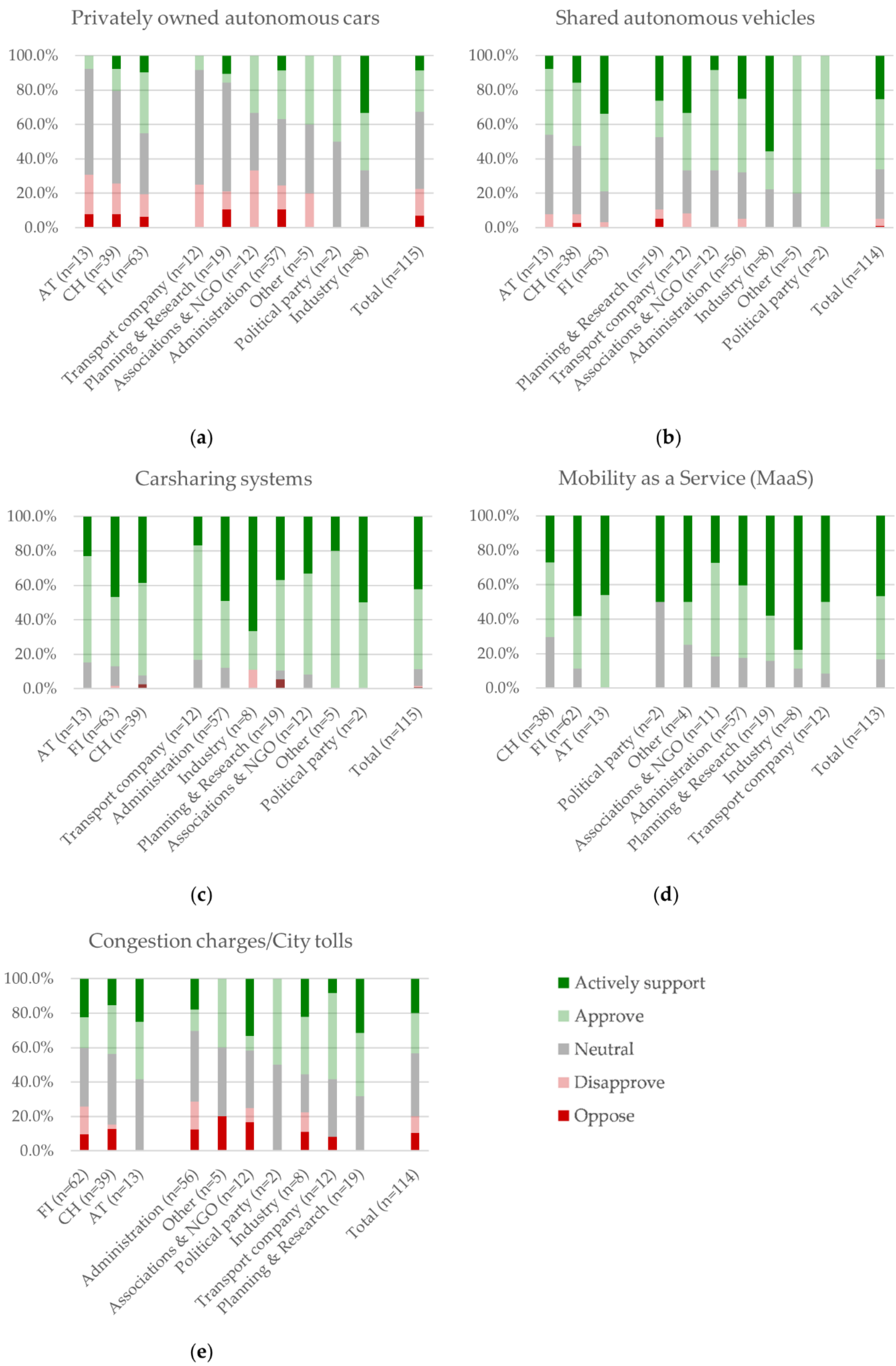


Figure 3: Openness of stakeholders regarding different innovations in commuting.

Stakeholders from all three case areas are rather opposing and skeptical towards the innovation 'Privately owned autonomous cars'—with the exception of people from industry. The high skepticism especially of stakeholders from transport companies, associations, planning and administrations leads to the assumption that these expect negative consequences for the transport system and an adverse sustainability effect if this innovation thrives. This result is not surprising, taking into account the fact that those autonomous cars could lower the price of individual motorized mobility and increase the number of cars on the street due to optimized traffic flows (Wadud et al., 2016). Additionally, the possibility for work or entertainment while traveling might lead to higher tolerance of even longer commuting distances as compared to today. However, our study shows (study number 7), that in Switzerland, the risk of urban sprawl through autonomous commuting is deemed to be small.

Carsharing systems are approved by all stakeholders and countries, with only little variance. In general, Finnish stakeholders seem to be quite in favor of innovations in commuting, and as such, see the surveyed innovations more positively than do the Swiss or Austrian stakeholders. However, regarding innovations that restrict or limit accessibility (push-measures) like 'Congestion charges', they are more on the opposing side.

In order to assess the general openness of stakeholders to innovations, the difference in openness to the various innovations, compared to the mean value among all stakeholders, is depicted in Figure 4. Administrations and associations & NGOs show a below average enthusiasm towards the investigated innovations. As the stakeholder category 'Administration' was the most represented one among all of the stakeholders, this aversion to innovations could be a major obstacle for the diffusion of new technologies. Especially concerning city tolls, administrations are strongly below average (15%). While the remaining stakeholders do have a rather average openness towards charges and city tolls, 'Planning & Research' is the counterweight with 24% above average openness.

The stakeholder category 'Industry' shows an above average enthusiasm towards the surveyed innovations, indicating that these types of stakeholder are likely to cooperate when implementing new mobility solutions. Even concerning the push-measure 'City toll', an average openness can be found. Interestingly, the biggest spread of openness between the stakeholders can be found for autonomous vehicles, yet for shared autonomous vehicles the stakeholders seem to have a more common view, and therefore less variance in the openness.

Finally, the openness of the stakeholder category 'Transport Company' does not differ strongly from the average, despite for autonomous cars, where they do clearly less support this innovation. Considering that such new mobility offers may disrupt the traditional mobility market, where stakeholders belonging to this category are likely to be currently active, the result reflects the expectations of the authors.

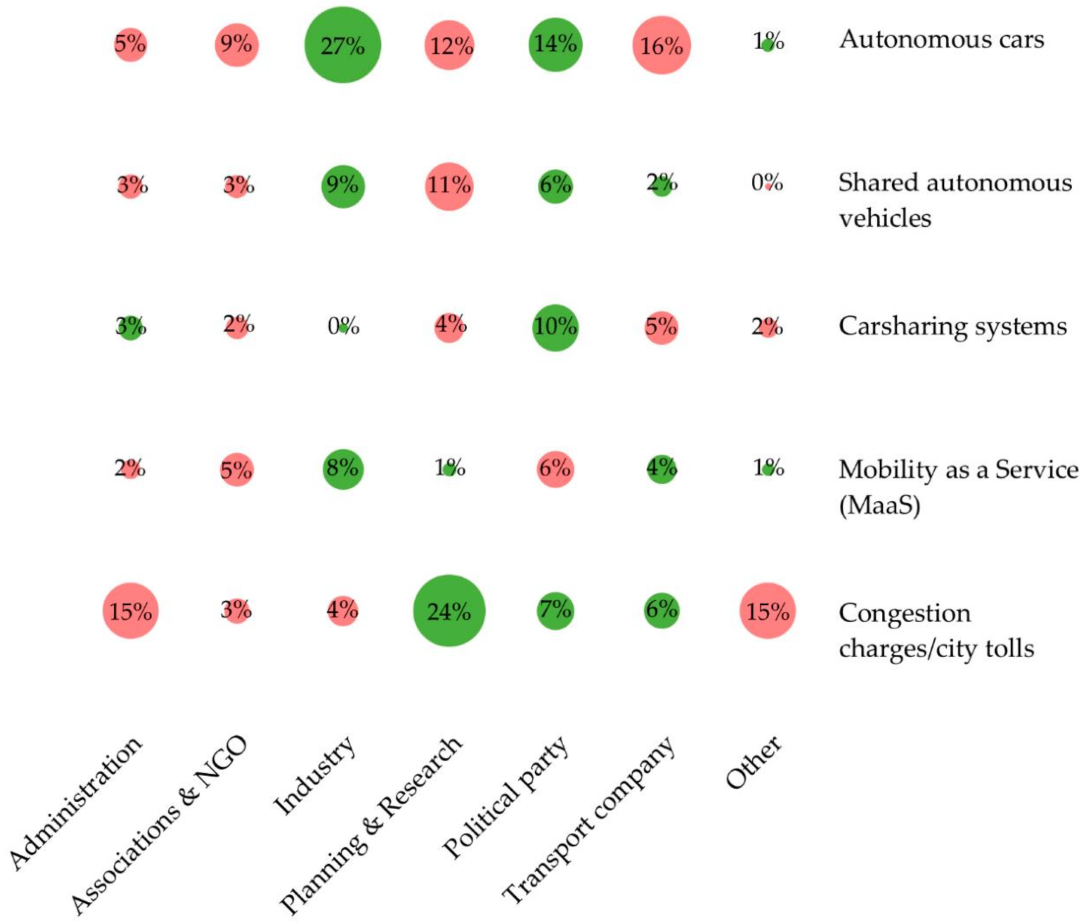


Figure 4: Deviation from the mean openness to the different mobility innovations.

We further investigated the openness to car- and ridesharing of commuters to and from Basel, Switzerland through an ordinal logistic regression analysis.

The results of the ordinal logistic regression analysis with the dependent variable openness to car-/ridesharing suggests that the openness to these sharing modes mostly depends on age, gender and the interaction between gender and mode choice ($p < 0.05$). A trend ($p < 0.1$) towards more openness to car-/ridesharing with lower incomes is also present in the data. Other factors, such as household size, location of residence or commuting distance, were not found to have a significant influence.

The Wald chi-square statistic implies that age is the strongest predictor of openness to car-/ridesharing, followed by gender and the interaction of gender and mode choice. The odds ratio of age is 0.96. Thus, a one-unit increase in age leads to a 4% decrease in likelihood to demonstrate a higher level of openness for car-/ridesharing and, hence, underlines the findings from (Sioui et al., 2013) that younger commuters are significantly more open towards these mobility options. Gender interacts with mode choice and, therefore, the odds ratio has to be calculated separately by taking the exponent of the sum of B values corresponding to the interaction. This leads us to the following results: male commuters using multimodal modes are 6.2 times more likely to demonstrate a higher level of openness to car-/ridesharing than their female counterparts. Likewise for public transport (by a factor of 5.1) and active modes (by a factor of 5.1). Yet for private motorized transport, the odds ratio of male/female is 0.6, defining the interaction. Figure 5 depicts this phenomenon in a graph with the y-axis representing the average openness score (from 0 “not open” to 2 “open to both car-/ridesharing”) and gender on the x-axis.

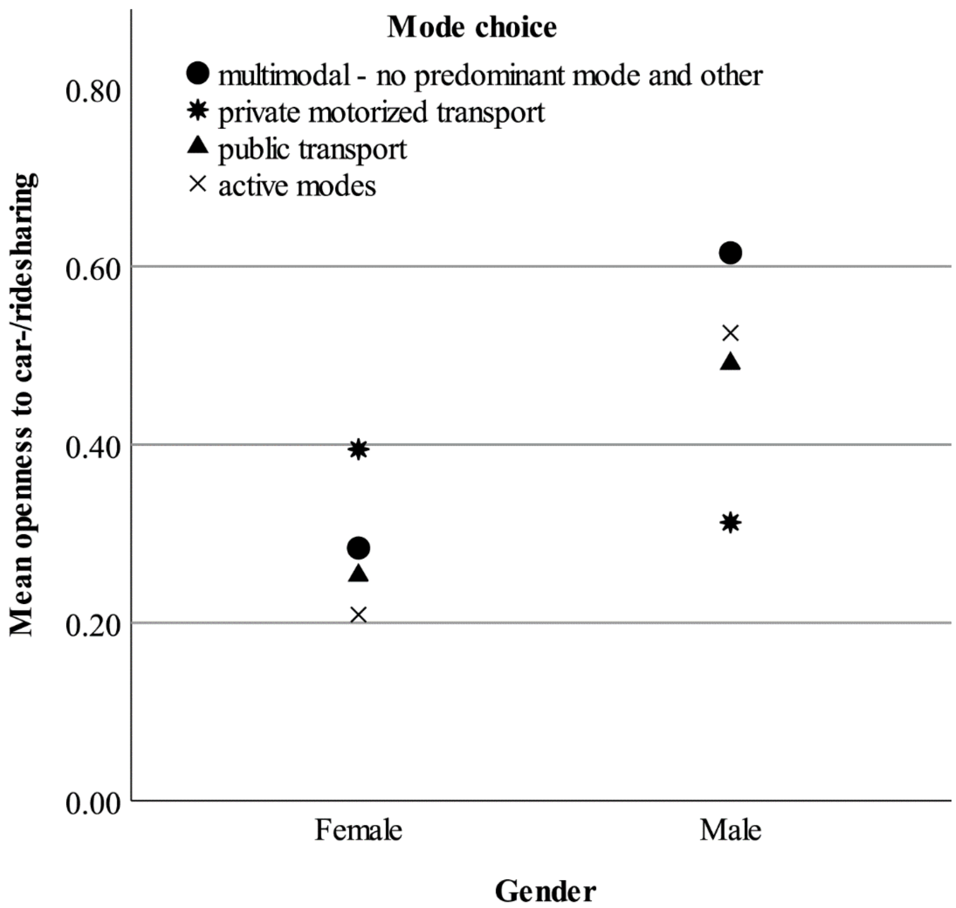


Figure 5: Interaction between gender and mode choice regarding mean openness to car-/ridesharing.

This effect might be explained by male travellers still seeing the private car also as a status symbol. This leads to a reluctance to share or even not owning a car, which might be less important for women. At the same time, women dominantly using public transport, active or no predominant mode for commuting are less inclined towards sharing a car. Polk (2004) investigated whether a car as a status object influences car use for men and women, finding a significant influence for men but no effect for women and underscoring our results. Lastly, the income of commuters gives a further indication whether or not the person is open towards car- and ridesharing, as those participants with below-average income tend to be more open to use such offers.

4.1.3 Mobility-as-a-service (study 4)

MaaS is a relatively new concept. One of the first comprehensive descriptions of it is presented in a study by Hietanen (2014). He summarizes the function of MaaS as a "mobility distribution model in which a customer's major transportation needs are met over one interface and are offered by a service provider" (Hietanen, 2014, p. 3). Heikkilä (2014) further popularized the term MaaS, spreading the notion across the personal transport sector. The core idea is to integrate various transport options into a single mobility service through a digital interface. It is accessible on demand and thus supposed to increase the flexibility of public transport as well as provide alternatives to the private car (MaaS Alliance, 2021). The digital interface, a medium commonly used with smartphones or web pages, allows trip planning, booking, ticketing, payment and real-time information provision that can be personalized and customized to meet the end users' needs (Jittrapirom et al., 2017). The transport options offered within MaaS are not limited to public transport but aim to include taxis, carsharing, ridesharing, and bike-sharing as well as other forms of mobility services.

This also allows for a multi-modal approach to mobility in which various trip options are available to the user, who can then make choices based on personal needs. A comprehensive overview of MaaS definitions is provided by Sochor et al. (2018).

At the time of writing, only a limited number of studies have considered the openness of the general public to using MaaS. Sochor et al., (2015) examined users' motives for using the UbiGo service – a MaaS project that has been trialled in Gothenburg – before and after they took part in a six-month field operational test. They conclude that the users' predominant motive before taking part in the trial was mainly curiosity, indicating that MaaS users could be considered early adopters (Sochor et al., 2015). During and after the experiment, the participants had the possibility to test living without a private car. Following that, the motives convenience and flexibility increased substantially in contrast to the motives indicated before participating in the field test. The aim of city planners and the government to reduce private car usage converge with the results of this MaaS field test since the participants rated their use of carsharing and rental services as more frequent and their attitudes towards these services as more positive than before. Similarly, Matyas and Kamargianni (2019) find through a stated preference survey covering the Greater London area that respondents, once decided for a MaaS bundle, would be willing to try sharing modes previously not used. However, Sochor et al. (2015) also identified issues that would need to be addressed for a successful implementation of MaaS. These include the possibility of making a profit, service providers losing their brand exposure (as they were all summarized under UbiGo), defining a payment procedure that suits low-income households, uniting already available travel services and issues related to smartphone technology, such as battery life, network access and proof of a valid ticket.

A new study by Schikofsky et al. (2020) investigated the role of values in acceptance of several different hypothetical MaaS plans, finding that a mix between communicating functional benefits and emotional values would be most effective. Also the feeling of being related to an associated user group could spur adoption.

Ho et al. (2018) conducted a stated choice study of 252 individuals in Sydney, Australia, to investigate the uptake and willingness to pay for MaaS (the transport options included public transport, carsharing, taxi and UberPOOL). In their study, the frequency of current car usage significantly influenced the potential uptake level, with the frequent car user (three or 4 days per week) being most open towards MaaS, the infrequent car user (one or 2 days per week) slightly less so, the very frequent car users (five to 7 days per week) exhibiting below average openness and the car non-users being the least likely adopters. Furthermore, participants aged between 35 and 44 showed a significantly higher likelihood of subscription to the MaaS scheme as opposed to their younger (18–24 years) and older (55 years or above) counterparts. This result doesn't reflect the generally higher openness of the younger generations to using new mobility concepts like carsharing or ridesharing commonly found in other studies (Münzel et al., 2019). The only other demographic influence that has been found is the number of children in the household, where households with two or more children were significantly less likely to subscribe to MaaS than households with only one child or none. Building on this research, Ho et al. (2019) conducted a similar stated choice analysis in Tyneside, UK comparing the new results to study previously done in Sydney. They find similar motives and barriers for the uptake of MaaS yet the actual adoption level strongly depends on local public transport and sharing offers. MaaS travel bundles customized to the travel needs would be key for adoption. Generally, MaaS plans including public transport are strongly preferred over plans with only sharing offers (e.g. bikesharing, carsharing) (Matyas and Kamargianni, 2018). Availability of child seats, reliability and security were some of the reported caveats with carsharing within a MaaS bundle (Matyas and Kamargianni, 2018).

We conducted an online survey with 995 participants from Switzerland (within SHEDS) to understand potential user needs as well as factors that would motivate the use of MaaS. By specifically focusing on three major trip purposes (commuting, weekday leisure and weekend trips) we add relevant findings to the literature. Figure 6 shows the percent of persons willing and not willing to use MaaS for commuting, weekday leisure and weekend trips.

Sixty-two per cent of the “commuting” group, 53% of the “weekday leisure” group and 46% of the “weekend leisure” group were unwilling to use MaaS for commuting, weekday leisure trips and weekend leisure trips, respectively. To better understand the reasons and needs that would motivate them to use such a service, we posed an open-format question. The respondents were asked to specify what characteristics such a combined service would need to have in order to make them willing to use it for the said purpose (either commuting, weekday leisure trips or weekend leisure trips). The results are shown in Figure 7, in which, from the answer totals of 217 (commuting), 269 (weekday leisure) and 240 (weekend trip), those related to being more ecological, usable without a smartphone, more comfortable, usable without a driving license, wheelchair accessible and promoting active mobility were mentioned too few (fewer than 10 times) and were thus excluded from Figure 7. The answers provide insights into the specific needs of the society concerning this new mobility service, thus supporting decision-makers and transport planners in the design and implementation of related proposals.

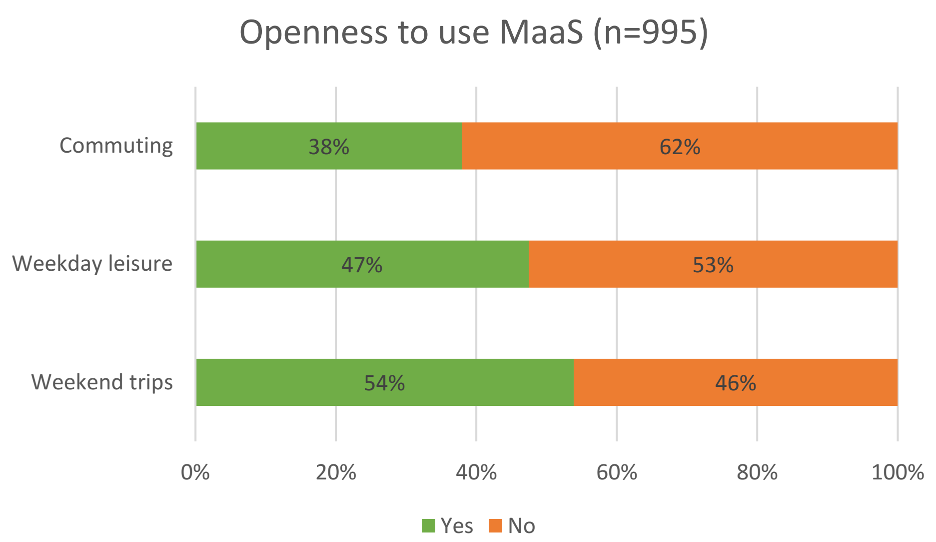


Figure 6: Percent of respondents being open to use MaaS for the three different trip purposes.

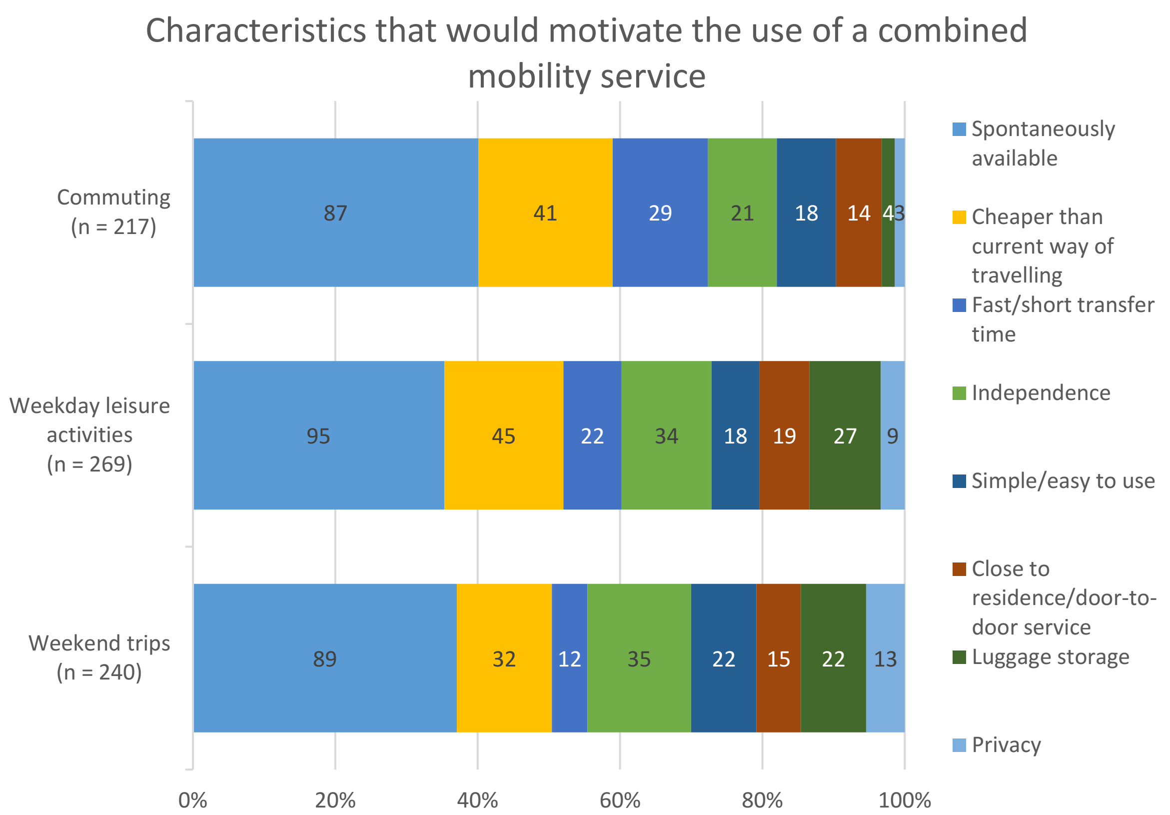


Figure 7: Characteristics that would motivate the use of a combined mobility service for each trip purpose.

We further adopted three binary logistic regression models to test relevant factors, which could increase the likelihood to be open to use MaaS for commuting, weekday leisure and weekend trips. We find that openness to using MaaS for commuting is lowest. Still, those who plan to reduce their car usage might be motivated to switch to a seamless travel service if it is sufficiently flexible and fast. For leisure activities, on the other hand—for which most people use their private car—a different set of factors is relevant. Here, higher education and previous experience with carsharing significantly increased openness to using MaaS. Further, the participants see MaaS as a sustainable alternative; as such, pro-environmental attitudes as well as announcements of future consumer-addressing policy measures would increase openness to use. Generally, participants that predominantly use public transport for travelling are more open to using MaaS than those who predominantly travel by private car. This result implies some challenges for one of the core expectations of MaaS—to reduce private vehicle ownership. We would thus encourage an increased focus on this group as well as develop MaaS services that target the following three key commuting needs: spontaneity, lower costs and short transfer times. For leisure trips (both weekday and weekend trips), we emphasize not only looking at spontaneity and lower price but also independence and luggage storage possibilities.

Overall, we conclude that providing information and experience is key in designing such combined mobility services. Future studies should pay attention to the differences in needs and motives for using MaaS for commuting and leisure trips. Once MaaS services become more widely available, large-scale surveys could benefit from a more established technical jargon that could mitigate biases due to misunderstandings. Furthermore, MaaS also benefits from the increasing popularity of sharing systems such as car-, bike- and scooter-sharing. Having some experience with such programs has been shown to increase openness to using

MaaS. As MaaS is still in its infancy, preferences might continuously change, calling for regular research into these preferences and the needs of potential users.

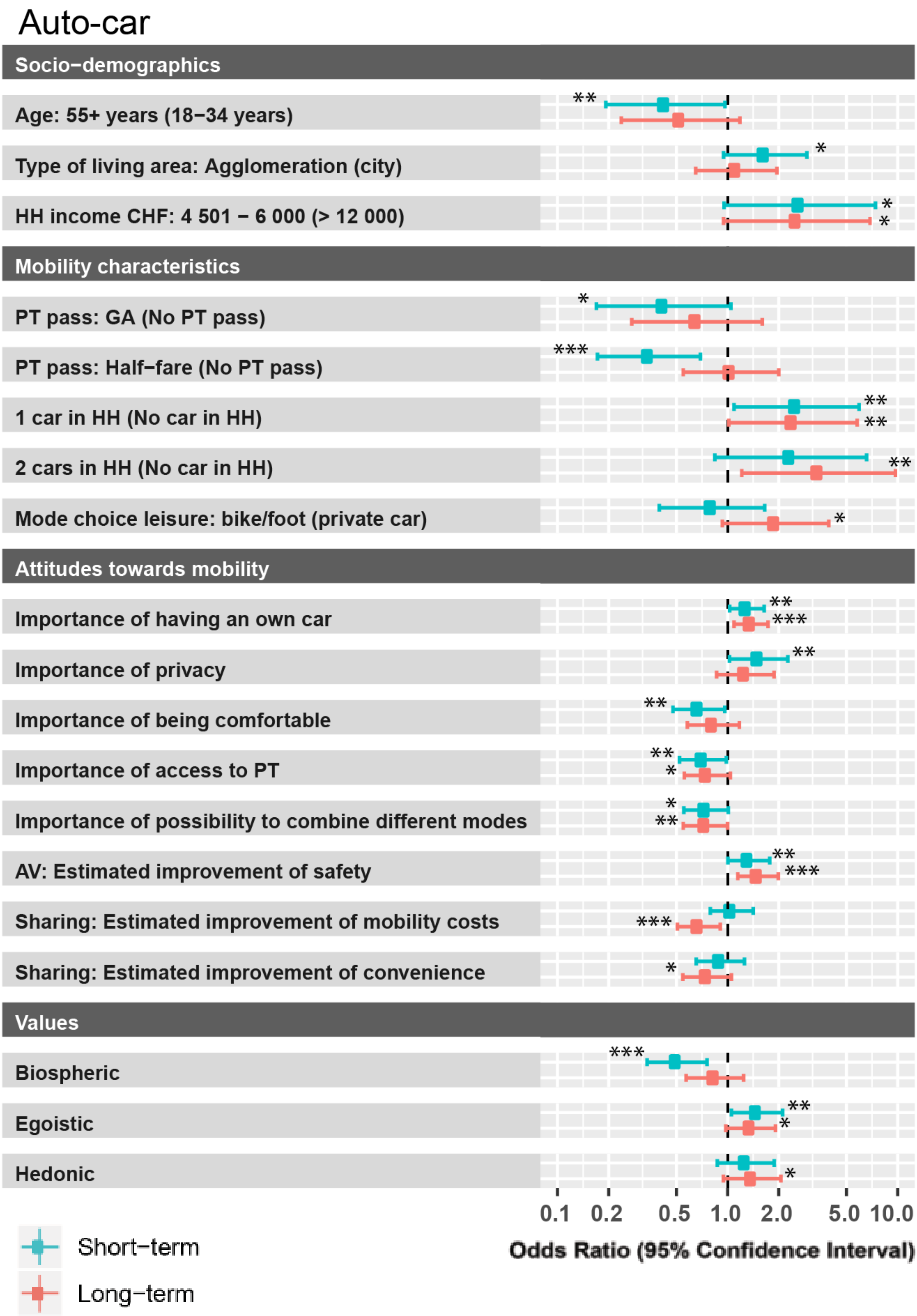
4.1.4 Autonomous vehicles (study 3, 6 and 7)

Since scholars point to potential negative sustainability effects of autonomous driving like decreased transportation costs (Bösch et al., 2018), which in turn could result in more driving, the emergence of empty driving (Kröger et al., 2019) or the access for the non-driving population like children and people without driving license (Harper et al., 2016), we focused on the adoption of pooled-use AVs. Hence, we implemented a choice experiment in the SHEDS survey 2018 covering auto-cars, auto-taxis and auto-shuttles for short-term (mode choice for a typical trip) and long-term (car purchase or subscription to services) decisions (refer to study 3 and 6 in Table 1).

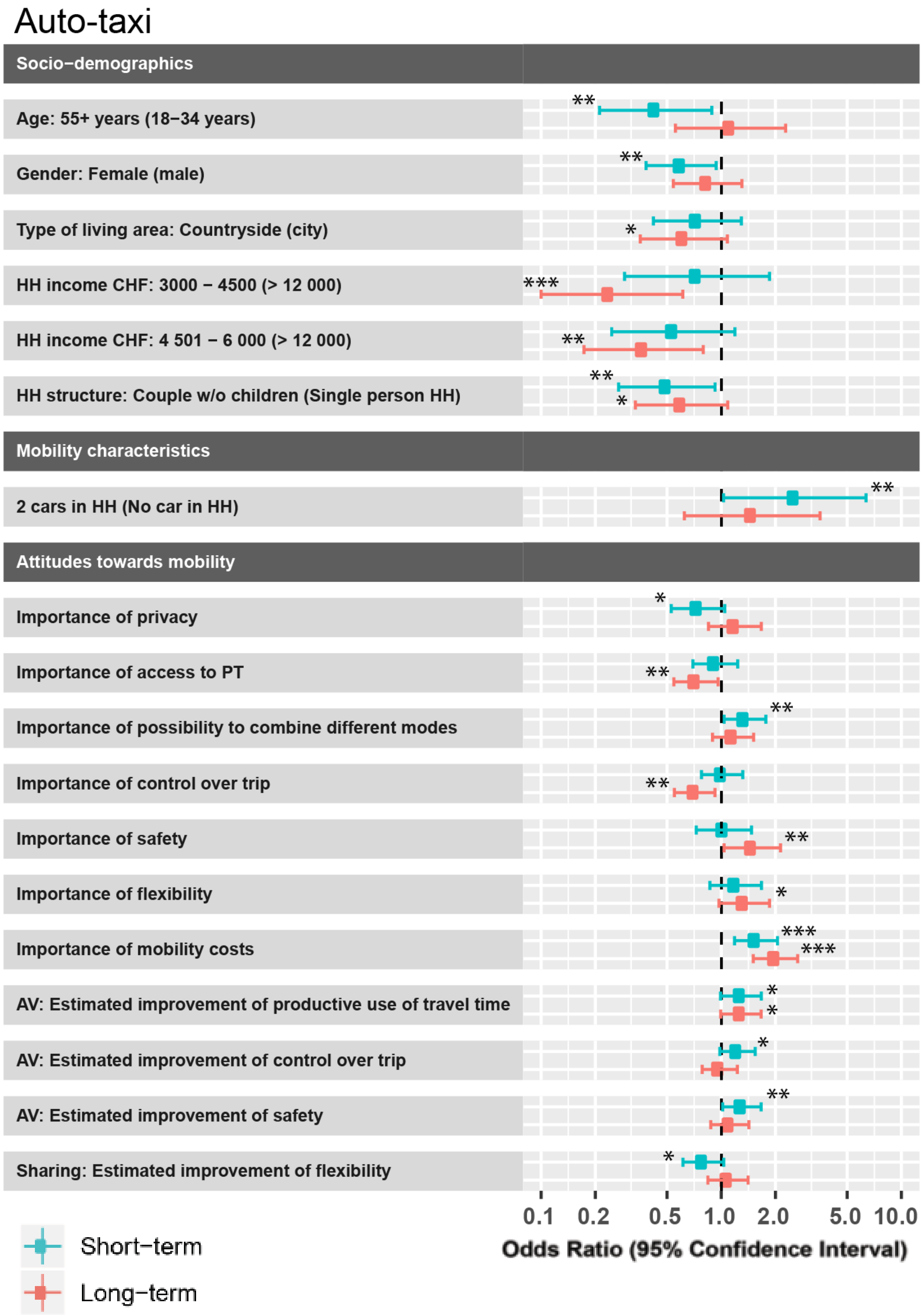
Results for whether users are likely to choose pooled modes for a typical trip, partly support the presumption made in many AV simulation studies. In the baseline condition, 61% of respondents rated their likelihood of choosing either a pooled-use auto-taxi or the auto-shuttle/train combination as higher than their likelihood of choosing a privately owned auto-car. However, 39% of the respondents still preferred the privately owned auto-car option or were indecisive. Thus, compared to findings from previous experiments, this research found a higher acceptance rate for shared AV (SAV) services. In comparison, Krueger et al. (2016) found a 13% adoption rate of pooled AVs in a choice set which included conventional cars. We find similar findings for long-term mobility decisions. Sixty-five percent of Swiss users, asked to reconsider their transportation mode choice in response to relocation, estimated their likelihood of subscribing to online auto-taxis platforms or purchasing a general public transport pass with auto-shuttle door-to-door service as higher than their likelihood of purchasing an auto-car. Overall, the majority of responses supports the presumption of public acceptance of pooled-use SAVs.

Investigations related to the test of instruments that influence choice factors related to comfort, cost, and time, yielded mixed results. For short-term mobility decisions, almost all instruments generated effects in the expected direction. Public transport cost reductions, kilometre-based taxes for auto-cars, reduction of available parking spaces, and combined instruments addressing comfort, cost, and time were among the highly effective instruments. Instruments aimed at the choice-relevant parameters identified in the literature, travel cost, waiting time, and travel time, produced significant effects, though the last was only tested in combination with other improvements to public transport. Our research suggests that comfort factors like reliability are also important factors affecting mode choice. We found fewer significant instruments aimed at factors relating to long-term mode decisions, and those instruments produced generally weaker effects throughout the experiment. Instruments designed to encourage a reduction in auto-car purchases yielded relatively small effects. Instruments that reduced subscription prices or combined improvements related to comfort, cost, and time resulted in the most significant changes in rate of acceptance, with users reporting increased likelihood of subscribing to an auto-taxis platform or purchasing a general public transport pass. However, these instruments did not affect users' likelihood of purchasing an auto-car any more than did the corresponding instruments designed to influence short-term decisions. Introduction of the instruments was not sufficient to induce Swiss users to give up auto-car ownership. This observation might partially call into question the stronger effects of the instruments on short-term mobility decisions since long-term decisions influence daily mode choices (Beige and Axhausen, 2012). In general, instruments increasing the attractiveness of pooled modes were more effective when they combined pull measures on comfort, cost, and time, and when they were introduced along with push measures away from auto-cars. Such push-and-pull measures will be highly relevant for encouraging pooled-use SAVs. This result could also be interpreted as calling into question current transportation policies intended to reduce greenhouse gas emissions. Transportation policies are often focused only on increasing the attractiveness of public transport, without introducing complementary push measures to discourage car traffic. For the introduction of AVs to substantially contribute to decarbonizing transportation, instruments including push strategies will be needed to foster a high level of support for pooling and reduced dependence on auto-car use.

In study 6, we further tested the drivers for utilizing private and pooled-used AVs regarding socio-economics, mobility characteristics, attitudes and values. Figure 8 summarizes the binary logistic regression results on the likelihood to be open to adopt auto-car, auto-taxi and auto-shuttle



Auto-car
Socio−demographics
Age: 55+ years (18−34 years)
Type of living area: Agglomeration (city)
HH income CHF: 4 501 − 6 000 (> 12 000)
Mobility characteristics
PT pass: GA (No PT pass)
PT pass: Half−fare (No PT pass)
1 car in HH (No car in HH)
2 cars in HH (No car in HH)
Mode choice leisure: bike/foot (private car)
Attitudes towards mobility
Importance of having an own car
Importance of privacy
Importance of being comfortable
Importance of access to PT
Importance of possibility to combine different modes
AV: Estimated improvement of safety
Sharing: Estimated improvement of mobility costs
Sharing: Estimated improvement of convenience
Values
Biospheric
Egoistic
Hedonic
0.1 0.2 0.5 1.0 2.0 5.0 10.0
Odds Ratio (95% Confidence Interval)
Short−term
Long−term



Auto-taxi
Socio−demographics
Age: 55+ years (18−34 years)
Gender: Female (male)
Type of living area: Countryside (city)
HH income CHF: 3000 − 4500 (> 12 000)
HH income CHF: 4 501 − 6 000 (> 12 000)
HH structure: Couple w/o children (Single person HH)
Mobility characteristics
2 cars in HH (No car in HH)
Attitudes towards mobility
Importance of privacy
Importance of access to PT
Importance of possibility to combine different modes
Importance of control over trip
Importance of safety
Importance of flexibility
Importance of mobility costs
AV: Estimated improvement of productive use of travel time
AV: Estimated improvement of control over trip
AV: Estimated improvement of safety
Sharing: Estimated improvement of flexibility
0.1 0.2 0.5 1.0 2.0 5.0 10.0
Odds Ratio (95% Confidence Interval)
Short−term
Long−term

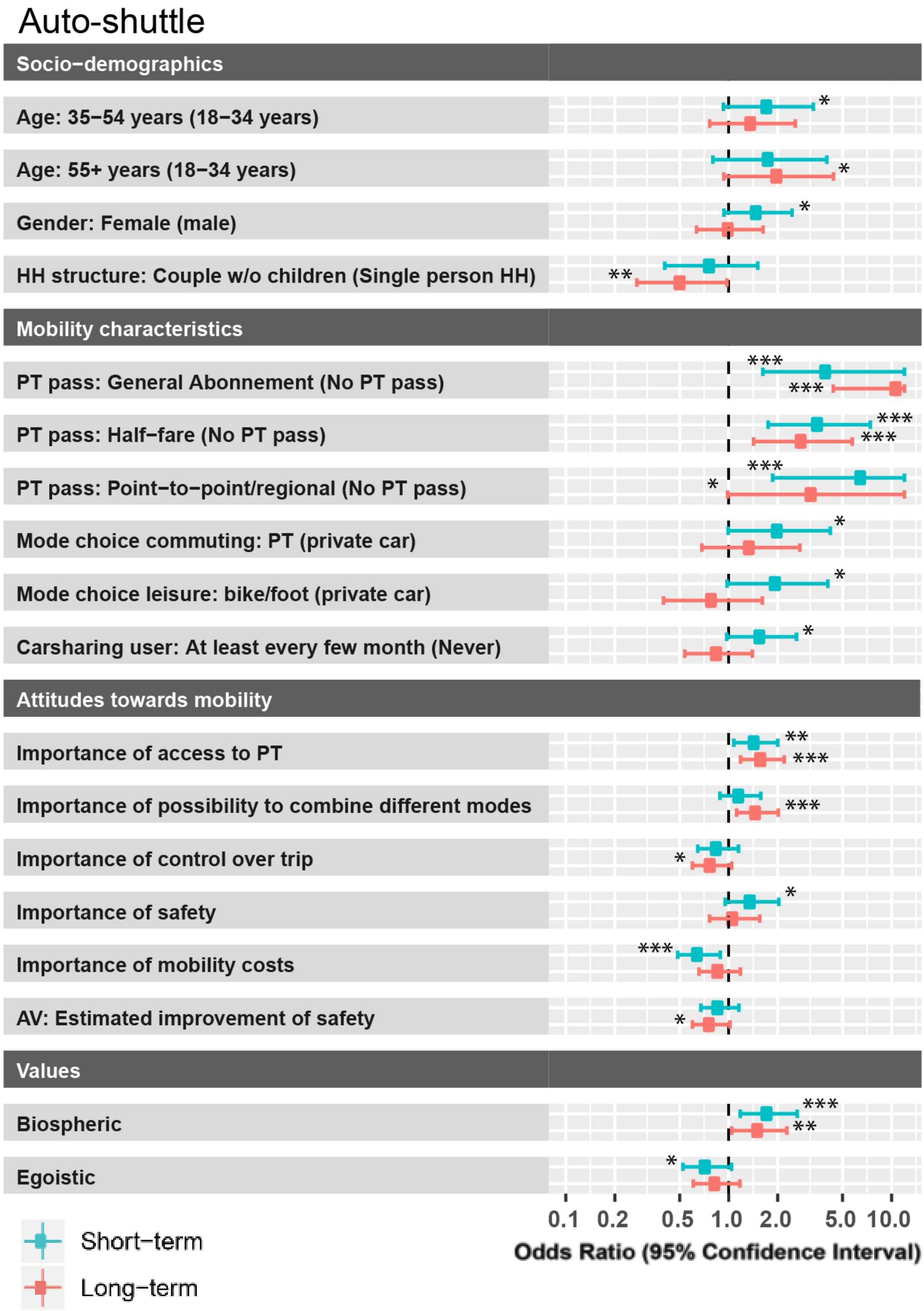


Figure 8: Binary logistic regression results on the likelihood to be open to adopt auto-car, auto-taxi and auto-shuttle.

The literature on AV and sharing is not univocal in terms of the socio-demographic situation (age and gender) of users. Our results suggest that younger respondents tend to stick to auto-cars and auto-taxis, whereas older respondents prefer a more transit-oriented mode of AVs. Further research is required on whether the different evaluation of taxi- or shuttle-oriented forms of pooled-use AV is systematic. Pakusch et al. (2018) observed that women have a weaker tendency to shift from public transport to automated sharing. Our results are consistent with this observation, identifying women as being more hostile toward auto-taxi adoption. We capture a very interesting effect regarding income. Higher-income groups seem to have a preference for subscription to auto-taxi sharing platforms. Whereas the current literature suggests the relationship of higher income and higher auto-car use (Pakusch et al., 2018), our result could indicate that auto-taxis are attractive for other user groups currently not primarily associated with sharing. This finding requires further testing in future research. Analysing current mobility characteristics, we find for auto-car and auto-shuttle options that respondents prefer remaining within their current mobility system in an AV future, which is in line with the results from the meta-analysis conducted by Whittle et al. (2019). However, we find no mobility characteristics explaining systematically the adoption of auto-taxis.

To the best of our knowledge, our study links an extensive set of attitudinal data with an experiment on AV adoption for the first time. Our exploratory analysis identifies different classic associations, such as the importance of having an own car being related to auto-car use. However, the observation on mobility costs is important, suggesting a shift from automated public transport to auto-taxis for respondents stating the high importance of this attribute. The cost structure of our experiment was chosen based on the work of Bösch et al. (2018), who suggested that auto-taxis are very likely to become the cheapest mode of transportation in the future. We observe that cost-sensitive respondents find auto-taxis an attractive transport mode, motivating them to shift away from (automated) public transport. This effect could be intensified in relation to the study of Pakusch et al. (2018), who observed a similar trend for a different reason. Furthermore, our study analyses values for the first time in the context of pooled-use AV adoption. In this context, we can confirm the classic observation that a high share of biospheric values is negatively related to individual modes (auto-cars) and positively related to public modes (auto-shuttles). Conversely, egoistic values are more linked to auto-car use. However, we do not find any value characteristic to provide an explanation for auto-taxi adoption.

Finally, in study 7, we investigated whether autonomous cars in commuting could lead to urban sprawl in Switzerland by analysing the Swiss Mobility and Transport Microcensus, a nation-wide travel survey conducted every five years. The aim was to identify what part of the population may use travel time for working purposes and, ultimately, lead to urban sprawl through the acceptance of longer trips.

With 24 percent of the total car commuter population suitable to actively use the travel time for work, we see a low risk in increased urban sprawl from autonomous commuting. It is important to consider, in this context, that many different factors influence housing location choices (e.g. family status, availability of leisure activities (Thomas et al., 2015)), the potentials of autonomous commuting being only one further possible element.

Since there is little experience with automated driving yet, we acknowledge the uncertainty in some of the assumptions made. We do not know yet if there will be a major mode shift to autonomous cars from people previously using public transport. However, the general trends and focus of sustainable mobility planners lies in car-free households and strengthening public transport, within a general push for urbanization. Moreover, while there are expectations for AVs to conquer the market in the long-term, the rate is uncertain due to policy aspects and the potentially negative effects of mixed traffic. One further important assumption in the discussion above concerns the professions suitable to work in an AV. Sectors based on office work could increase in the future with further digitalization of the economy. This would mean that, potentially, more people would be involved in jobs requiring activities, which could be done in a moving car. However, when including the share of trips on the highway or major road in the picture and considering that many jobs like service delivery, construction work or maintenance will still be needed in the future, we estimate this effect to remain small. Furthermore, not all people having professions we defined as suitable for working in an AV will exploit this possibility. Similarly, some people from categories defined not suitable may find some tasks suitable to be performed in an AV. All in all, one could expect the overall effect to level out. Another assumption was that only streets without too many curves and uneven surfaces (highways and other major roads) would be suitable to work while commuting due to travel sickness issues. While some ideas to counteract this problem are already in development, see for example Kuiper et al. (2018), it is not known yet how effective and compatible these measures will be with an extensive use in the car. We further assumed that commuting time does not affect the possibility to work within an AV. In reality, however, only a share of working tasks can be done within a limited time range and it is not clear whether or not commuters would start working unless the trip duration exceeds a certain time. The share of trips driven on highways or other major roads between the countryside and the city/agglomeration exceeding five, 10 and 15 minutes are shown in Table 2. If we introduce the assumption that it would only make sense to start working on trips longer than five, 10 or 15 minutes, the number of trips suitable for working reduces significantly.

Table 2: share of trips driven on highways or other major roads between the countryside and the city/agglomeration.

	Total population suitable to work
Share of trips exceeding five minutes	21%
Share of trips exceeding 10 minutes	19%
Share of trips exceeding 15 minutes	15%

We conclude by observing that there seems to be a common agreement that a shared and pooled autonomous fleet would be beneficial over private autonomous vehicles in many aspects (Fagnant and Kockelman, 2018; Zhang et al., 2015). It should be noted, however, that the assumption of a lower value of travel time in AVs should then be made with further care, since the range of suitable working tasks or activities might be reduced when sharing the same car with other commuters.

4.2 Governance innovations

4.2.1 Mobility management (study 1)

As of today, very few numbers of peer-reviewed papers consider the attitude of stakeholders and experts in new sustainable commuting technologies. Roby (2010) for example, emphasizes the uptake of organizationally embedded travel plans by companies to support the sustainable commuting of their employees. Yet, Willamowski et al. (2014) discovered challenges for the public administrators in supporting such travel plans, as each organization has their own specific resources, needs and motivations. Still, local governments are found to be open towards new ways of promoting sustainable commuting, as well as providing workers a better commuting experience (Castellani et al., 2014). Nevertheless, decision-makers in companies and transport planners in administrations need valid reasons to implement sustainable commuting strategies. A crucial factor is the return on investments. Robèrt (2017) thus underlines the importance of a holistic approach focusing on all employee travel options, together with cost-benefit assessments of these options so to illustrate the potential savings of expenses.

In order to increase consensus building in transportation planning and adopt sustainable commuting strategies, Cascetta et al. (2015) propose a decision-making model. Therein, a transparent, cognitive and rational decision making should be combined with stakeholder engagement and a quantitative analysis. Le Pira et al. (2016) further stress the importance of public participation in combination with the aforementioned stakeholder engagement in transport planning.

The acceptability of mobility management strategies within a university campus in Catania (Italy), such as parking management, has been investigated by Le Pira et al. (2016) using agent-based modelling. They find that preliminary knowledge on stakeholders' opinions can foster the emergence of consensus. Similarly, Giuffrida et al. (2019) propose a participatory approach in decision making related to transport decisions. By using Public Participatory Geographic Information Systems (PPGIS), a web-based map can provide easy access to information for a wider public, including stakeholders as well as citizens. Within PPGIS, any potential spatial effects of planned mobility projects can be visualized and provide a platform for interaction and decision-making. PPGIS have been found to be a valid aid for transport decision-makers (Giuffrida et al., 2019).

In our study within the EU project Smart Commuting (study 1) we derived the characteristics that a mobility management needs to have in order to be successful and leverages its full potential in fostering sustainable commuting. Five expert interviews in Switzerland were organized to yield insights into the extent of how companies can profit from and incorporate new mobility services. All interviewed experts are active within the field of mobility management in companies or similar.

- Interview 1: Representative of a public-transport company
- Interview 2: Representative of an active-mobility lobby group
- Interviews 3 and 4: Representative of a consulting firm for mobility management
- Interview 5: Representative of a car-pooling implementation project within a private company

In addition to these interviews, two stakeholder workshops were carried out in Basel and in Winterthur, Switzerland. The aim of the first workshop was to identify and prioritize the components and aspects of future mobility strategies of administrations, especially with regard to commuting mobility. The target group were representatives of administrations in the Basel region, preferably working in the area of mobility and commuting. The second workshop's aim was to identify how companies can benefit most effectively from mobility management and which components and aspects must be considered for a forward-looking mobility management in companies, thus having a more narrow view in contrast to the first workshop. The target group were representatives of companies interested in mobility management or who were practicing it already.

Figure 9 gives a holistic overview of the many best practice examples and recommendations that were mentioned by the interviewed experts as well as workshop participants. It is important to focus on a combined effort of both the administrations and companies in order to yield satisfactory outcomes of a mobility management. Administrations can set the right requirements, infrastructure and resources, while companies need to provide an internal caretaker, good working culture and parking management. Public private partnerships are necessary to build a suitable mobility service that is an integral part of the mobility management. Consulting firms could accelerate such processes by highlighting the return of investments, good networking and user guides (goal and common steps).

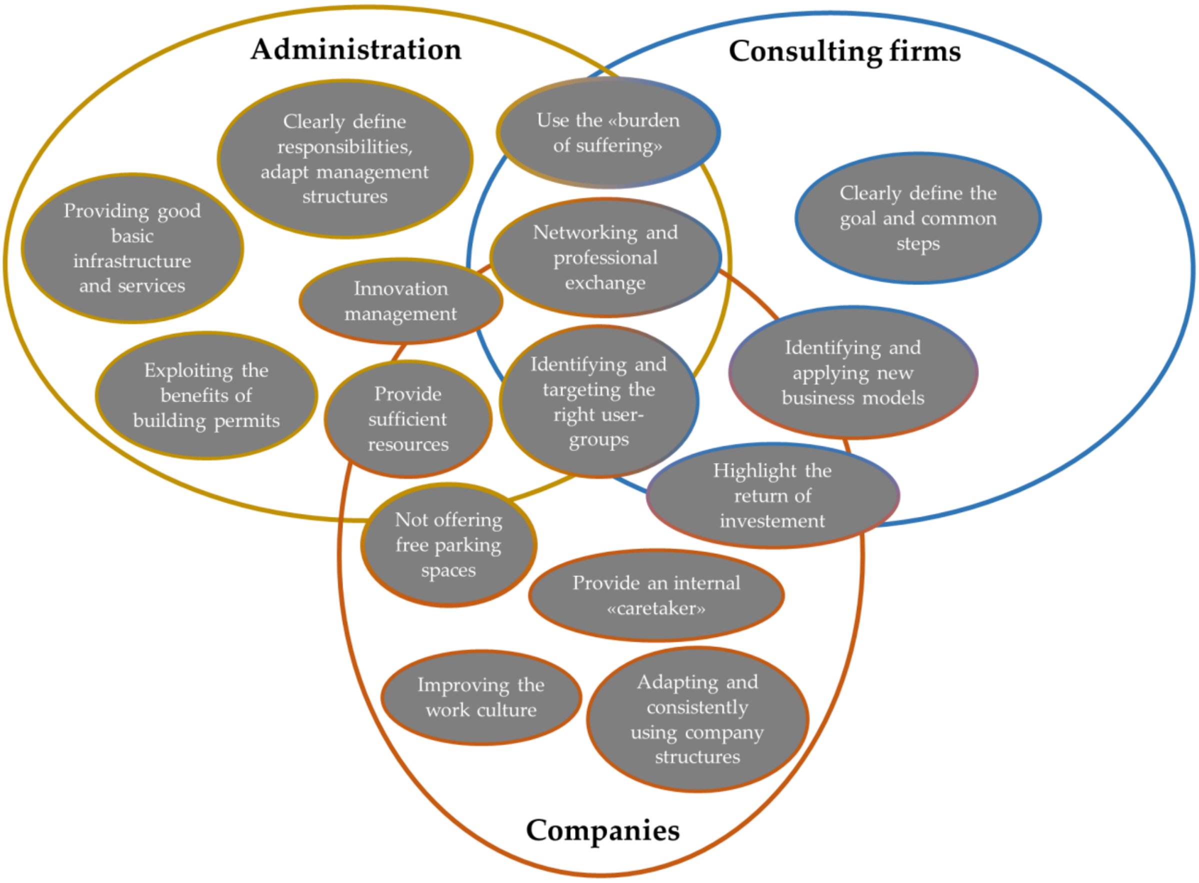


Figure 9: Overview of best practice recommendations in mobility management regarding administrations, consulting firms and companies.

Mobility management in companies was identified as a possible way to make commuter mobility more sustainable. The qualitative interviews with experts on their experiences resulted in a number of starting points that can be helpful beyond the actual mobility management at the measure level:

- Developing infrastructure and services: Services must be developed in such a way that they offer alternatives to the car for commuting, so that work and everyday life are compatible.
- Use building permits: Administrative instruments can generally provide a great lever in the service of overarching strategies for sustainable commuting.
- Creating resources and competencies: Investment in personnel, know-how and the continuous continuation of measures is needed, beyond temporary projects.
- Abolish free parking: In addition to establishing alternatives to cars, incentives for their use must be abolished - in particular, the space can be used differently and better.
- User group focus: A focus on certain groups with high potential for the use of alternative offers is at least initially more promising than one-fits-all approaches.

Changes in the economy and society, as well as new technologies, would enable a greater flexibility of work in terms of time and place and a higher quality of life through time savings - by replacing physical mobility with digital mobility. In order to solve problems associated with mobility and commuting, a more flexible working environment would be needed. In the area of mobility and transport systems themselves, the development of innovative, attractive and individualizable public transport services is one way in particular, and this must be accompanied by framework conditions - so that alternatives to the car are a better choice for the user. Cooperation between the transport sector, politics and planning, as well as the economy, is indispensable for this - best guided by sufficiency strategies that bring, not only ecological, but also economic and social benefits for Switzerland as a whole.

4.2.2 Tailored interventions (study 8)

Campaigns to promote pro-environmental behaviour including sustainable mobility often fail to achieve their goal due to their «one size fits all» character, which ignores different motivational structures of different societal segments. This gave rise to recent efforts dealing with segmentation concepts that could be applied for identifcation of target groups and designing tailored campaigns.

Haustein and Hunecke (2013) differentiate between a-priori and post-hoc segmentation approaches. A priori segmentation involves assignment of test persons to the previously defined segments and assignment rules. Post hoc segmentation approach involves defining segments within the segmentation process based on the similarity of test persons with regard to a selection of segmentation variables by typically applying a cluster analysis or related statistical methods.

In addition to a priori versus post hoc segmentation Haustein and Hunecke (2013) group the approaches based on variables used for segmentation into (1) geographic segmentation, (2) behavioural segmentation, (3) socio-demographic segmentation, (4) lifestyles or milieus, (5) mobility styles and (6) mobility types.

Geographic segmentation deals with purely objective factors, such as spatial, residential and transportation infrastructure. This approach is often used in national travel surveys to explore the influence of the spatial context on travel behaviour by typically differentiating between urban, suburban and rural areas (Markvica et al., 2020). Other examples include the influence of the settlement structure (Aditjandra et al., 2012; Krizek and Waddell, 2002; Scheiner, 2006) and or quality of locations, such as accessibility (Geurs and van Wee, 2004) or walkability (Madsen et al., 2013) on travel behaviour.

Behavioural segmentation is based on the revealed transportation behaviour, such as travel frequency, mode choice, pursued activities or travel destination. Since these variables are normally the variables to be explained in the transportation research and the same variables cannot be placed on the both sides of the equation, the behavioural segmentation has rather descriptive than explanatory role. An example of behavioural segmentation is the segmentation conducted within the German National Travel Survey (Lenz et al., 2010) based on the frequency of public transport, car and bicycle use, car availability and accessibility. Belonging to this group of segmentation approaches is also the post hoc segmentation of daily travel behaviour conducted by Prillwitz and Barr (2011) by the means of a cluster analysis. In the context of travel behaviour, Böhler et al., (2006) identify four groups based on the number of trips and kilometres travelled. Another example of behavioural segmentation is the study of Ausserer (2013), who identify walking types based on the frequency and attractiveness of walking.

The socio-demographic segmentation based on e.g. age, gender or household type is frequently applied, since the collection of the corresponding data is cost-effective and accurate. The socio-demographic variables are often combined into life stages either a priori (Hunecke et al., 2010; Jäger, 1989) or post hoc (Ryley, 2006).

It has been increasingly recognised that social stratification in modern societies involves complexity of social activities that cannot be sufficiently explained solely by socio-demographic variables (Haustein and Hunecke, 2013). This insight gave rise to the increased consideration of attitudes and values for the segmentation purposes, which have been integrated in the transportation research by the lifestyle approach. The most prominent example of the lifestyle-based segmentation is the Sinus milieu approach (Sinus, 2020), which is based on a combination of attitudes, values, aesthetic preferences and social position parameters. Dangschat and Mayr (2012) found based on an Austrian dataset that the Sinus milieus were associated with the highest explanatory power regarding the use of transportation modes, which was especially true for the case of walking. Schubert et al. (2020) found based on the Swiss Household Energy Data Survey (Weber et al., 2017), that Otte lifestyles – a typology related to the Sinus milieus – was successful in differentiating between flyers and non-flyers as and explaining frequency of short- to middle-distance air travel.

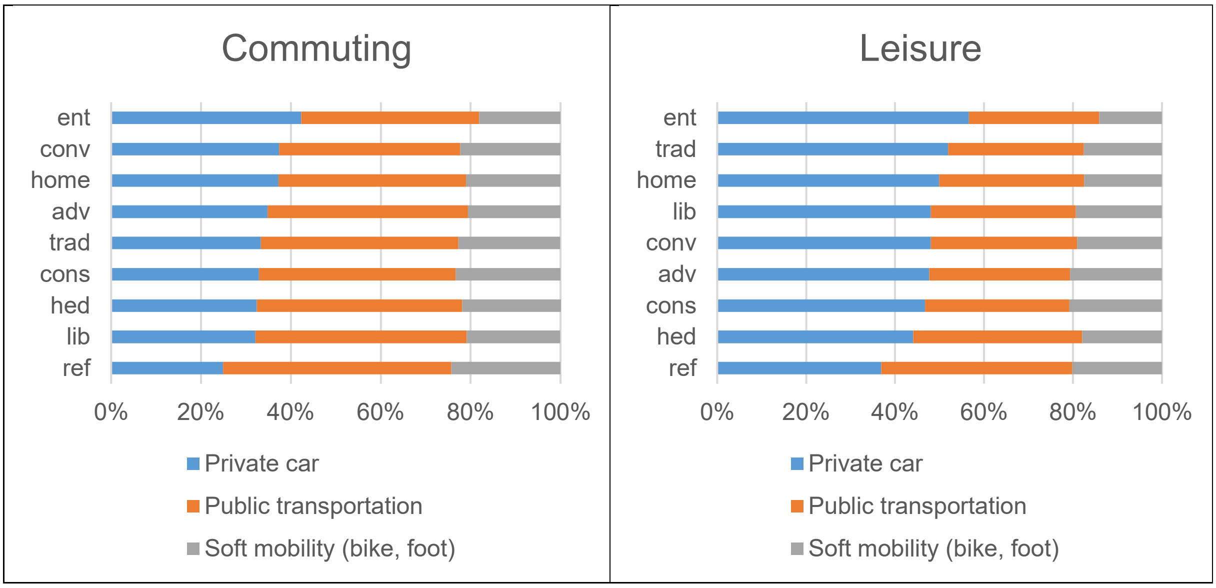
Lifestyle approach has been further developed within transportation research to the so called mobility styles. They are based on the insight from the social sciences that specific behaviours can be better explained by corresponding than by general attitudes and orientations. So, the mobility types include in addition to lifestyle elements mobility-related behavioural patterns and attitudes. Examples include the studies of Goetz et al. (1998) for the cities of Freiburg and Schwerin, (Lanzendorf, 2002) for the city of Cologne and (Ohnmacht et al., 2009) for the Swiss conurbations.

In contrast to lifestyles and mobility styles, mobility types are based solely on the psychographic features, such as values, norms, attitudes and beliefs. To avoid the arbitrariness in the choice of the psychographic features for the construction of the mobility types, the choice is often based on the established constructs from psychology shown to be relevant for travel behaviour. The mobility types developed by Anable (2005) and Hunecke et al. (2010) are particularly characterised by a theoretical foundation. Both are mainly based on an expanded version of the TPB (Ajzen, 1991). The common methodology of most attitude-based segmentations is to first identify the underlying attitude dimension through a factor analysis and then run a cluster analysis based on the obtained factors.

Hunecke et al. (2010) discuss the advantages and disadvantages of the six segmentation approaches described above based on the five established criteria from the market research: predictive power, actionability, measurability, stability, accessibility and efficiency (Dibb, 1999; Meffert et al., 2015). Motivated by a favourable mix of actionability and accessibility associated with lifestyle-based approaches from the market research, such as the Sinus milieu approach, and intending their hurdles in terms of efficiency (large survey required) and public availability, we explore the potential Otte's lifestyle typology (Otte, 2004), for segmentation regarding commuting and leisure travel. Otte's typology is open-source, transparently documented and the short version can be constructed based on only ten questionnaire items.

The results of a multinomial logit reveal that, controlled for age, sex, income and education, there is a significant effect of lifestyles on the mode choice for leisure and commuting. In particular, not being entertainment-oriented increases the probability of choosing public transport instead of private car for commuting by 68.6%. Not being reflective instead decreases the probability of choosing public transport instead of private car for commuting by 35%. Not being reflective also decreases the probability of choosing soft mobility instead of private car for commuting by 38%.

Investigating the influence of lifestyles on leisure mode choice reveals that not being hedonist and reflective decreases the probability of choosing public transport instead of private car for leisure by 19.5% and 43.5% respectively. In addition, not being entertainment-oriented instead increases the probability of choosing public transport instead of private car for leisure by 93.4%. All the results have to be interpreted relative to the group of advancement-oriented, which were taken as a reference group due to their position exactly in the middle of the endowment-modernity space, on which the typology is based. The lifestyle-specific modal split presented in the Figure 10 illustrates these lifestyle-specific tendencies.



Note: trad: = traditional workers, home = home-centred, ent = entertainment-oriented, conv = conventionalists, adv = advancement-oriented, hed = hedonists, cons = conservatives, lib = liberals, ref = reflexives

Figure 10: Lifestyle specific modal split for commuting and leisure travel.

5 Discussion and recommendations

In this section we draw upon our findings of the eight studies related to the mobility and governance innovations and discuss their potential for transforming the Swiss mobility system by utilizing the three spheres of transformation developed by O'Brien (2018). Figure 11 illustrates these three spheres, which are classified as the practical, political and personal spheres.

Figure 11: Three spheres of transformation by O'Brien (2018).

The **practical sphere** denotes the actions that directly contribute to a specific outcome and are usually well measurable like CO_2 emission reduction or the share of electric vehicles in new car sales. The progress in this sphere can easily be tracked by using, for example, energy intensity of GDP and has thus been the focus of most climate change mitigation and adaption research, policies and actions. Changes in the practical sphere could act as a trigger for transformations in the political or personal sphere.

The **political sphere** represents the norms, rules, regulations, institutions and regimes that facilitate or constrain practical responses to the system transformation. As an example, the Paris Agreement has successfully developed a common goal, which might trigger structural change to support innovations in the practical sphere.

Last, the **personal sphere** summarizes the individual and shared understandings, values, worldviews and paradigms, which can be used to justify ideologies, policies and actions.

We adopted a qualitative approach to measure the current transformative nature of each niche innovation regarding the practical, political and personal sphere. In this sense, we used a 7-point Likert scale from 1, no transformability visible yet to 7, highest transformation potential reached. Regarding the three spheres, a score of 1 corresponds to: not yet ready to be transformative on the practical level, no basis for political transformation and established policies/goals, no acceptance and lifestyle change in the personal sphere. A score of 7 would imply that the technology is fully available and mature in the practical sphere, the political agenda is clear and concise on a national and international level and supporting measures are in place to secure the transformation path, a lifestyle change has happened in the personal sphere including new paradigms embracing the niche innovation. We constructed a survey comprising of these Likert scale questions and a rough estimate on the time-scale at which the niche innovation might be part of a new mobility regime and sent it to mobility experts within the SCCER Mobility network. The time scale is also measured on a 7 pint scale with the categories: 1) Still more than 20 years needed, 2) Between 15 to 20 years, 3) Between 10 to 15 years, 4) Between 5 to 10 years, 5) Between 3 to 5 years, 6) Between 1 to 3 years and 7) Already fully integrated. In order to validate the ratings of the participants, we also included a question related to their perceived expertise in each of the 6 niche innovations. In total, 27 experts finished the survey.

Generally, the level of expertise of the survey participants was highest for electric mobility. The niche innovations carsharing, MaaS and autonomous vehicles received similar expertise scores, while mobility management and tailored interventions were the least known niche innovations. Figure 12 depicts the level of expertise for all niche innovations.

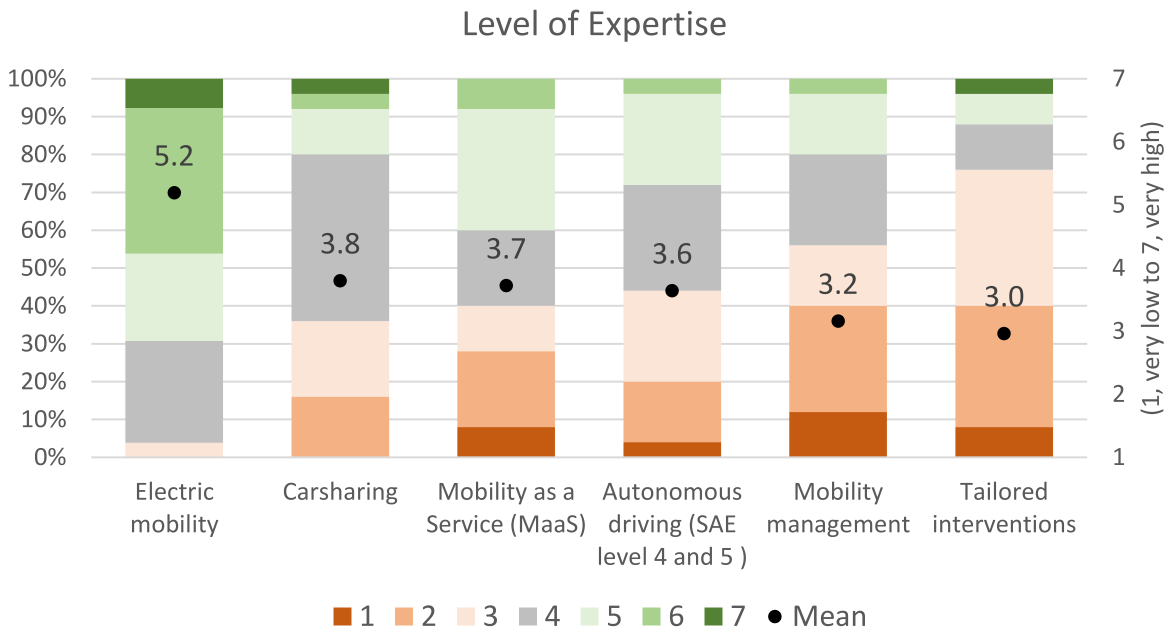


Figure 12: Level of expertise of mobility experts regarding the six niche innovations.

In the following sections, we will present the findings of the expert survey for each niche innovations and discuss the main challenges and opportunities.

5.1 Electric mobility

Figure 13 shows the results regarding transformation state of electric mobility for each sphere and the time needed to be fully part of a new sustainable mobility regime.

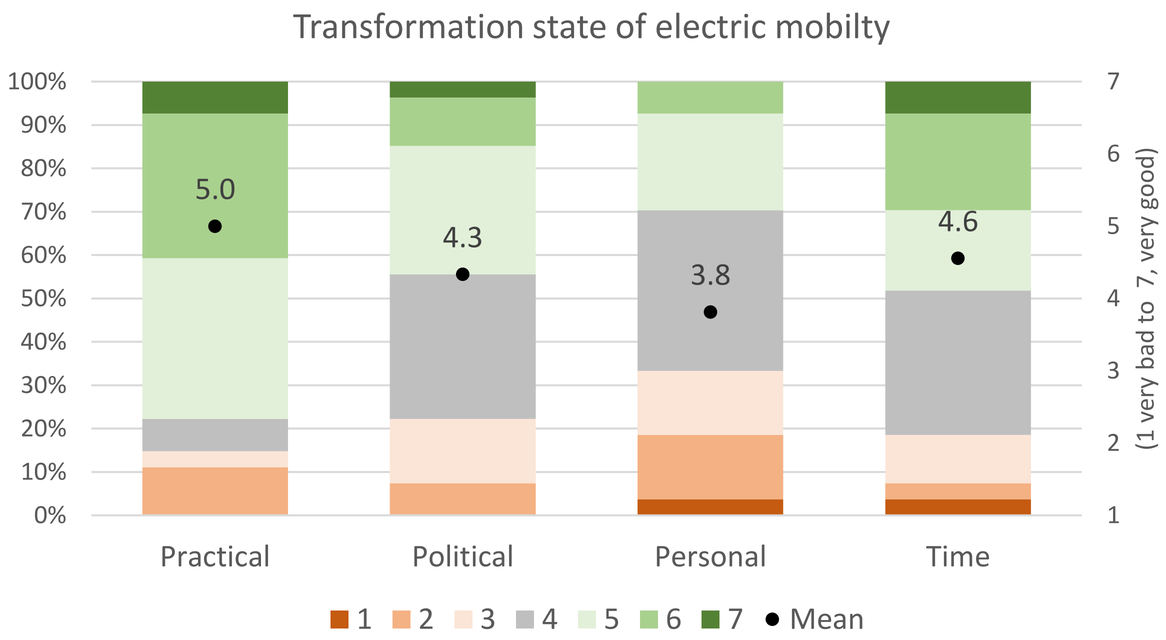


Figure 13: Experts view on the transformation state of electric mobility.

Electric mobility is technically feasible and is steadily growing in sales. Especially since everyday trips can be easily covered with current battery electric vehicles (BEVs) even in countries like the US (Needell et al., 2016), the barriers to a fasted uptake mostly lies on the personal sphere. Still, hindrances in adoption occur due to the lack of charging infrastructure in apartment buildings and households with leased parking lots in particular (EBP, 2020). The political agenda is set to foster electric mobility through e.g. the Paris Agreement or a variety of subsidies on BEV purchase and use. Further, the most important original equipment manufacturers (OEMs) have included a roadmap to produce BEVs. The electric mobility transformation is clearly underway, shows high CO_2 emission reductions in combination with renewable energy and reduces noise pollutions in cities and therefore receives the highest overall score. The highest potential for improvement has been found to be on the personal sphere. While political agendas and improvements on the practical sphere can spur a paradigm change towards fully electrified vehicles, we emphasize to clearly communicate the utility of a small to mid-sized BEV in combination of e.g. carsharing and other mobility services to cover the need for everyday trips and occasional longer trips. Advertisements in this regard might help to develop a more sustainable worldview on how mobility needs need to be fulfilled, including small BEVs for everyday trips.

5.2 Carsharing

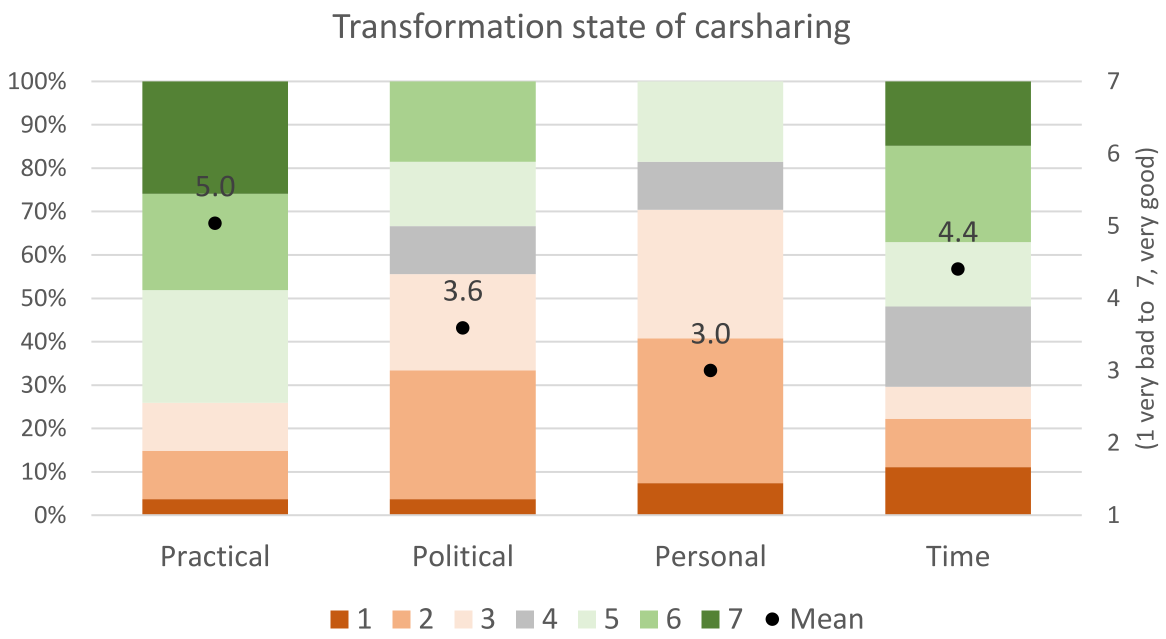


Figure 14: Experts view on the transformation state of carsharing.

Despite a rapid growth in new **carsharing** business models like freefloating and one-way carsharing due to the opportunities of digitalisation, questions still remain on how to redistribute the cars to locations with high demand and in the case of one-way station-based carsharing, redistribute cars back to stations lacking cars. Nugding and other incentivized approaches are currently being tested, e.g. in Switzerland with the carsharing operator Mobility, yet there is still room for improvements. As such, the practical sphere can be summarized as being in a dynamic phase with uncertainties and open questions, still the SCCER Mobility experts believe that carsharing is already well advanced in a practical sense. The structures and systems as well as policies to foster carsharing is in place, with Mobility being present all over Switzerland providing access to station-based round trip carsharing. Carsharing is also recognized to be a contributor to sustainability and many collaborations are made, for example with the Swiss Federal Railways (SBB) to provide park&ride. This is important, since carsharing should complement the public transport system and therefore also increase the attractiveness of public transport and approaches like MaaS. Similar to electric mobility, carsharing is not yet recognized as a standard paradigm. It is often seen as less comfortable as the private car and too expensive due to the suppressing of sunk and periodical costs in privately owned vehicles (e.g. purchase price, maintenance, depreciation) (Andor et al., 2020). While studies show that carsharing could indeed lead to savings compared to owning a private car, this is not yet considered by the general public (Bert et al., 2016). As such, awareness raising and further simplifying the access and handling of carsharing is necessary to increase its uptake. Further, with an increasing trend towards environmental friendly mindsets, carsharing could be advertised as a possible core asset of modern mobility service lifestyles included in a MaaS subscription plan, fostering the paradigm of service usage instead of ownership, thus enhance the transformation on the personal sphere.

5.3 MaaS

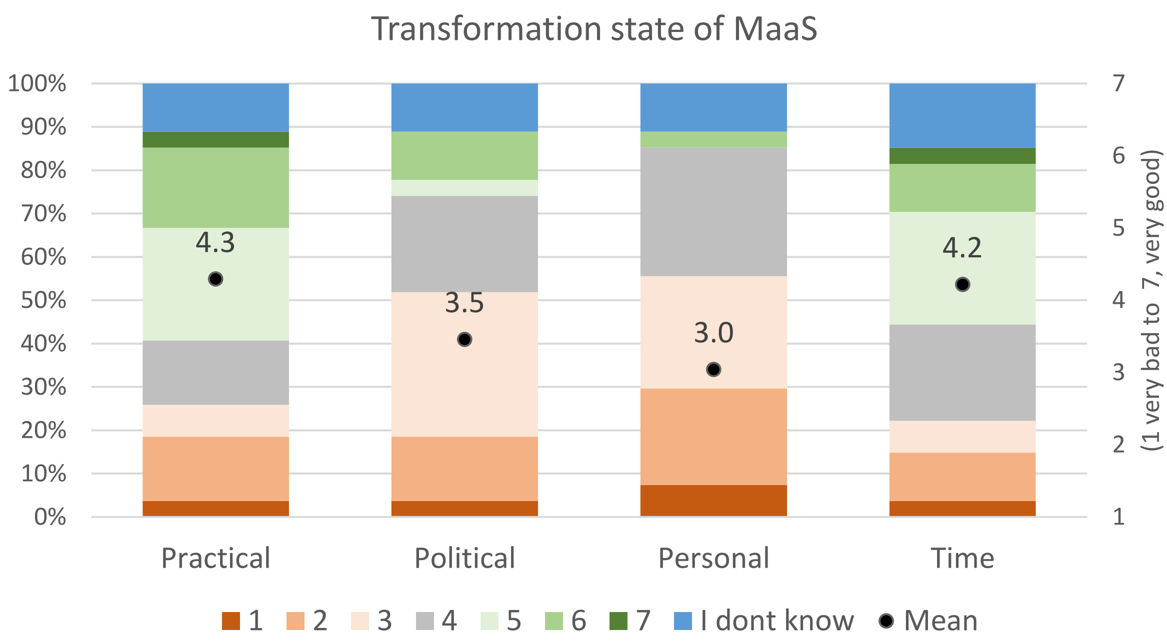


Figure 15: Experts view on the transformation state of MaaS.

Similar to carsharing, interest and pilot projects for **MaaS** are rapidely growing around the globe. However, a fully function MaaS platform including ticketing and route planning covering all modes of transport with just one app has yet to become mature. As such, research in MaaS is already well developed but not fully proven in practice. Companies and administration bond together to support MaaS (see e.g. yumuv or ZüriMobil). Also in Switzerland, the government is actively supporting MaaS initiatives and sees its potential to contribute to sustainable mobility. Still, many challenges and questions need to be addressed. The best solution for the customers would be one MaaS platform for whole Switzerland. How the market plays out and if the government needs to steer the development has yet to be seen. Once MaaS is accessible and easy to use, its integration into a new worldview of mobility and transformation of the regime could happen fast, since people are used to mobile apps and the different modes included in a MaaS subscription plan like bicycles, cars, public transport or other forms of services like parking.

5.4 Autonomous vehicles

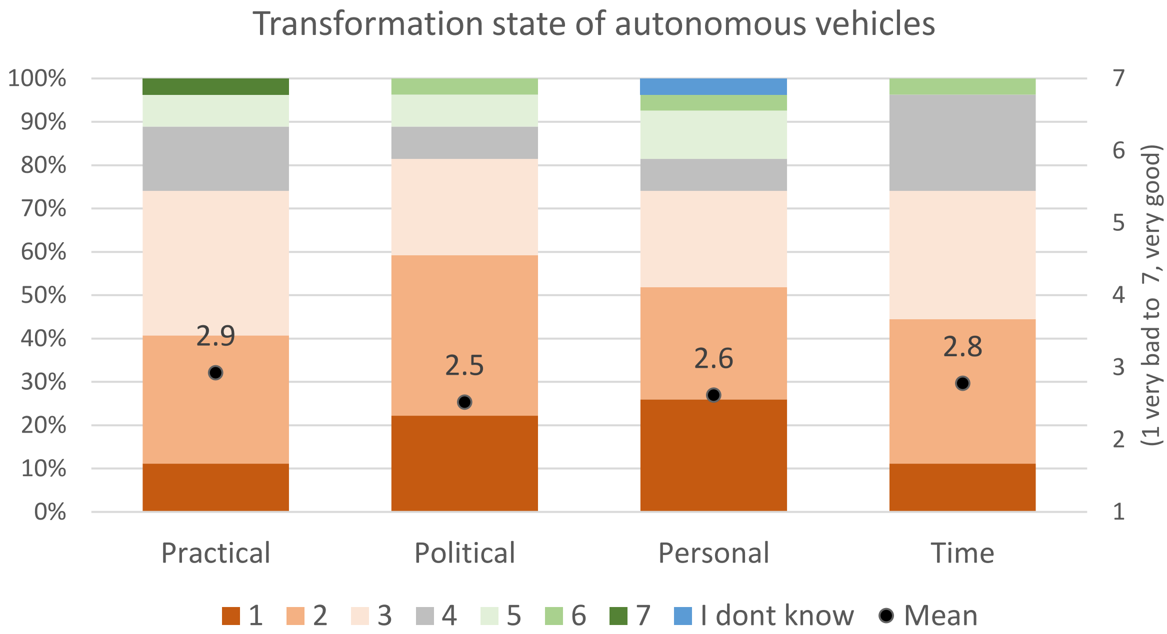


Figure 16: Experts view on the transformation state of autonomous vehicles.

Autonomous vehicles are the most controversial niche innovation included in this report. Since no SAE level 5 vehicles are available to date and only very little experience has been made with mixed traffic of autonomous and conventional cars, autonomous driving is not transformative today. Also regarding the political discussion, uncertainties on how autonomous driving could contribute to sustainable mobility remain. Still a consensus seems to be emerging in Europe to focus on shared autonomous vehicles. This is backed by Roos and Siegmann (2020) who state that if autonomous cars would be used, they need to be operated as a shared and pooled-use taxi fleet to reduce vehicle miles travelled compared to private autonomous cars – therefore reducing congestion and need for parking lots. Stoiber et al. (2019) (study 3) show that the Swiss population is already open to use a pooled-use autonomous taxis instead of a privately owned autonomous car. However, whether people would actually be open to sit in a taxi without a driver is yet to be seen. Since many studies point to adverse sustainability effects of autonomous cars including increased traffic and urban sprawl and only a shared and pooled-use autonomous taxi fleet shows a clear potential to reduced traffic, the impact on sustainability once the technology is fully developed and implemented is considered to be medium. Still the literature point to other sustainable effects like the increased access to mobility for the non-driving population, reduced accidents and increased energy efficiency (e.g. through platooning).

5.5 Mobility management

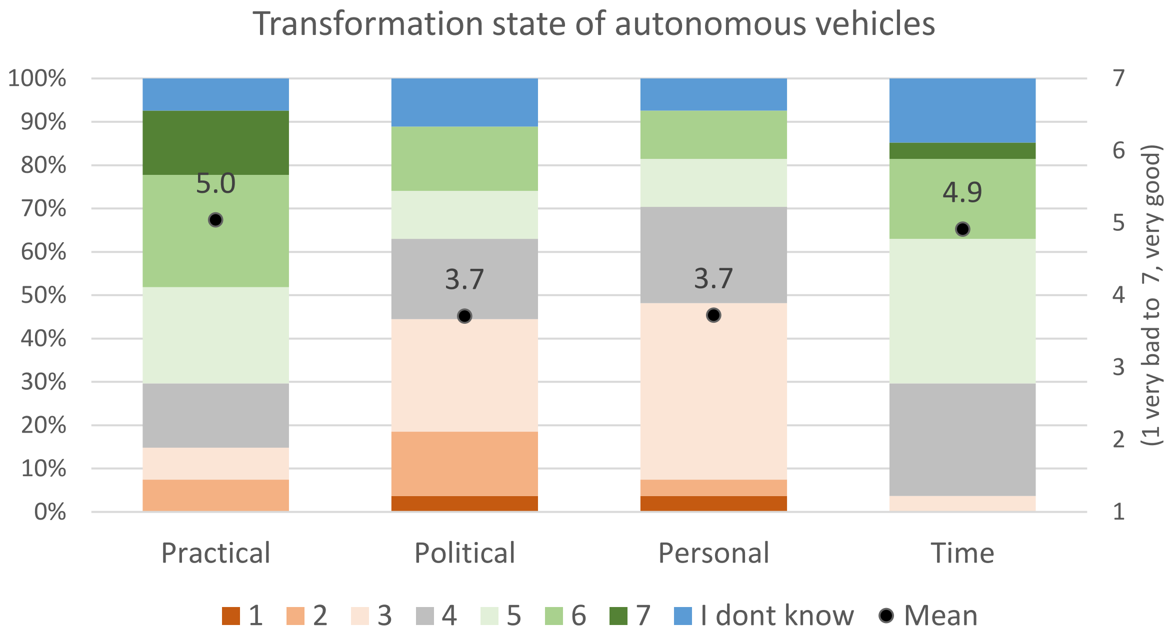


Figure 17: Experts view on the transformation state of mobility management.

A concise **Mobility management**, including a clear strategy and a person in charge is not yet widely adopted by companies in Switzerland. One of the forerunners is the Paul Scherrer Institute with its mobility management including carpooling, bikesharing, bonus malus system for parking management, electric vehicle incentives, optimised public transport connections and an information leaflet as well as periodic events around sustainable commuting. While the government supported mobility management in companies with its program of "Mobilitätsmanagement in Unternehmen (MMU)" by EnergieSchweiz and consulting firms specialized in mobility management exist, a clear strategy and focus on supporting mobility management on a larger scale is lacking. Further, regarding the personal sphere a common understanding and culture of mobility management is not yet established. As an example, employees still see free parking lots as a requirement by the company they work at. Contrary, the call for more flexible working hours including homeoffice and telework is increasing as well as supporting measures regarding electric vehicles like charging facilities. Generally, mobility management could be implemented fast once a political drive is present.

5.6 Tailored interventions

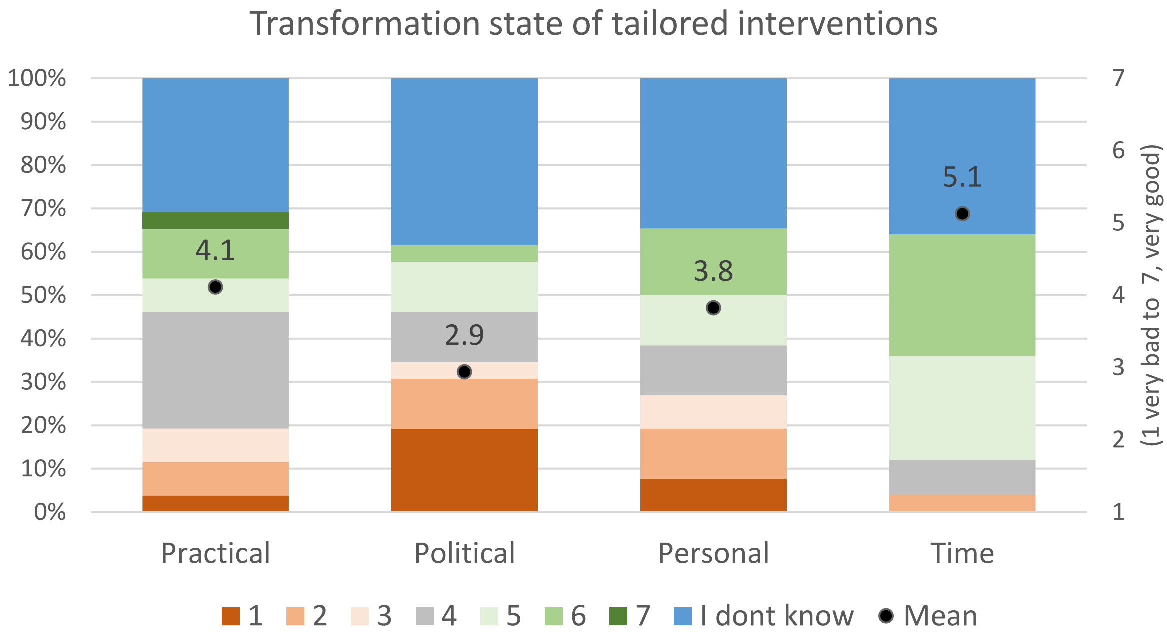


Figure 18: Experts view on the transformation state of tailored interventions.

Despite some promising pilot projects in the field of personalised travel plans (Ahmed et al., 2020) or promoting pedestrianism (Pangbourne et al., 2020), tailored interventions are still not well established in the political sphere according to our short survey. The reasons for that could be seen in data availability and data collection efforts associated with tailored interventions. This highlights the need for the segmentation concepts such as the Otte lifestyle typology (Otte, 2004), which are not associated with extensive data requirement and produce meaningful segments for tailoring interventions to promote sustainable mobility, as shown by Tomic et al. (2019) (study 8). Other appealing approaches include the segmentation approach of the European Project SEGMENT (Anable and Wright, 2013) based on the Theory of Planned Behaviour (Ajzen, 1991) or the segmentation based on values (van den Broek et al., 2017). All these concepts deserve more attention, since, once the data is collected and the segments are defined, they can be quickly implemented according to the experts from our survey.

Table 3 provides a holistic summary of the results from the expert survey regarding transformation state of the niche developments on the practical, political and personal sphere, as well as on the time scale needed to be fully part of a new mobility regime. We further include a rough estimate on the impact on sustainability once the niche innovation would reach the highest score on the three spheres (corresponding to a score of 7) based on the presented studies and literature. Finally, we provide an overall score with which a qualitative assessment of the current potential to reach a sustainable transport system by 2050 can be made.

Table 3: Summary of results from the mobility expert survey regarding transformation state for each niche innovation including impact on sustainability when fully adopted and an overall score included by the authors.

Niche-innovation	Practical	Political	Personal	Time-scale to be part of the regime	Impact on sustainability when fully adopted	Overall score
Electric mobility	5	4	4	5	7	6
Carsharing	5	4	3	4	5	4
MaaS	4	3	3	4	6	4
Autonomous vehicles	3	3	3	3	4	3
Mobility Management	5	4	4	5	5	5
Tailored interventions	4	3	4	5	5	4

6 Conclusion

In this report we provided a detailed analysis of six niche innovation with the potential to transform the Swiss mobility system. We referred to eight studies conducted during the Phase 2 of SCCER Mobility, providing empirical insights in how to foster the uptake of these innovations. We further applied a qualitative assessment of the current transformability state of each innovation using the framework of the three spheres of transformation (practical, political and personal) and a survey with experts of the SCCER Mobility network.

Electric mobility is seen as the most advanced and established innovation in this regard. However, providing support for charging infrastructure for leased parking lots, e.g. in apartment buildings, is a must for a fastened uptake (Patt et al., 2019). Communication campaigns may benefit from a lifestyle segmentation approach to create tailored messages reaching the right audience and, as such, increase adoption of niche innovations. Messages could address the underestimation of total cost of ownership commonly found for private cars, deterring from adopting EVs who have higher upfront cost, as well as carsharing, which seem expensive compared with the average fuel cost of private cars (Andor et al., 2020). Also, the still prevalent range-anxiety regarding BEV could be addressed more often by launching a broader public discussion on the average kilometres used in every-day trips compared to the range of current BEVs. While BEVs have a high potential to transform the Swiss mobility system, it is not sufficient to simply replace the current internal combustion engine fleet with BEVs but rather embrace the mutual relationship with other mobility services like carsharing and MaaS in general. Hence, BEVs could be further fostered by supporting a multimodal lifestyle with carsharing supplementing current range shortages of small to mid-sized BEVs. MaaS on the other hand needs to have a strong public transport core to support a seamless multimodal and connected transport service to have the potential to replace private car ownership. In order to foster new mobility services like carsharing, ridesharing or electric mobility and reduce anxieties in adopting them, mobility management can act as a gateway to get first contacts with these services through the workplace, eventually leading to higher acceptance and adoption rates. Lifestyle segmentations – as shown in this report – provide a promising opportunity to increase the effectiveness of communication strategies.

The report acts as a guideline and source for policy planners and practitioners in the realm of sustainable mobility in Switzerland.

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