

# Traditional Taxis vs. Automated Taxis – Does the Driver Matter for Millennials?

Christina Pakusch, University of Siegen, Germany, [christina.pakusch@uni-siegen.de](mailto:christina.pakusch@uni-siegen.de)

Johanna Meurer, University of Siegen, Germany, [Johanna.meurer@uni-siegen.de](mailto:Johanna.meurer@uni-siegen.de)

Peter Tolmie, University of Siegen, Germany, [peter.tolmie@uni-siegen.de](mailto:peter.tolmie@uni-siegen.de)

Gunnar Stevens, University of Siegen, Germany, [gunnar.stevens@uni-siegen.de](mailto:gunnar.stevens@uni-siegen.de)

## ABSTRACT

It is anticipated that Autonomous Vehicles will have a huge impact on the creation of sustainable smart cities and communities. In relation to this, shared autonomous vehicles might reduce traffic accidents, greenhouse emissions, the number of vehicles on the road and the need for parking spaces. However, there are also disadvantages to autonomous vehicles. One of the key concerns is how automation may threaten jobs in the transport industry, including the traditional role of taxi drivers. To begin to explore how important an actual taxi driver is to customers and the extent to which they might be happy to have autonomous taxis replace traditional taxis, we conducted qualitative interviews with 29 Millennial-aged participants. Millennials were focused upon because, given current figures and likely future projections of use, they form the key market for prospective future autonomous taxis. The results show that the kind of taxi rides Millennials make are particularly suitable for automated taxis because interaction with a human driver is not a high priority for this group, while the prospect of autonomous taxis being cheaper *is*. Meanwhile the fate of taxi drivers does not play a significant part in how Millennials reason about this. An incidental finding, here, is that, by offering a convenient and affordable alternative, the advent of automated taxis may also pose a threat to public transportation.

## KEYWORDS

Shared Autonomous Vehicles, Sharing Economies, Automated Taxis, Mobility Behavior, Travel Mode Choice, Social Sustainability

## 1 Introduction

In order to realize the visions associated with sustainable cities and communities, the future character of mobility is going to play an important role (Pantidi et al., 2015). A controversial aspect of this that is currently receiving a lot of attention is autonomous driving. Its implementation could have far-reaching consequences for society, people's mobility and the character of everyday life. While the consequences of this disruptive innovation are potentially far-reaching, they are also very difficult to anticipate because, not only is the technology evolving, but the behavior of users and citizens is also changing in parallel. Many positive outcomes are foreseen as a consequence of vehicle automation and the connected car. These include: increased road safety and

fewer accidents through the elimination of human error; the construction of lighter vehicles demanding fewer raw materials; improved traffic flow through the exchange of information and, as a result, better energy efficiency, fewer emissions and less noise; and, for the passengers, a better or more efficient use of travel time. Some experts are also convinced that automation will strengthen sharing economies and that people will use vehicles on demand instead of owning them permanently - which in turn could significantly reduce the overall number of vehicles on the road.

In the spirit of all of this, imagine an automated on-demand vehicle that picks you up and takes you to your destination - an automated taxi without a human driver. Given that automated taxis are likely to be cheaper than taxis with drivers in the long term, it is evident that automation poses

a major threat to professional taxi drivers. Indeed, many experts suggest that, in the age of automated vehicles, there will be no more professional drivers (Davidson and Spinoulas, 2016; Litman, 2017; Walker and Marchau, 2017). In order to find out whether this threat is realistic and whether consumers would actually prefer automated taxis to traditional taxis with taxi drivers, we conducted a qualitative study with 29 Millennials (the generation born between the early 1980s and the late 1990s (Hanks et al., 2008)). By addressing so-called Millennials, we focus on a group of people who have grown up in a digital and connected world, who are untroubled by the use of innovative technologies, but who are not yet mature in terms of their mobility behavior (De Haas et al., 2018; Müggenburg et al., 2015). This group constitutes about 41.8% of all taxi users in Germany. 40-59 year-olds account for 31.6%, and the over-60s about 26.8% (IFAK, 2014a). Millennials, then, represent an important customer group for taxi businesses (Garikapati et al., 2016). Given this background, we have sought to address the following questions: 1) How important do Millennials think it is to have a human driver in their transportation services?; and 2) Will Millennials prefer autonomous taxis over traditional taxis? By addressing these questions, we contribute to a growing body of literature regarding the potential impact of (shared) autonomous vehicles on mobility behavior and the fate of affected stakeholders such as professional drivers.

## 2 Related Work

### 2.1 Millennials and their Mobility Behavior

The way people move from A to B is changing. People can connect digitally with each other, plan their routes multimodally, become providers of mobility services themselves and find their way more easily, even in foreign cities, with the help of transport information systems and new services. Millennials are particularly involved in this transformation. In this paper, we use this term to refer to those born between 1980 and 2000 (Hull et al., n.d.; Stein, 2013), although definitions vary (Seppanen and Gualtieri, 2012) with 1974 being the earliest starting age (Barton et al., 2013) and 2002 being the latest starting age (Pendergast, 2010; Sago, 2010). As a group, they use new services such as carsharing or ridesharing and order taxis via smartphone apps more often than representatives of older generations (Becker et al., 2017; Rayle et al., 2014; Schulz and Faus, 2019).

Millennials differ fundamentally from their predecessor generations in terms of both consumer behavior and the demands they make regarding work and lifestyle (Stratmann, 2017). They stay longer with their parents, either marry later or not at all, and are slower in setting up their own household. They are very well educated but have little political

commitment. Yet they prefer a good work-life balance to a high salary. As Millennials are receptive to comfort and convenience, they appreciate and enjoy the benefits that the digital world offers them (Bialik and Fry, n.d.).

For many Millennials, being mobile is a basic social need and a prerequisite for professional success. In contrast to older people, they often use the mobile internet and various routing apps to find their way around in foreign environments. In addition, the younger generation is on average fitter than the older generation, so they can move around and manage luggage more easily on their own. Thus, they are more prepared to consider different options than older people when choosing their means of transport (Metz, 2000; Nobis and Kuhnimhof, 2018). To date, the car has been the most important means of transport in the mobility mix for Millennials (Nobis and Kuhnimhof, 2018). However, as in many other developed countries (Delbosc, 2017), the number of young people in Germany who get a driver's license or buy a car has dropped in recent years, both in real numbers and as a proportion (Kraftfahrt-Bundesamt, 2010, n.d.). Thus, according to statistics from the Federal Statistical Office and the Federal Motor Transport Authority (KBA), 63.4% of 17-24-year-olds in Germany had a driving license in 2010 compared with 59.7% in 2019.

Shifts in patterns of work and education are another important reason for the change in the mobility behavior of Millennials. The number of young people studying after school has been rising steadily for some years now. While in 2001 the proportion of first-year university students in a generation was 36.1%, by 2018 it had risen to 55.9% (Statistisches Bundesamt, 2019). This has had two effects. First, more young people do not earn money until later in life and thus postpone obtaining a driving license or buying a car (Schleiffner et al., 2017). Second, many first-year students move to cities, receive a cheap university student ticket for local public transport and do not need a car because of the better mobility opportunities in the cities (Scheiner, 2017). In rural areas, the need for a car is still high, even for young people.

Further details about the situation in Germany were revealed by a representative survey called "Mobilität in Deutschland" (Nobis and Kuhnimhof, 2018). The modal split for cars has decreased during the past few years, while the share of public transport, bicycles and footpaths has increased (Lenz et al., 2010; Nobis and Kuhnimhof, 2018). The proportion of people who use bicycles, public transport or multimodal transport is significantly higher among those under 29 than among older people (Buehler and Hamre, 2015; Heinen and Chatterjee, 2015; Nobis and Kuhnimhof, 2018).

With regard to taxi use, in all age groups taxis are predominantly used for private purposes. 88.7% among 20-39 year-olds, 85.1% among 40-59 year-olds, and 96.1% among

the over 60s, use taxis for private trips. Young adults mainly use taxis for events and leisure activities (74% - for 40-59 year-olds the figure is 61.1%; for over 60s 37.1%). More occasionally they use them for trips to stations/airports, etc. (6.8%; 40-59 year-olds 12.2%; over 60s 17.2%). Unlike older generations, Millennials use taxis much less frequently for medical reasons (4.4%; 40-59 year-olds 8.4%; over 60s 25.9%) (IFAK, 2014b).

It is also the case that car-related status and having an emotional connection to a car no longer feature in the same way in the reasoning of Millennials (Dutzik et al., 2014; McDonald, 2015; Sivak and Schoettle, 2012). Instead, the choice of a car as a means of transport is more likely to be based on its practicality. Despite all the practical advantages, 6 out of 10 Millennials now believe that they do not necessarily have to own a car (Zukunftsinstitut, 2015). Nowadays, living in a nice apartment (55%) and travelling (28%) is more important to young adults than car ownership (10%) when it comes to a question what they like to spend their money on. 81% of Millennials say they do not care what other people think about the car they drive (Zukunftsinstitut, 2015).

Mobility researchers have also addressed the peculiarities of different age groups and their respective mobility behavior. Within the mobility biographs framework (Axhausen, 2008; Lanzendorf, 2010; Muggenburg et al., 2015; Scheiner and Holz-Rau, 2013), young adults were found to be an interesting age group to take into account because their travel patterns have typically not yet become firmly consolidated, with a number of relevant life events within their household, employment and residential biography still to come (De Haas et al., 2018; Muggenburg et al., 2015). Most changes are particularly associated to age (Beige and Axhausen, 2012; Hultsch and Cornelius, 1995). Most changes in people's work career take place between the ages of 20 and 35, when young adults first switch from school to higher education and then to work (Beige and Axhausen, 2008; Schoenduwe et al., 2015). At the same time, the most significant changes in household configuration take place at this age, with young adults moving out of their parental home and/or starting a family (Rau and Manton, 2016). Both of these work-related and personal changes are often accompanied by changes in their place of residence and need for mobility, with concomitant changes in their choice of means of transport (Oakil et al., 2014). In this phase of life, socializing is given a particular emphasis, according to their habits, interests and financial possibilities (Scheiner, 2017). In the long run, this shapes a mobility lifestyle that determines individual mobility behavior (Baslington, 2008; Hausteine et al., 2009).

In a generational comparison, Millennials have already been found to be very open to autonomous driving and see it as offering advantages at both an individual and societal

level (Pakusch et al., 2018b; Payre et al., 2014). Thus, as a specific user group, Millennials are particularly interesting to look at because they are comparatively likely to adapt their mobility behavior in response to the advent of innovations in the field of automated mobility on demand.

## 2.2 *The Taxi Industry*

Taxis are an important part of modern public transportation, in particular with regard to supporting opportunity-based mobility (Gwilliam, 2005). According to a survey on customer satisfaction with the taxi industry in Germany, the vast majority of customers use taxis for private journeys (90%) (IFAK, 2014a). On these private trips, most taxi customers use cabs for getting to and from parties or events (53%). A smaller number use them to get to or from airports and train stations (14%), or for medical reasons (10%) (IFAK, 2014a). Taxis are primarily turned to, then, in situations where customers cannot or do not want to drive themselves and there is little or no other choice (Davidson et al., 2017). A recent study of taxi customers also found that 77% of taxi trips happen in situations where no other means of transportation is available (IFAK, 2014a). In Germany 27% of taxi customers are younger than 29, 14% are 30 to 39 years old, 16% are 40 to 49 years old, 15% are 50 to 59 years old, 11% are 60 to 69 years old and the remaining 15% are 70 or older. So almost twice as many people using taxis are under 29 as in any other age group.

The taxi industry is undergoing a worldwide transformation. New technologies have entered the industry, changing the activities of taxi drivers and putting them under pressure from new competition. Taxi drivers use navigation systems that support them in their journeys. E-hailing apps such as mytaxi connect customers directly with taxi drivers - without a classic taxi dispatcher. Customers can use such apps to request a taxi, make cashless payments and rate taxi drivers. At the same time, digitalization and the sharing economy have also created new, disruptive players such as Uber. In its best-known service, Uber brokers trips between private car drivers and customers. These trips are usually cheaper than classic taxi trips, so they have become serious competition for taxi drivers in many cities. A number of studies (Bond, 2014; Lewis and MacKenzie, 2016; Sun et al., 2017) have investigated how the market entry of transportation network companies (TNCs) like Uber affect the taxi industry. One study showed that, in San Francisco, the number of journeys by taxi decreased from January 2012 to July 2014 by about 65%, from about 1400 to about 500 per month. In many cities, taxi driver communities have joined forces to protest against those new forms of competition (Fleisher, 2014).

In the future, the threat to taxi drivers may come from another direction: the development of autonomous driving.

With the introduction of autonomous vehicles (AVs) to the market, especially shared autonomous vehicles (SAVs), the taxi driver profession risks becoming obsolete (Liang et al., 2016; Strawn, 2016; Walker and Marchau, 2017). This has been challenged by other experts, who claim that the professional driver's role is vastly underestimated (Cohen and Hopkins, 2019). Taking a more differentiated view on the future development of the taxi industry, they suggest that the profession of taxi driver will only be redefined, not disappear completely with the advent of automated taxis (Alessandrini et al., 2015; Chou, 2017; Madrigal, 2018; Mönch, 2018). It is conceivable that taxi driving with a human driver will develop into a luxury service – rather like chauffeur services today or that taxi drivers will focus on other niche markets (Center for Global Policy Solutions, 2017; Valerio, 2016).

### 2.3 *Autonomous Driving and the Impact of Automated Taxis*

According to the international standard for full automation (J3016), a vehicle is fully automated when the system dynamically and fully autonomously performs all aspects of the driving tasks under all roadway and environmental conditions without the need for a human driver (SAE International, 2016). Vehicle automation opens up new possibilities for private mobility and enables new ways of using sharing-based transportation concepts. Automated mobility on demand concepts suggest that driverless, automated taxis, will pick up their passengers, chauffeur them to their destination, and then drive on to the next customer (Fagnant et al., 2015; Fagnant and Kockelman, 2015; Krueger et al., 2016; Pakusch et al., 2018a). In the literature, SAV is now an established term. However, in this paper we will use the terms automated taxi and SAV synonymously as often done in literature (Burghout et al., 2015; Kolarova et al., 2018), even if they are not necessarily the same. The elimination of the driver, whose labor costs make up a large part of the operating costs (Gladstone, 2017), along with savings resulting from efficiency enhancements, will reduce the cost of such mobility services (Burns, 2013; Fagnant et al., 2015; Fagnant and Kockelman, 2014; Hao and Yamamoto, 2018). Currently, labor costs make up to 57% of the cost in New York (Greenblatt and Saxena, 2015), 54% in Berlin, Germany and up to 64% in larger taxi companies (Krause, 2016). With a relatively low cost, and a higher level of convenience and service, automated taxis may be an affordable solution for customers. This alone may encourage a more rapid deployment of SAVs than would otherwise have been the case (Pakusch et al., 2016).

A few studies have already investigated people's willingness to adopt SAVs (Pakusch et al., 2018a). When asking if people would adopt self-driving technology and in what

form, (Howard and Dai, 2014) found that people's willingness to use self-driving cars as taxis was not high, with wealthier people being more willing to use a self-driving taxi than those with a lower income. Another study recently focused on SAV preferences and found that younger people with more multimodal travel patterns would be the typical profile of potential SAV users (Krueger et al., 2016). In a recent study by Moreno et al. (2018), 41.5% of the respondents stated they were willing to use an AV as an SAV when asked how they would consider using automated vehicles. Those who were younger than 35, male, did not own a conventional car and made 3 to 4 trips a day had the highest probability of using an SAV.

Experts see great potential in the shared use of AVs and estimate that automated taxis have the potential to reduce the number of private vehicles by more than 90%. To achieve such results, several simulated studies have recently been undertaken relating to fleets of automated taxis. Burns (2013) simulated the use of an SAV fleet in a small, a medium and a metropolitan city. He suggested that SAV trips could actually be cheaper than trips by private car or taxi when looking at the cost per mile (\$0.41, which currently corresponds to €0.22 per kilometer). He also calculated that all trips could be executed with a fleet of only 15% of the number of privately-owned vehicles. Fagnant and Kockelman (2015) and Fagnant et al. (2015) have suggested that the amount by which traditional car trips could be replaced is a more modest 3.5% or 1.3%, respectively. On this basis, each SAV could replace around eleven (or nine) conventional vehicles, with a reasonable wait time (one minute or less) and with travel fares less than a third of what a traditional taxi currently charges. Against this, both of these studies found that the mileage traveled might increase, by 10% or 8%, respectively, due to the repositioning of vehicles. Burghout et al. (2015) have concluded that it is possible to replace private car commuter trips in a metropolitan area with self-driving on-demand taxis such that there would be a need for less than 5% of the passenger vehicles currently in operation, with the same going for parking places. Spieser et al. (2014) simulated the use SAV transportation in Singapore and came to the conclusion that an effective fleet would need to have only one third of today's private vehicles. Although, as intimated above, these studies show that the total distance traveled by all vehicles will increase (Fagnant et al., 2015; Spieser et al., 2014), it is also generally agreed that automated vehicle sharing concepts offer great economic and ecological potential. It is widely assumed in these studies that the operating costs of an SAV will be higher in the early phases of their adoption and that these costs will be offset in the long term through their greater efficiency.

While there has been a major upsurge in studies about autonomous driving in general, and shared autonomous vehicles as a more specific business model, only a few studies have so far addressed the issue of people's willingness to use shared autonomous vehicles in the future. Furthermore, while lots of studies claim that the advent of AVs will put the job of professional drivers, i.e. taxi drivers, at risk (Davidson and Spinoulas, 2016; Litman, 2017; Walker and Marchau, 2017), these studies do not reflect upon such consequences in a more differentiated way. Thus, there still is a gap in the automated driving literature regarding the impact of SAVs on other modes of travel or their social consequences, such as job losses, especially from a more deeply rooted empirical perspective.

### 3 Methodology

To address our research questions, we conducted 29 problem-centered narrative interviews with regard to the relevance of having a human taxi driver and, more broadly, the concept of SAV services (Witzel and Reiter, 2012). Qualitative interviews are particularly suitable for exploring more prospective fields of research and for uncovering the subjective perspectives of users (Sanders and Stappers, 2008) and are well-established as a method for analyzing travel behavior (Bruns and Matthes, 2019; Farinloye et al., 2019; Møller et al., 2018; Zarabi et al., 2019). Openness and flexibility in this research process provide space for discovering new, previously unknown phenomena. The interviews were conducted in German, but the excerpts in the paper have been translated into English (Brumby et al., 2016).

#### 3.1 Participants and Procedure

To contact and recruit participants, we used a combination of qualitative sampling (Coyne, 1997) and snowball sampling (Biernacki and Waldorf, 1981). We did not ask for any prior knowledge about AVs and the interviewees took part in the interviews on a voluntary basis and without being compensated. As indicated above, the study focused on so-called "Millennials". The study was undertaken in Germany, the participants consisted of 11 women and 18 men aged 20 to 34 years (see Table 1). 17 interviewees lived in rural areas, the other 12 in small, medium and large cities with a decent public transport infrastructure. All of the participants held a driver's license and 21 of them owned a private car.

For the analysis, we evaluated an interview data set (n=25) that originally focused on closely related research questions. These interviews were conducted to find out what requirements the participants have for an SAV service, how they would use it and how their mobility behavior could

change as a result. Thus, while the core focus was on questions related to different aspects of service design, other topics such as daily mobility behavior, attitudes towards, experiences with and use of different means of transport (bicycle, car, public transport, taxi, carpooling and carsharing) were also an integral part of the interviews. In this context we also talked with the participants about whether and how often and on what occasions they use taxis, what experiences they have had with taxi services, what they like and dislike about the service and what their relationship is with the taxi driver. Then we talked about the topic of autonomous driving in general, their current knowledge, where they have heard about the topic so far, where they expect benefits and see disadvantages in this context and under what conditions they would use driverless vehicles. However, at the beginning of the interviews, the participants only knew that their mobility behavior, autonomous driving as well as autonomous taxis were the main topics. Up to this point in the interviews, we had not given any background information on AD in order not to influence the respondents. While the idea of driverless vehicles is increasingly becoming well-known in the public domain, we expected the notion of SAVs to be largely unknown. We intended to address this problem and chose a press release on Lyft's and Uber's plans on an SAV fleet that served as an envision stimulus. The press release briefly announced the TNC's plans to develop an automated vehicle that would transport passengers from A to B in the long term without the need of a driver. In addition to the wishes and requirements of the interviewees for a Level 5 SAV like this, we asked them about their possible reasoning for using such a service and attitudes towards it. It was not until the last part of the interviews that we told them the results of the simulation studies and that autonomous taxis could be operated considerably cheaper. We then asked the participants to put themselves in the following situation: In the age of autonomous driving, they are at a party in the evening, have had a drink and want to get a taxi to go home. We gave them the choice of taking either a conventional taxi with a human driver or an automated driverless taxi that would be 30% cheaper. We then asked them to choose one of the services and justify their decision.

Thus, the dataset provided us with all the content relevant to the research questions at hand. We analyzed the interviews again with regard to the questions we wanted addressed in this study. Based on this set of interviews, we conducted four more interviews with Millennials. Having learnt from our initial findings, we focused more strongly on the use of conventional taxis and their existing interactions with taxi drivers. The interviews lasted between 20 and 45 minutes.

Name (anonymized)	Gender	Age	Job	Main Travel Mode	Place of Residence
Alex	male	27	Student	PT*	Urban
Tim	male	22	Student	Car	Rural
Lisa	female	23	Medical Assistant	Car	Rural
Luis	male	23	Online Marketing Manager	Car	Rural
Daniel	male	28	Cutting Machine Operator	Car	Rural
Sophie	female	26	Geriatric Nurse	Car	Rural
Fabian	male	34	Engineer	Car	Urban
Tobi	male	22	Student	Car	Rural
Lara	female	22	Student	Car	Rural
Robin	male	21	Student	Car	Rural
Helen	female	26	Automobile Sales Person	Car	Rural
Max	male	26	Student	PT	Urban
Nora	female	34	Architect	Car	Urban
Jonas	male	26	Student	Car	Urban
Oli	male	21	Student	Car/PT	Rural
Leon	male	21	Student	Car	Rural
Philip	male	22	Industrial Mgmt. Assistant	Car	Rural
Sandra	female	20	Apprentice	Car	Rural
Lukas	male	24	Student	PT	Urban
Markus	male	22	Assistant Tax Consultant	Car	Rural
Nina	female	20	Student	PT	Urban
Manuel	male	22	Student	Car	Urban
Stefanie	female	25	Student	PT	Urban
Dennis	male	30	Nurse	Car	Rural
Jan	male	22	Student	PT	Urban
Stefan	male	21	Student	PT	Urban
Julia	female	21	Student	PT	Rural
Emma	female	32	Housewife	Car	Rural
Marie	female	27	Consultant	Car	Urban

**Table 1: Socio-Demographic Data of Study Participants**

\*PT = Public Transportation

### 3.2 Data Analysis

The interviews were conducted face-to-face and audio-recorded. They were then fully transcribed and analyzed independently by three researchers. For the content analysis of the dataset, we followed a thematic analysis procedure based on (Braun and Clarke, 2006). Thematic analysis is a method for identifying, analyzing and creating topics from datasets (Boyatzis, 1998), which is used to meaningfully

summarize the key aspects of a large amount of data. Thematic analysis, highlights similarities and differences between datasets. It also enables unforeseen new in-sights to be generated. It is often used for the analysis of qualitative data and is flexible because it is not bound to any theoretical framework. For our analysis, we first familiarized ourselves with the material. As transcription of the interviews was divided up among the researchers, some familiarization had already been achieved during the transcription, as well as through close reading of the other transcribed interviews. In

the next step, we started to code the interviews. To do this, we chose a deductive semantic approach. We followed this more theory-driven, rather than inductive, approach because we had clear research questions that had already shaped the structure of the interviews. We knew, for example, that we wanted to extract the advantages and disadvantages of taxi services, which therefore had corresponding codes. Not only were passages coded that were related to our specific inter-view questions, but also interesting passages such as subordinate clauses explaining other concerns. During the initial coding, we began to assign topics and sub-topics by making color mappings. Once we had systematically coded the complete data set, we checked the pre-structured codes, searched for topics and combined them into motifs. We then reorganized the code system by grouping the codes into themes and subtopics before finally sorting the themes. In the next phase, we checked whether the topics were consistent with the elaborated, coded passages and the entire dataset. The coding system was then applied to all of the interviews and iteratively refined, extended and adapted as and when new interviews required it. Finally, we selected meaningful examples of the most relevant topics, representing the diversity and breadth of the interviews, prior to working up the analytic results in text form as findings.

## 4 Findings

In this section we present the results of the interviews. Asking the participants only about their opinions of the SAV concept would have provided us with purely speculative answers. We therefore began by discussing their existing mobility practices. In the findings, we will commence by examining how the participants' currently used taxis and their attitudes to them, illustrating different aspects through quotations and examining the background relevance of having an actual taxi driver, prior to any possible replacement by automated taxis. This will then serve as a backdrop against which to examine the later findings regarding the notion of using SAVs.

### 4.1 Use of taxis

Most of the participants only used taxis very rarely and for private purposes. There was, however, one female participant - Marie, 27 - who, for professional reasons, used a taxi several times a week that was paid for by her employer. Her taxi use centered upon getting from home to the airport, from the airport to work, and getting to a hotel after business lunches. In everyday life, the other participants used taxis mainly for trips home after events or parties: *"Taxis make sense in that you can order a car if you are no longer*

*able to drive yourself or do not have a suitable means of transport and there are no public transport stops nearby."* (Daniel, 28, car-user). However, they emphasized that they would only order a taxi if the route could not be covered by alternatives such as public transport, family or friends taking them in the car, using a bicycle or going by foot - i.e. *"only if there is no other way"* (Markus, 22, car-user). The high cost of taxis was repeatedly mentioned as a reason why this comfortable means of transport was not used more frequently: *"Taxis are relatively expensive, especially in Germany, so as a student, if I found another way, I wouldn't spend any money on a taxi now and yes, so I take taxis maybe two or three times a year, that's why."* These comments in the context of taxi usage show how very price-sensitive Millennials are when it comes to travel mode choices - particularly students, who made a point of mentioning that they had a limited financial budget when discussing the use of taxis.

Outside of their everyday life, Millennials use taxis occasionally during vacations or when they are in foreign cities for other (e.g. professional) reasons: *"On vacation, for example, I always hire taxis, if I don't know my way around at all - because then it's actually quite convenient - you don't have to look at any big train schedules - maybe you don't have the time or the desire to do so - then of course it's also a reason to order a taxi, because you can also get in and the taxi driver will take you from A to B"*. (Markus, 22, car-user). In these situations, where *"not knowing one's way around"* plays a role, the taxi driver has the big advantage of being street-smart, so that the customer doesn't have to figure this out for her/himself and can save a certain amount of effort by not having to study *"bus schedules"*, which can be very complicated in places you don't know.

So, for Millennials, taxis are considered relatively expensive and therefore are used only when you don't want to drive and have no other choice, but are a good option when you are somewhere you don't know.

### 4.2 Positive Opinions Regarding Taxi Services

The respondents saw some clear advantages in using taxi services compared to mobility alternatives such as a car or public transport (PT). Generally, the participants take for granted the fact that 'taxi' is a conflation of a vehicle and the person who drives. Thus, when talking generally about a taxi service, they do not differentiate between the taxi vehicle, the service and the taxi driver. So, we find Lukas saying: *"Yes, the advantages are, of course, that it is very convenient that you have almost no waiting time, because you actually always get to a taxi, most of the time they are standing in front of the discotheques and then you just have to get on and they take you immediately to the location where you want to go, you don't have to go to any bus stop or home from a bus*

stop.” (Lukas, 24, PT). The comment suggests that for Lukas “convenient” means that the service is very quickly available and easy to get to when it is needed, especially compared to PT, which has restrictions because of bus stops and fixed departure times. In addition, many participants mentioned that a great advantage of a taxi is that you do not have to drive it yourself, so it is particularly suitable as a means of transport in situations where the user is no longer roadworthy, for instance, because of drinking alcohol at a party. However, there were other situations the respondents appreciated the aspect of not having to drive themselves: “Sometimes at super important appointments that follow one another directly, such as an exam, an interview or an apartment inspection, it is practical, because one does not have to drive and isn’t that stressed.” (Stefanie, 25, PT). So, for Stefanie, not-driving-herself was the main advantage of a taxi, because she often got stressed in situations where she wanted to concentrate on important things. Finally, Leon particularly appreciated the use of taxis for journeys to or from the airport: “Advantages, especially in comparison to buses and trains, are that it is more flexible - almost like your own car [...] and that you can transport things or luggage in the trunk of your car.” (Leon, 21, Car).

So, Millennials appreciate that taxis are almost as flexible and fast as private vehicles, can also be used for time-critical trips, but offer the advantage of not having to drive yourself.

#### 4.3 Orientations to the Driver

When the participants talked about their opinion of taxi services, they also mentioned positive and negative experiences related to the taxi drivers themselves. Jonas (26, Car) appreciated the fact that taxi drivers usually know an area well: “It’s nice to be able to sit in a car and the drivers know their way around and take you where you want to go, even if you don’t know anything about a place”. The taxi driver takes the effort of finding all the necessary information one needs to orientate, plan and carry out a journey independently off the customer’s shoulders by using his or her knowledge.

Some participants, however, reported unpleasant experiences they had had during taxi rides, related to the behavior of the actual drivers. Julia described various occasions where she had ended up having a negative view of the behavior of the driver: “Of course it takes all sorts of drivers. Some were very unfriendly. There are some who smoke in the car. I don’t like that because I don’t smoke myself”. For Julia, as a customer, certain kinds of behavior amount to a form of disrespect, taking for granted the right to smoke being one of them. She added: “What has already happened to me is that drivers were on their mobile phones while they were driving because they received other orders and then I said,

‘Could you perhaps put your mobile phone away?’ That makes me feel kind of insecure.” Julia here describes a situation that is known to be risky in road traffic, namely the use of a mobile phone while driving. This is a crime in many countries. Julia felt “insecure” because the taxi driver, into whose care she had placed herself, was putting her in danger by breaking the traffic rules. Other respondents also commented that taxi drivers do not always adhere to traffic rules. Jonas (26, car-user) considered this to be one of the disadvantages of using a taxi “that you cannot determine your driving style yourself. I have experienced that taxi drivers drive much too fast. Sometimes I feel endangered when driving in a taxi.”. The phrase “cannot determine your driving style yourself” shows that Jonas generally preferred to be in control in situations that can be potentially dangerous like driving a car. Marie criticized the attention of drivers in road traffic: “Recently drivers have overlooked cyclists more frequently”. The term “overlooked” suggests that she feels that the drivers are not concentrating enough on their work and are missing important features of the traffic, potentially endangering the safety of the occupants and other road users. An outcome of this is a reduction of trust in taxi drivers.

To sum up, Millennials value that they can rely on taxi drivers’ knowledge of areas and routes. However, they dislike unfriendly and risky behavior, especially when drivers do not obey traffic rules.

#### 4.4 Use of the Taxi Driver’s Services

By and large, the respondents said that before or during trips they interacted very little with the taxi drivers. Some did say they talked to the taxi driver while driving. Julia (21, PT-user) used taxis or Uber occasionally when on holiday in foreign cities, especially on the way from and to the airport. In this situation she converses with the driver: “When you are in a foreign city, you can chat like: ‘What things can you do here? Which restaurants are good?’” However, she reflected on this statement afterwards to consider whether this interaction with the driver was really necessary: “Nowadays, there are so many other possibilities to inform oneself and there is hardly a place where I don’t know anyone who has been there before and whom I could ask beforehand, so this is no longer a real advantage of a taxi driver. Especially because many taxi drivers - depending on where you are - don’t speak English very well.” Apart from these specific occasions, when she liked to talk to the drivers, Julia, as with many of the other interviewees, did not generally like chatting with taxi drivers: “It’s not like I always talk to taxi drivers. That depends more on my mood or the driver’s mood.” Julia and many of the others associated the situation of being in a taxi with a social situation in which it is (culturally) appropriate to talk to each other. This expectation or the fact that the

drivers start a conversation (because the driver may also think it is part of his job) was often expressed as the reason why the interviewees talked to the driver. Less often was a conversation motivated by real interest. Marie, who uses a taxi 5-6 times a week for business, even said that it *"bothers"* her when the taxi drivers want to talk to her: *"Because I have no interest in conversations and sometimes simply want to have my peace. [...]".* Even though taxi drivers are usually very skilled at having conversations with their passengers and know what kinds of topics may be safely broached between strangers, Marie sometimes disliked the topics that the taxi drivers came up with during a ride: *"Preferably no personal stories. (...) If he starts telling me about his children or their school problems or that they are rejected on apartment inspections because they are foreigners, I don't care."* Marie personally didn't consider conversations about very private subjects, such as the driver's children or his visits to rental apartments to be appropriate, as she had no close relationship with the driver. She didn't want to know private details about the driver, comment on them or reveal anything about herself. Emma (32, Car) even actively tried to avoid such situations because she found them so unpleasant: *"When we are driving in groups, I prefer to sit in the back and think someone else can talk to him in front"*.

Apart from chatting and getting tips, the interviewees only discussed the help they received when loading or unloading luggage. Marie appreciated this service: *"I like that the drivers help me with the suitcases. If you travel a lot, this service makes a difference."* She found it pleasant that she was helped with her heavy luggage, especially as she took a taxi so often and frequently had heavy luggage with her, not for her private pleasure, but for professional purposes. Notice her emphasis upon *"if you travel a lot"*. This marks out the fact that she needed to account for her interest in this service. So, she did not take it for granted that this was something that just anyone would want or like. Julia, who only used taxis privately, also appreciated this service: *"When you travel and have a lot of luggage, it's pleasant to have a taxi driver who lifts the luggage into the trunk."* As she already had the topic of autonomous taxis in mind during the conversation, she added: *"But so far I have always tried to make sure that I can carry my luggage myself."* With this comment she made it clear that she did not assume that she would need the help of a taxi driver and could do without one if necessary. Emma also used taxis during her holidays: *"In Thailand I used taxis a lot with luggage. I don't know if they helped at all - but I think so. But that is not important for me at all."* She can't even remember if the drivers helped her with the luggage, which is made clear by the addition *"I don't know [...] I think so"*. This example shows again that some aspects of what taxi drivers do are more or less taken

for granted and often do not result in passengers being any more impressed by the service.

However, lots of the participants felt rather independent and like to stow their luggage or pack their purchases into the vehicle by themselves. Although Emma had (probably) made use of luggage services during her holidays, she generally had a very strong need to do things like this on her own: *"I'm not so into services. I also thought it sucked when they introduced an attendant at the gas station who fills up the car for you - I don't like such things and want to do it by myself. That's why I find taking a taxi unpleasant, because it's a person who provides a service for me."* She even said that it was *"unpleasant"* when describing how she felt when being served. The example of the gas station attendant shows that she didn't like to have other people perform such services, which she could do herself or that she actually did by herself.

Thus, some participants like to chat with drivers, and appreciate their assistance with luggage, but these interactions don't seem to be very important. So, Millennials probably wouldn't miss them if travelling in an SAV. However, it is possible that Millennials benefit from other interactions or services that they currently take wholly for granted when using a taxi, hence their failure to mention them. Unpicking the taken-for-granted aspects of taxi travel will require further empirical study in the future.

#### 4.5 Choosing Between Traditional and Automated Taxis

When we asked the participants to choose either a traditional taxi with a driver or an automated, driverless taxi given the scenario described in the methodology section, a relatively uniform picture emerged: Most of the Millennials chose the automated, driverless taxi - mainly because of the lower price: *"I would choose the autonomous service because it is cheaper, and I have the same benefit. The only question is whether you trust people or technology. But since I don't find most taxi drivers trustworthy, I would use the automated driving service."* (Stephanie, 25, PT-user). So, for Stephanie, two points were decisive for her decision in favor of the driverless taxi: first, the lower cost; second, her distrust of taxi drivers. For Max (26, PT-user), too, it was not just the cheaper price that was decisive for his choice: *"I've also experienced far too often that taxi drivers drive very bad, so I'd almost prefer to get into an autonomous taxi than if a driver were sitting in it."* So, Max could imagine doing without a driver because the driver could make him feel his life was at risk. With Alex (27, PT-user), his distrust of taxi drivers was the predominant reason for choosing an automated, driverless taxi: *"I would choose the autonomous service, even if it were more expensive. It would probably bring me home*

*safer than an insane taxi driver who wants to make as much profit as possible.*" Alex was very well-informed about autonomous driving and open-minded about the possibilities that autonomous driving offers. He expressed a hope that *"the technology will soon be used nationwide"*. Apart from his distrust of taxi drivers, his enthusiasm for autonomous driving was probably one of the reasons why a cost advantage was not relevant to him when making his decision. In his case, he even said he would accept an extra charge for an autonomous taxi. Emma's reasoning needs to be set against the fact that she doesn't like to have services provided for her. She, too, opted for the automated taxi. She justified her choice in the following way: *"I would choose the automated taxi because it is cheaper - I don't get anything out of a driver"*. This statement clearly sums up the fact that she sees no added value in the mere presence of a driver.

Another feature of the findings was that many of those involved initially expressed concerns about the safety of driverless taxis. Sophie (26, car-user), for instance said: *"If it's still something new, I'd say I'd rather take the taxi driver, I can talk to him and say: 'Oh watch out, over there!'. With the other one I don't know which button I have to press to intervene and with the taxi driver I can at least grasp the steering wheel. But if that is something that is already totally established and has become normal, then it wouldn't make any difference, then I would order the driverless taxi as well."*. Sophie's comment shows clearly that her safety concerns are mainly based on the fact that the technology is not yet available, that it has not yet been tested, that others cannot yet report on their experiences with it and that she did not know how to intervene with a driverless taxi in the case of doubt. This she posed in contrast to an actual driver, where she could at least say something or *"grasp the steering wheel"*). It is, of course, important that not all Millennials have confidence in a driverless technology. However, we do not want to elaborate on concerns about safety and confidence in the technology at this point. In this particular study, the focus was on the importance of the driver.

Interestingly, the prospect of any threat to taxi drivers' jobs posed by autonomous vehicles did not seem to play a role in the choice between the two alternatives. Some respondents raised this issue of job losses on their own when we talked about autonomous driving in general: *"If only these cars are used and then no buses, coaches and trains are used anymore and so on, that of course costs a lot of jobs, people will be rationalized and that is of course a critical point"* (Markus, 22, car-user). Like Markus, some participants associated the emergence of AVs and SAVs with a threat to jobs. However, for none of the respondents did this feature in their actual decision-making.

In other words, most participants would opt for a driverless taxi rather than a human taxi – provided the technology

has been established – mainly for reasons of lower cost and their distrust of human drivers.

#### 4.6 Use Scenarios

After introducing the topic of automated taxis, we also asked the participants what kind of trips they could imagine with a driverless taxi. We were interested in the question of use scenarios because we wanted to ascertain whether driverless taxis might be used exclusively for certain type of journey. This would have implications, in turn, for whether all taxi journeys might be carried out by driverless taxis in the future, or only some of them. Most of the participants replied that they would mainly undertake the same trips with an autonomous taxi that they are currently using a traditional taxi for: *"For the occasions for which I now use a normal taxi. When I want to go home in the evening and don't come home any other way or when I want to travel and get from the airport to the city. If I want to get from home to the airport, I'm lucky that someone always drives me. But of course, you could also use an automated taxi for that."* (Lisa, 23, car-user).

Interestingly, some participants also mentioned other journeys that they do not currently make by taxi but would consider suitable for an SAV. Alex was so enthusiastic about the idea of an autonomous taxi that he said he would use an SAV for all of his trips: *"I'd use it, so if the price is right, I'd use it to shop, go to work, travel longer distances and visit someone or to drive to the airport or something like that."*. For this, however, he set a condition, namely *"if the price is right"*. At present Alex mostly uses local public transport. He had the following to say about what the right price meant for him: *"I would be satisfied if one kilometer with an autonomous vehicle costs me 20 cents on average. It would definitely have to be cheaper than a taxi. Any cheaper than owning a car - I don't know, I've never calculated it exactly."* He suggested an amount of 20 cents per kilometer, which is very cheap in comparison to other means of transport. At the same time, he made it clear that he hadn't looked at the cost of other means of transport in detail, making it difficult for him to compare the amounts directly and judge them. It was easier for him to make a clear statement about a taxi because the classic use of a taxi would be similar to an SAV in terms of use-dependent costs. This is different for cars, which have fixed costs in addition to their use-based costs. It turned out that it was also difficult for him to determine the cost of using PT per trip, because he had a PT ticket for a whole semester and did not pay for the trips individually.

A few of the participants could not imagine using an automated taxi for their daily trips. This was especially true for the participants whose main means of transport was a car. It was hard for them to picture using an SAV instead of their

own car. This was either because they were used to the flexibility of having their own vehicle available at all times and its associated private space, or because the use of an SAV would not be practicable for them. For example, for Emma, who is the mother of two children aged 1 and 3, the use of an automated taxi for everyday trips was simply deemed unsuitable: *"With automated taxis it would be very complicated. We need child seats. Currently they always stay in the car, but then they would always be in our house, probably in the basement. Then you have to drag them up, then you install them in the car and hope that it fits, because not every seat fits into every car model. Then you would drive somewhere and then you would have to remove the seats if you didn't have the same car on the way back. And for example, when shopping, you stand there with two seats, that would suck."* (laughs). She had at least one child with her on most of her trips and therefore needed a lot of things like child seats or toys, which she left in the car all the time. Using an automated taxi instead of her own car would require a lot of additional effort and coordination. However, she foresaw situations in which she could imagine using an automated taxi: *"The only thing I can imagine is when I go out in the evening and return late by train, then I find it super scary to walk down the mountain to my home [10 minutes by foot]. The other day I walked down and then a man walked behind me in 10 meters distance, it was pitch dark and the way goes through the forest. I wet my pants! In such cases, even if it doesn't matter how long the route is, I would order one of those things. I think taxi drivers say it's too short for them, so I never thought about calling a taxi for it."* So, she thought it made sense to use an automated taxi for a route that she currently did on foot - without children - but where she felt insecure because of the nature of the environment. Using an automated taxi would be a safer option for her, here, as she would be alone in a lockable space and brought to the front door of her house.

So, overall, Millennials would prefer to use automated tax-is for the journeys they now make with traditional taxis and, to some extent, they would use them instead of PT. Depending on the complexity of their travel organization, some would also use AVs for additional trips.

## 5 Discussion

We now want to discuss some of the implications of these results for the taxi industry. To this end, we will divide this section into four parts that relate to different aspects of the findings, covering the kinds of rides that might be performed by automated taxis, the necessity of interaction with a human driver, the implications for the taxi driving profession, and the implications for other forms of transport.

### 5.1 The kind of taxi rides Millennials make are particularly suitable to be performed by automated taxis

The purposes for which our participants use taxis largely correspond to the results of more extensive surveys: trips to or from events, arrivals and departures at train stations or airports, and trips in foreign environments, especially on holiday (IFAK, 2014a). Looking at these three types of trips to judge how well or poorly they could be done with a driverless taxi, we need to ask what an automated and driverless taxi could *not* cope with. Thus, whether the driver plays a further role apart from just the driving.

Let's first look at the trips to or from events and parties. Millennials use taxis mainly because they drink alcohol and therefore cannot drive themselves. Sometimes you can actually observe that people are so drunk after a party that they can't walk straight or articulate themselves clearly. Based on this situation, an autonomous taxi might find it difficult to understand where the customer wants to go. Here a taxi driver might have an advantage, because he/she could interact more closely with the customer, could have an identity card with the address shown to him or could be shown the way through gestures at intersections. Experienced taxi drivers sometimes also know their customers, so that they remember where to take them. Here AV viability will depend on things like whether the vehicle will be able to reason in socially nuanced ways and cope with non-verbal communication.

Arrivals and departures at railway stations or airports are often associated with travel where customers take luggage with them. With traditional taxis, the taxi driver usually loads and unloads luggage. It is to be expected that automated taxis would also offer the possibility of stowing luggage. However, a driverless taxi could not physically help its customers to stow luggage in the trunk unless the vehicle was equipped with technical aids such as grab arms, or other lifting mechanisms capable of performing this service, or level access, as is now widely provided for PT. We also saw above that even Millennials sometimes appreciate the human aspect of this service.

Orientation and navigation play a particularly important role with regard to trips in foreign cities or places. Customers appreciate the fact that drivers know their way around and that they can rely on the driver to find the right route. Given that intelligent traffic management systems and GPS navigation already exists, it might be assumed that automated taxis would have the appropriate technological equipment and be capable of intelligent and dynamic routing. However, many taxi drivers are very experienced and know their area very well, so that they know shortcuts or alternative routes that are better and faster than the routes registered in navigation

systems. This can be especially important when it comes to sudden changes in traffic circulation resulting from unforeseen events.

Against the background of the results of the interviews and the possible design of driverless taxis, the three types of journeys examined above seem to be suitable for driverless taxis. However, this is only the current view of the participants in relation to a non-existent technology. When there are autonomous taxis at some point, these people will be older, they will probably use taxis for other occasions, and may-be they will value the support that a human person could provide more than they do today. Then a new generation of young adults may constitute the bulk of taxi users, so we can only assume they will have similar attitudes and needs to our participants.

### *5.2 Interaction with the human driver is not a valuable advantage that justifies the use of a traditional taxi, especially if the automated taxi is cheaper.*

Currently, for Millennials, interaction with taxi drivers is mostly limited to organizational matters such as communicating the destination or payment. Some of this communication is already done via taxi apps like *mytaxi*. This type of communication and coordination could also be handled via an app for automated taxis. Some participants, however, did talk to taxi drivers. Nonetheless, when analyzing their comments, it was noticeable that they did not usually actively seek conversations, but rather reacted passively to questions and comments from the taxi driver. Some even found such conversations awkward rather than entertaining. In this respect the automated taxi would have no disadvantage. Even if a customer would like to have entertainment or tips on the surroundings, a language assistant such as Siri or Alexa could provide this kind of service (Lugano, 2017).

However, as we have pointed out already, the social organization of a taxi ride is about much more than just chatting with the driver and loading luggage. Usually, passengers do not experience these activities, because drivers do them as a matter of course and in tacit ways, while other activities are not noticed by the passengers because they accept them as a given. Thus, the participants did not mention these activities and interactions in the interviews. We have in mind here, in particular, things like anticipatory work based on intersubjective reasoning that it is unlikely an automated taxi would be able to replicate. There are forms of interaction that take place before rides and at the ends of rides that are often based upon non-verbal exchanges that it is hard to imagine automated taxis handling. Thus, when arriving at busy terminals with long queues of vehicles waiting to pick up

passengers, much of the initial interaction at the moment is handled through mutual gaze and gesture. When arriving at a destination, taxi drivers currently judge just where to drop people and how long to wait for them to exit on the basis of subtle visual monitoring and a mutual exchange of glances. Some of this would be challenging for AVs as they are conceived at present. All of this points to a serious need to engage in further, more thoroughgoing and systematic investigation of how passenger-driver interactions actually proceed, before embarking upon the serious deployment of SAVs. We need to develop a richer understanding of what is actually lost if a real taxi driver is taken out of the equation. Some studies have already been undertaken in this direction (see, for instance (Haddington and Keisanen, 2009) and (Goodwin, 2014)). However, these studies do not focus systematically on the whole course of the ride and are not geared towards providing insights for design.

### *5.3 The fate of taxi drivers, whose profession is threatened by automation, does not play a significant role in how Millennials make a choice.*

Although some participants associated Autonomous Driving with job losses, this aspect did not influence their decision. They clearly have some sympathy for the challenges confronting taxi drivers, but other factors outweighed such considerations, especially cost. At present, to manage this, they accept the disadvantages of other means of transport – such as greater coordination effort or less comfort. Dispassionately, advantages such as a lower price outweigh the disadvantage of possible job losses in their reasoning. The frequently-mentioned issues regarding distrust of taxi drivers may also play a part in this.

### *5.4 The Advent of Automated Taxis also Poses a Threat to PT*

When the participants were considering which routes they might possibly use an automated taxi for, some also mentioned everyday routes, rather than the ones they currently travel in taxis. It was noticeable that PT users, in particular, see an advantage in the flexibility and comfort of SAVs when compared to PT. Most of the participants insisted, however, that using an automated taxi would hinge upon them being cheaper than a conventional taxi (though some individuals were willing to pay more). Simulation-based studies have shown that journeys using SAVs could be substantially cheaper than journeys by private car or taxi, with costs per mile of as little as \$0.41 (Burns, 2013). This currently translates into €0.22 per kilometer. Costs at this level can compete not only with taxis but with public transport. The amount also comes very close to the concrete proposal of

one of the participants regarding the conditions in which he could imagine using an SAV for all of his trips (€0.20 per kilometer). If an alternative means of transport, such as a future automated taxi, could be deployed at these kinds of costs, it would be immediately attractive to many of those who currently use PT. Unlike car drivers, PT travelers are often not tied to their means of transport because they have made no long-term investment in their provision. Thus, it may not be difficult for them to switch to a new offer like an automated taxi. Clearly, further research is required regarding this topic, but the fact that automated taxis could seem particularly attractive and affordable to PT users is important to consider. This is especially important because, even now, AD research is putting a great deal of emphasis upon analyses of how business models can be run profitably (Bösch et al., 2018; Fagnant et al., 2015; Spieser et al., 2014) and which factors might increase the attractiveness of autonomous vehicles and autonomous taxis for users (Krueger et al., 2016; Nordhoff et al., 2017).

To set against this, a shift away from sustainable mass PT to individual PT could lead to unintended negative environmental impacts. All of this is obviously speculative in nature, but it should nonetheless be considered in the development and regulation of automated taxis.

## 6 Conclusion

Automation threatens the traditional taxi industry. If autonomous vehicles become a reality, the profession of taxi driver could become obsolete as a result (Walker and Marchau, 2017). This is despite the fact that representatives of the taxi industry and the taxi driver community currently perceive no threat coming from the introduction of autonomous vehicles (Mönch, 2018). In order to examine the question of whether taxi drivers would still be able to exist in the age of autonomous vehicles, we conducted interviews with 29 ‘Millennials’. We found that Millennials could dispense with human taxi drivers and that some even welcomed this (assuming that automated taxis have been established as a safe means of transport).

Millennials are very self-reliant and hardly ever make use of the additional services offered by taxi drivers. As these younger adults are, on average, fitter than older generations, they can manage luggage more easily on their own and are not dependent on the help of a driver, e.g. when getting in or out or when loading or unloading purchases or luggage. The trips for which Millennials use taxi services are particularly suitable for driverless taxis.

The taxi driver as a person offers no added value to Millennials. On the contrary, some people prefer not to talk to the driver and many have had negative experiences with taxi

drivers who have been unfriendly or who have ignored traffic rules. Overall, the taxi drivers so far encountered by the participants had not demonstrated a high level of service commitment or customer orientation. Of course, there are many professional and socially aware drivers who are capable of judging accurately whether a passenger is in the mood to chat or not. However, this does not seem to be the rule. Service orientation and customer orientation are of central importance in the taxi driving profession and offer one of the few ways to stand out from automated driving services.

The taxi industry should therefore address the threat posed by automated taxis well in advance. When the majority of trips are no longer carried out by traditional taxis but rather by automated ones, fewer taxi drivers will be needed. This also needs to be considered by politicians and transport planners when issuing taxi concessions. It is important to actively shape this structural change with the involvement of all stakeholders in the taxi industry instead of being caught out by the pace of innovation and shifts in the patterns of customer service consumption.

We cannot draw conclusions about the entire taxi clientele from this study. Millennials represent only a specific part of the population and taxi customers. In Germany, however, under 39s account for up to 41% of taxi customers, a significant proportion of the taxi business. If Millennials as a customer group were to completely or even partially shift to using automated and driverless taxis, this would mean a significant loss in sales for traditional taxi companies, driving many out of business. It is also the case that the over-40s use taxis mainly for trips that do not necessarily have to be accompanied and supported by a human driver (IFAK, 2014a). Only 10% of trips involve active assistance from a driver, for instance when taking patients to hospital. Clearly there is a need to understand these other groups as well, so future research needs to cover the preferences of other taxi customers.

We also feel there is a need for a more differentiated view when considering the impact on the taxi industry. Analysis of the AD literature and the discussion of its social impact reveals a recurrent claim that drivers will be affected or become obsolete in the advent of driverless vehicles (Davidson and Spinoulas, 2016; Litman, 2017; Mounce and Nelson, 2019; Walker and Marchau, 2017). So, we need analysis not only of how much of the business (i.e., journeys) will be threatened by automation, but also of *how* the profession of driver will change and what developments will take place on the way to full automation, during the transitional phases. Against the background of these kinds of research results, there will be a need to discuss how changes in industries with professional drivers can be undertaken in a socially acceptable way.

Beyond all of this, the design of automated vehicles is still in its infancy and deployments are limited and, at best, exploratory. It is therefore pressing that adequate research be conducted now, before the push to deployment outstrips our understanding. For instance, we found that, despite their expressed preferences, Millennials do not necessarily take into account the range of ways in which taxi drivers interact with their customers and the extent to which these interactions may be critical to the provision of an effective service. Nor do we yet know how taxi services may shift to certain niche markets. In short, it is early days to assume the future for taxi drivers is bleak, but we do need to explore the character of future transport provision in a way that more comprehensively examines their current contribution.

## References

- Alessandrini, A., Campagna, A., Delle Site, P., Filippi, F., Persia, L., 2015. Automated vehicles and the rethinking of mobility and cities. *Transportation Research Procedia* 5, 145–160.
- Axhausen, K.W., 2008. Social networks, mobility biographies, and travel: survey challenges. *Environment and Planning B: Planning and design* 35, 981–996.
- Barton, C., Haywood, J., Jhunjhunwala, P., Bhatia, V., 2013. *Traveling with Millennials*. Boston Consulting Group.
- Baslington, H., 2008. Travel socialization: A social theory of travel mode behavior. *International Journal of Sustainable Transportation* 2, 91–114.
- Becker, H., Ciari, F., Axhausen, K.W., 2017. Comparing car-sharing schemes in Switzerland: User groups and usage patterns. *Transportation Research Part A: Policy and Practice* 97, 17–29.
- Beige, S., Axhausen, K.W., 2012. Interdependencies between turning points in life and long-term mobility decisions. *Transportation* 39, 857–872.
- Beige, S., Axhausen, K.W., 2008. Long-term and mid-term mobility decisions during the life course: experiences with a retrospective survey. *IATSS research* 32, 16–33.
- Bialik, K., Fry, R., n.d. How Millennials compare with prior generations. Pew Research Center's Social & Demographic Trends Project. URL <https://www.pewsocialtrends.org/essay/millennial-life-how-young-adulthood-today-compares-with-prior-generations/> (accessed 9.24.19).
- Biernacki, P., Waldorf, D., 1981. Snowball sampling: Problems and techniques of chain referral sampling. *Sociological methods & research* 10, 141–163.
- Bond, A.T., 2014. An app for that: Local governments and the rise of the sharing economy. *Notre Dame L. Rev. Online* 90, 77.
- Bösch, P.M., Becker, F., Becker, H., Axhausen, K.W., 2018. Cost-based analysis of autonomous mobility services. *Transport Policy* 64, 76–91.
- Boyatzis, R.E., 1998. *Transforming qualitative information: Thematic analysis and code development*. sage.
- Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 77–101.
- Brumby, D.P., Blandford, A., Cox, A.L., Gould, S.J.J., Marshall, P., 2016. Research Methods for HCI: Understanding People Using Interactive Technologies, in: *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems, CHI EA '16*. ACM, New York, NY, USA, pp. 1028–1031. <https://doi.org/10.1145/2851581.2856682>
- Bruns, A., Matthes, G., 2019. Moving into and within cities—Interactions of residential change and the travel behavior and implications for integrated land use and transport planning strategies. *Travel Behaviour and Society* 17, 46–61.
- Buehler, R., Hamre, A., 2015. The multimodal majority? Driving, walking, cycling, and public transportation use among American adults. *Transportation* 42, 1081–1101.
- Burghout, W., Rigole, P.J., Andreasson, I., 2015. Impacts of shared autonomous taxis in a metropolitan area, in: *Proceedings of the 94th Annual Meeting of the Transportation Research Board*, Washington DC, 2015.
- Burns, L.D., 2013. Sustainable mobility: a vision of our transport future. *Nature* 497, 181–182.
- Center for Global Policy Solutions, 2017. *Stick Shift - Autonomous Vehicles Driving Jobs and the Future of Work*. Washington, DC: Center for Global Policy Solutions.
- Chou, C.-Y., 2017. A Lie on Sharing Economy: Solutions for Uber Drivers' Dilemma When Self-Driving Cars Arrive.
- Cohen, S.A., Hopkins, D., 2019. Autonomous vehicles and the future of urban tourism. *Annals of tourism research* 74, 33–42.
- Coyne, I.T., 1997. Sampling in qualitative research. Purposeful and theoretical sampling; merging or clear boundaries? *Journal of advanced nursing* 26, 623–630.
- Davidson, A., Peters, J., Brakewood, C., 2017. *Interactive Travel Modes: Uber, Transit, and Mobility in New York City*.
- Davidson, P., Spinoulas, A., 2016. Driving alone versus riding together—How shared autonomous vehicles can change the way we drive. *Road & Transport Research: A Journal of Australian and New Zealand Research and Practice* 25, 51.
- De Haas, M.C., Scheepers, C.E., Harms, L.W.J., Kroesen, M., 2018. Travel pattern transitions: applying latent transition analysis within the mobility biographies framework. *Transportation Research Part A: Policy and Practice* 107, 140–151.
- Delbosc, A., 2017. Delay or forgo? A closer look at youth driver licensing trends in the United States and Australia. *Transportation* 44, 919–926.
- Dutzik, T., Inglis, J., Baxandall, P., 2014. Millennials in motion: Changing travel Habits of young Americans and the implications for public policy.
- Fagnant, D.J., Kockelman, K., 2015. Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice* 77, 167–181.
- Fagnant, D.J., Kockelman, K.M., 2014. The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. *Transportation Research Part C: Emerging Technologies* 40, 1–13.
- Fagnant, D.J., Kockelman, K.M., Bansal, P., 2015. Operations of Shared Autonomous Vehicle Fleet for the Austin, Texas Market. *Transportation Research Record: Journal of the Transportation Research Board* 98–106.

- Farinloye, T., Mogaji, E., Aririguzoh, S., Kieu, T.A., 2019. Qualitatively exploring the effect of change in the residential environment on travel behaviour. *Travel Behaviour and Society* 17, 26–35.
- Fleisher, L., 2014. Thousands of European Cab Drivers Protest Uber, Taxi Apps: Protesters in London, Madrid, Milan Say the Apps Skirt Regulations. *Wall Street Journal*.
- Garikapati, V.M., Pendyala, R.M., Morris, E.A., Mokhtarian, P.L., McDonald, N., 2016. Activity patterns, time use, and travel of millennials: a generation in transition? *Transport Reviews* 36, 558–584.
- Gladstone, K.A., 2017. The search for the sustainable fleet: driverless taxi system simulations (PhD Thesis). Princeton University.
- Goodwin, M.H., 2014. Shifting frame, in: *Social Interaction, Social Context, and Language*. Psychology Press, pp. 89–100.
- Greenblatt, J.B., Saxena, S., 2015. Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles. *Nature Climate Change* 5, 860–863.
- Gwilliam, K.M., 2005. Regulation of taxi markets in developing countries: issues and options.
- Haddington, P., Keisanen, T., 2009. Location, mobility and the body as resources in selecting a route. *Journal of Pragmatics* 41, 1938–1961.
- Hanks, K., Odom, W., Roedel, D., Blevis, E., 2008. Sustainable millennials: attitudes towards sustainability and the material effects of interactive technologies, in: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, pp. 333–342.
- Hao, M., Yamamoto, T., 2018. Shared autonomous vehicles: A review considering car sharing and autonomous vehicles. *Asian Transport Studies* 5, 47–63.
- Haustein, S., Klöckner, C.A., Blöbaum, A., 2009. Car use of young adults: The role of travel socialization. *Transportation research part F: traffic psychology and behaviour* 12, 168–178.
- Heinen, E., Chatterjee, K., 2015. The same mode again? An exploration of mode choice variability in Great Britain using the National Travel Survey. *Transportation Research Part A: Policy and Practice* 78, 266–282.
- Howard, D., Dai, D., 2014. Public perceptions of self-driving cars: The case of Berkeley, California, in: *Transportation Research Board 93rd Annual Meeting*.
- Hull, J.S., Bachman, J.R., Haecker, S., n.d. Understanding Millennial Interest in Participating in Wine Tourism-A Case Study on the Kamloops Wine Trail, British Columbia, Canada.
- Hultsch, D.F., Cornelius, S.W., 1995. Kritische Lebensereignisse und lebenslange Entwicklung: Methodologische Aspekte. *Kritische Lebensereignisse* 3, 72–89.
- IFAK, 2014a. Kundenzufriedenheit mit Taxiunternehmen in Deutschland 2014.
- IFAK, 2014b. Kundenzufriedenheit mit Taxiunternehmen in Deutschland 2014 - Tabellenbericht.
- Kolarova, V., Steck, F., Cyganski, R., Trommer, S., 2018. Estimation of the value of time for automated driving using revealed and stated preference methods. *Transportation research procedia* 31, 35–46.
- Kraftfahrt-Bundesamt, 2010. Fahrerlaubnisbestand im Zentralen Fahrerlaubnisregister (ZFER) am 1. Januar 2010.
- Kraftfahrt-Bundesamt, n.d. Bestand an allgemeinen Fahrerlizenzen im ZFER am 1. Januar 2019 nach Geschlecht, Lebensalter und Fahrerlizenzenklassen. 2019.
- Krause, T., 2016. Untersuchung zur Wirtschaftlichkeit des Taxigewerbes in der Bundeshauptstadt Köln. Linne & Krause.
- Krueger, R., Rashidi, T.H., Rose, J.M., 2016. Preferences for shared autonomous vehicles. *Transportation research part C: emerging technologies* 69, 343–355.
- Lanzendorf, M., 2010. Key events and their effect on mobility biographies: The case of childbirth. *International Journal of Sustainable Transportation* 4, 272–292.
- Lenz, B., Nobis, C., Köhler, K., Mehlin, M., Follmer, R., Gruschwitz, D., Jesske, B., Quandt, S., 2010. *Mobilität in Deutschland 2008*.
- Lewis, E.O., MacKenzie, D., 2016. MacKenzie 1 UberHOP in Seattle: who, why, and how? - Google-Suche. *Transportation Research Record: Journal of the Transportation Research Board* accepted.
- Liang, X., de Almeida Correia, G.H., Van Arem, B., 2016. Optimizing the service area and trip selection of an electric automated taxi system used for the last mile of train trips. *Transportation Research Part E: Logistics and Transportation Review* 93, 115–129.
- Litman, T., 2017. Autonomous vehicle implementation predictions. *Victoria Transport Policy Institute* 28.
- Lugano, G., 2017. Virtual assistants and self-driving cars, in: *2017 15th International Conference on ITS Telecommunications (ITST)*. IEEE, pp. 1–5.
- Madrigal, A.C., 2018. Could Self-Driving Trucks Be Good for Truckers? *The Atlantic*. URL <https://www.theatlantic.com/technology/archive/2018/02/uber-says-its-self-driving-trucks-will-be-good-for-truckers/551879/> (accessed 9.3.19).
- McDonald, N.C., 2015. Are millennials really the “go-nowhere” generation? *Journal of the American Planning Association* 81, 90–103.
- Metz, D.H., 2000. Mobility of older people and their quality of life. *Transport policy* 7, 149–152.
- Møller, M., Haustein, S., Bohlbro, M.S., 2018. Adolescents’ associations between travel behaviour and environmental impact: A qualitative study based on the Norm-Activation Model. *Travel Behaviour and Society* 11, 69–77.
- Mönch, A., 2018. Wir machen das Taxigeschäft effizienter.
- Moreno, A.T., Michalski, A., Llorca, C., Moeckel, R., 2018. Shared Autonomous Vehicles Effect on Vehicle-Km Traveled and Average Trip Duration. *Journal of Advanced Transportation* 2018.
- Mounce, R., Nelson, J.D., 2019. On the potential for one-way electric vehicle car-sharing in future mobility systems. *Transportation Research Part A: Policy and Practice* 120, 17–30.
- Müggenburg, H., Busch-Geertsema, A., Lanzendorf, M., 2015. Mobility biographies: A review of achievements and challenges of the mobility biographies approach and a framework for further research. *Journal of Transport Geography* 46, 151–163.
- Nobis, C., Kuhnimhof, T., 2018. *Mobilität in Deutschland - MiD Ergebnisbericht*. Studie von infas, DLR, IVT und infas 260 im Auftrag des Bundesministers für Verkehr und digitale Infrastruktur (FE-Nr. 70.904/15). Bonn, Berlin.

- Nordhoff, S., van Arem, B., Merat, N., Madigan, R., Ruhrort, L., Knie, A., Happee, R., 2017. User Acceptance of Driverless Shuttles Running in an Open and Mixed Traffic Environment, in: Proceedings of the 12th ITS European Congress.
- Oakil, A.T.M., Ettema, D., Arentze, T., Timmermans, H., 2014. Changing household car ownership level and life cycle events: an action in anticipation or an action on occurrence. *Transportation* 41, 889–904.
- Pakusch, C., Bossauer, P., Shakoor, M., Stevens, G., 2016. Using, Sharing, and Owning Smart Cars, in: Proceedings of the 13th International Joint Conference on E-Business and Telecommunications (ICETE 2016). Presented at the 13th International Joint Conference on e-Business and Telecommunications (ICETE 2016), pp. 19–30. <https://doi.org/10.5220/0005960900190030>
- Pakusch, C., Stevens, G., Bossauer, P., 2018a. Shared Autonomous Vehicles: Potentials for a Sustainable Mobility and Risks of Unintended Effects, in: EPiC Series in Computing. Presented at the ICT4S2018. 5th International Conference on Information and Communication Technology for Sustainability, EPiC Series in Computing, pp. 258–269. <https://doi.org/10.29007/rg73>
- Pakusch, C., Stevens, G., Bossauer, P., Weber, T., 2018b. The Users' Perspective on Autonomous Driving-A Comparative Analysis of Partworth Utilities, in: Proceedings of the 15th International Joint Conference on E-Business and Telecommunications (ICETE 2018).
- Pantidi, N., Ferreira, J., Balestrini, M., Perry, M., Marshall, P., McCarthy, J., 2015. Connected sustainability: Connecting sustainability-driven, grass-roots communities through technology, in: Proceedings of the 7th International Conference on Communities and Technologies. ACM, pp. 161–163.
- Payre, W., Cestac, J., Delhomme, P., 2014. Intention to use a fully automated car: Attitudes and a priori acceptability. *Transportation research part F: traffic psychology and behaviour* 27, 252–263.
- Pendergast, D., 2010. Getting to know the Y generation. *Tourism and generation Y* 1, 1–15.
- Rau, H., Manton, R., 2016. Life events and mobility milestones: Advances in mobility biography theory and research. *Journal of Transport Geography* 52, 51–60.
- Rayle, L., Shaheen, S., Chan, N., Dai, D., Cervero, R., 2014. App-Based, On-Demand Ride Services: Comparing Taxi and Ridesourcing Trips and User Characteristics in San Francisco. SAE International (Ed.), 2016. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles.
- Sago, B., 2010. The influence of social media message sources on millennial generation consumers. *International Journal of Integrated Marketing Communications* 2.
- Sanders, E.B.-N., Stappers, P.J., 2008. Co-creation and the new landscapes of design. *Co-design* 4, 5–18.
- Scheiner, J., 2017. Mobility biographies and mobility socialisation—new approaches to an old research field, in: *Life-Oriented Behavioral Research for Urban Policy*. Springer, pp. 385–401.
- Scheiner, J., Holz-Rau, C., 2013. Changes in travel mode use after residential relocation: a contribution to mobility biographies. *Transportation* 40, 431–458.
- Schleiffer, N., Fojcik, T.M., Kurowicki, L., Proff, H., 2017. Mobilitätsverhalten der Generation Young, in: *Innovative Produkte Und Dienstleistungen in Der Mobilität*. Springer, pp. 11–27.
- Schoenduwe, R., Mueller, M.G., Peters, A., Lanzendorf, M., 2015. Analysing mobility biographies with the life course calendar: a retrospective survey methodology for longitudinal data collection. *Journal of Transport Geography* 42, 98–109.
- Schulz, L., Faus, R., 2019. Öffentliches Meinungsbild Taxidienste und Uber. pollytix.
- Seppanen, S., Gualtieri, W., 2012. The millennial generation research review. National Chamber Foundation, US Chamber of Commerce. Accessed November 18, 2014.
- Sivak, M., Schoettle, B., 2012. Recent changes in the age composition of drivers in 15 countries. *Traffic injury prevention* 13, 126–132.
- Spieser, K., Treleaven, K., Zhang, R., Frazzoli, E., Morton, D., Pavone, M., 2014. Toward a systematic approach to the design and evaluation of automated mobility-on-demand systems: A case study in Singapore, in: *Road Vehicle Automation*. Springer, pp. 229–245.
- Statistisches Bundesamt, 2019. Entwicklung der Studienanfängerquote\* in Deutschland von 2001 bis 2018.
- Stein, J., 2013. Millennials: The Me Me Me Generation [WWW Document]. URL <https://time.com/247/millennials-the-me-me-me-generation/>
- Stratmann, G., 2017. Zielgruppe Millennials – die „digitale“ Generation und ihre Bedürfnisse. *Marketing im Pott*. URL <https://www.marketingimpott.de/blog/zielgruppe-millennials-die-digitale-generation-und-ihre-beduerfnisse/> (accessed 9.24.19).
- Strawn, G., 2016. Automation and Future Unemployment. *IT Professional* 18, 62–64.
- Sun, Z., Yu, M., Zeng, J., Wang, H., Tian, Y., 2017. Assessment of the Impacts of App-based Ride Service on Taxi Industry: Evidence from Yiwu City in China.
- Valerio, P., 2016. Taxi Drivers, Your Job has an Expiry Date. *Cities of the Future*. URL <https://citiesofthefuture.eu/taxi-drivers-your-job-has-an-expiry-date/> (accessed 9.27.19).
- Walker, W.E., Marchau, V.A., 2017. Dynamic adaptive policymaking for the sustainable city: The case of automated taxis. *International Journal of Transportation Science and Technology* 6, 1–12.
- Witzel, A., Reiter, H., 2012. *The problem-centred interview*. Sage.
- Zarabi, Z., Manaugh, K., Lord, S., 2019. The impacts of residential relocation on commute habits: A qualitative perspective on households' mobility behaviors and strategies. *Travel Behaviour and Society* 16, 131–142.
- Zukunftsinstitut, 2015. *Automotive Zeitgeist Studie 3.0. We-Mobility - Eine Trendstudie über Millennials und die Bedeutung der Mobilität für die Gemeinschaft*, Hg. v. Ford-Werke GmbH und Zukunftsinstitut GmbH.