COVER PAGE

Submission number: _____155_____

RIDING IN AN AUTONOMOUS CAR: WHAT ABOUT THE USER PERSPECTIVE?

LENZ, Barbara [a], FRAEDRICH, Eva [b] and CYGANSKI, Rita [c]
[a] *DLR Institute of Transport Research, Berlin (Germany)*
Email: barbara.lenz@dlr.de
[b] *DLR Institute of Transport Research, Berlin (Germany)*
Email: eva-maria.fraedrich@dlr.de
[c] *DLR Institute of Transport Research, Berlin (Germany)*
Email: rita.cyganski@dlr.de

ABSTRACT

Autonomous driving has come within reach and is expected to have significant impact on the way we travel and how the transport system develops. The user will play an important role for the dynamics of autonomous driving implementation. Key issues are the impact of mode choice behavior and the increased attractiveness of road transport because of the possibility for alternative time use while riding in a self-driving vehicle. The article shows that although people have just started thinking about autonomous driving and imaginable consequences for their personal life, a significant share of them is aware that the self-driving car could change their mode choice behavior. At the same time, however, people do not anticipate major changes in travel time use – at least not at present. This brings into question the frequently addressed remarks on the particular usefulness of autonomous driving for alternative (and more productive) travel time use.

Keywords: autonomous driving, user acceptance, user behavior, time use, mode choice

Subject area: (Please put a "X" as appropriate, you may choose more than one)

	a)	Transportation Infrastructure and Built Environment
	b)	Sustainability Issues in Transportation
	c)	Travel Behavior Modeling
	d)	Technology and Information
x	e)	Transport Geography
	f)	Transport Dynamics
	g)	Logistics and Supply Chain Management
	h)	Transport Networks

Preferred mode of presentation: (Please put a "X" as appropriate)

	Oral presentation only		Poster presentation only
x	No preference		

Name of presenter/key speaker:

Barbara Lenz

Request for the consideration of publication in the Proceedings: (Please put a "X" as appropriate)

x	Presentation and Publication		Presentation only

Submission for HKSTS Outstanding Student Paper Award (You are a postgraduate student and the sole author of the paper): (Please put a "X" as appropriate)

[ ] Yes [x] No

Submission for HKSTS Outstanding Dissertation Paper Award (You are PhD graduate who is citizen of an Asian country and who has completed your PhD study within three years and the first author of the paper): (Please put a "X" as appropriate)

[ ] Yes [x] No

RIDING IN AN AUTONOMOUS CAR: WHAT ABOUT THE USER PERSPECTIVE?

LENZ, Barbara [a], FRAEDRICH, Eva [b] and CYGANSKI, Rita [c]
[a] *DLR Institute of Transport Research, Berlin (Germany)*
Email: barbara.lenz@dlr.de
[b] *DLR Institute of Transport Research, Berlin (Germany)*
Email: eva-maria.fraedrich@dlr.de
[c] *DLR Institute of Transport Research, Berlin (Germany)*
Email: rita.cyganski@dlr.de

ABSTRACT

Autonomous driving has come within reach and is expected to have significant impact on the way we travel and how the transport system develops. The user will play an important role for the dynamics of autonomous driving implementation. Key issues are the impact of mode choice behavior and the increased attractiveness of road transport because of the possibility for alternative time use while riding in a self-driving vehicle. The article shows that although people have just started thinking about autonomous driving and imaginable consequences for their personal life, a significant share of them is aware that the self-driving car could change their mode choice behavior. At the same time, however, people do not anticipate major changes in travel time use – at least not at present. This brings into question the frequently addressed remarks on the particular usefulness of autonomous driving for alternative (and more productive) travel time use.

Keywords: autonomous driving, user acceptance, user behavior, time use, mode choice

1. INTRODUCTION

Autonomous driving – particularly on roads – has become a hot topic in research. It is assumed that in a longer term perspective, the transport system will change from human-driven to self-driving vehicles with implications on the system itself and on the use of transport modes in particular. Besides the expected increase in comfort and new mobility options, one new and notably relevant aspect when traveling in a self-driving car is the possibility of alternative time use: time does no longer need to be invested in the driving task, but can be used for other productive or recreation- and leisure-oriented activities, possibly even sleeping. Given that autonomous driving offers new mobility perspectives and may heavily impact user behavior, the acceptance of the new technology is assumed to being the key to the dynamics of the implementation of autonomous driving. Research on acceptance and behavioral impact of autonomous driving, however, is still in its infancy.

Against this background we put up a survey that aimed at understanding the attitudes, expectations and reservations of today's road users towards autonomous driving, together with their assumptions of personal mode choice once the self-driving car is available, and expected time use when traveling in a self-driving car. The complete survey was published in 2016 (Fraedrich *et al*. 2016); whenever we refer to the original text, we will indicate this by the corresponding page numbers. The survey was held in Germany in 2014 with a sample size of 1,000 persons, the large majority of them car users. To deal with the challenge that is linked to the examination of users who lack direct experience with the topic in question we applied an approach that combined questions on autonomous driving with questions for specific use cases – both within the framework of a quantitative approach. In the following, we will specifically focus on the expectations of respondents towards their future mode choice and time use in an autonomous vehicle. After a short outline of the literature, we will describe the design of the empirical study, then report and discuss the respective study results and end with conclusions and an outlook on further research needs.

2. TRAVELING IN A SELF-DRIVING CAR

So far, the human aspect of increasing driving automation has been studied almost exclusively in the context of driving assistance focusing on Human Machine Interaction (HMI). With the perspective of self-driving cars getting into the transport system, new issues arise as it is no longer the direct interaction between driver and vehicle that has to be understood, but the interaction between humans and the transport *system* where the self-driving car is about to represent a "new" means of transport. At present, there are two categories of studies concerning autonomous driving and user behavior. These categories can be distinguished by their objectives and the methodologies they apply. One category consists of "what if" studies which aim at exploring the impact on travel demand and travel behavior coming along with changes in "travel conditions" by the self-driving car. Many studies of this category concentrate on new services enabled by autonomous vehicles and their impact on travel demand and mode choice. "What if" studies typically apply travel demand models. The second category comprises empirical studies on user acceptance that explore attitudes, expectations and reservations towards autonomous driving as well as anticipated individual behavioral change. These studies use qualitative and quantitative methods of empirical social research.

One of the leading "what if" studies so far is the "Urban mobility upgrade" experiment for the Lisbon case (ITF/OECD 2015). The general approach of this experiment consists in the reproduction of the current transport demand and its application on a self-driving car sharing fleet. The study assumes that all trips of 1 km and more are made with self-driving vehicles. Taking into account aspects like the availability of alternative transport modes at ease, maximum waiting times and maximum trip duration times, the study identifies individual "least cost itineraries". One important result of the study is that the preference for the [shared] car would increase considerably.

Other "what if" studies focus on the particular aspect of time use and its implications on modal choice and travel behavior (e.g. Silberg *et al*. 2012). They come to the result that the alternative time use in a self-driving vehicle will lead to an increased preference for the car or car-like road vehicles respectively thus having substantial impact on modal choice and car ownership. Further outcome of changing travel behavior can be the increase in vehicle kilometers traveled (e.g. Fagnant and Kockelman 2013; Willumsen 2013; Litman 2015).

Studies that address the acceptance of autonomous driving investigate and analyze attitudes, expectancies and reservations of potential users of self-driving cars. In the early phase of autonomous driving, studies found that users' perception concentrated on the car itself, its safety and comfort, but also on issues of liability (Fraedrich and Lenz 2015a). At the same time, the skepticism towards the reliability of self-driving car was still high, but potential users also expressed optimistic views on the new technology. In the explorative part of their study, Zmud *et al*. (2015) got similar findings, and, most interestingly, found their respondents concluding that using the self-driving car would "be like using public transit but better" (p.36).

In parallel to qualitative research first quantitative studies appeared with the specific interest how likely people are to use a self-driving vehicle and how people see their travel behavior once they have access to a self-driving car (Continental 2013, Schoettle and Sivak 2014; Zmud *et al*. 2015). One specific aspect in these studies was the alternative use of travel time which represents one major promise about the usefulness of autonomous driving. So far, however, respondents do not expect a major change in their time use; they indicate their favorite "activities" would continue to be listening to music or talking to other passengers in the car (Continental 2013). Also, it is [still] a minority of car drivers who welcome the possibility for being productive while travelling in a car (Fraedrich and Lenz 2015b; Schoettle and Sivak 2014). Only a few studies take a direct look at people's expectations about changes in their personal travel behavior once they travel in a self-driving car. In the qualitative part of their analysis, Zmud *et al*. (2015) found that two thirds of the respondents did not expect any change, while 25% thought they will travel more, above all due to an increase in long distance and leisure trips.

Altogether, studies say that users become aware of autonomous driving, many of them believing that this technology will be the future of transportation, while still having reservations in particular towards the safety and reliability of the self-driving car. There are also first considerations about how people might change their travel behavior. At the same time, it is worth noting that most research tries to meet the particular challenge that autonomous driving is not yet directly observable and evident for users in one way or the other. In the following, we will elaborate the methodological approach of our study and how we tried to meet the users' lack of experience.

3. STUDY APPROACH AND SAMPLE CHARACTERISTICS

The aim of our survey was to explore user perspectives on autonomous driving by asking users of the transport system in Germany about their attitudes and mindsets towards autonomous driving and about their expectations with respect to individual behavioral change once they have access to a self-driving car. The sample consisted of 1,000 completed questionnaires and was stratified by gender, age, income and education in order to be nearly representative for the German population aged 18 or above. Table 1 provides an overview of the sociodemographic characteristics of respondents and the sample structure as well as information on driving license possession and car ownership rates.

Table 1. Selected socio-demographic and transport behavioral characteristics of the data set (cf. Fraedrich *et al*. 2016, pp. 32-33)

Attribute	Level	Percent
Gender	female	56 %
Age	18-29 years	9 %
	30 – 49 years	34 %
	50 – 64 years	32 %
	65+ years	26 %
Children under 18 in the HH	no	76 %
Household size	1 person	17 %
	2 persons	48 %
	3+ persons	36 %
High school degree	yes	30 %
Occupational status	full-time (≥ 35 h/w)	32 %
	part-time (18 - < 35 h/w)	13 %
Driving license	yes	90 %
Number of cars in the household	0	13 %
	1	52 %
	2+	36 %
Usual car usage (driver)	(almost) daily	55 %
	1-3 days a week	23 %
	1-3 days a month	5 %
	less than monthly	5 %
	(almost) never	12 %

In order to check for representativeness the key indicators presented in the table were compared to the corresponding shares in the Mobility in Germany 2008 survey (MiD2008), Germany's national travel survey with a sample size of 60,000 persons and 26,000 households. Most key indicator values of our study came close or very close to those of MiD2008. The only notable difference existed for household sizes with a much higher share of smaller households in our study (17% single- and 48% two-person households compared to 4% and 26% respectively in MiD2008).

A first section of the questionnaire included information on the socio-demographics of the participants, their level of knowledge and interest in the topic of autonomous driving as well as their previous use of driver assistance systems. Subsequently, the current use of and attitudes towards the available transport modes were collected. Additionally, the respondents were interviewed on their usual time use when traveling by car, long-distance train and public transport (cf. Fraedrich *et al*. 2016, pp. 29-30).

In the second part of the survey, participants were randomly assigned to one out of four use cases and asked detailed questions on that specific use case. Hereby, 250 interviews were obtained for each use case. The use case oriented questions addressed anticipated use and deployment purposes, prospective substitute transport modes, perceived usefulness and expected changes in time use. Furthermore, attitudes towards the described vehicle, the respective need for intervention, and different aspects of design requirements were examined. The use cases were: Highway Pilot, Parking Pilot, Fully Automated Vehicle still allowing a driver to take over whenever requested, and Vehicle on Demand, in the literature or the media often also referred to as "robotaxi". Although the selection was not exhaustive, the four use cases represented proxies of fully automated applications that cover the range of autonomous driving functions from those that can be 'switched on' whenever requested to vehicles where no human driver is allowed anymore. The decision to distinguish the different use cases of autonomous driving was made to explicitly address different impacts that could come along with them regarding user perception and evaluation, as well as time use while traveling and changes in travel behavior. This article, however, will focus on "Fully Automated Vehicle" and "Vehicle on Demand".

4. AUTONOMOUS DRIVING AND USER PERSPECTIVES – SOME GENERAL OBSERVATIONS

As we pointed out before, autonomous driving is an issue that is still far from direct experience by today's car and road users and thus from their direct assessment. Therefore, we did not only ask questions that could be answered by answer categories or item batteries, but also integrated questions into the questionnaire that had to be answered by free text. This provided the opportunity to explore what respondents currently associate with the technology of the self-driving car: we asked them to explain in their own words what "autonomous driving" is to get insight into the sometimes apparent, sometimes latent valuations and meanings that people attribute to this technology. Of the 531 valid statements we received, 43% clearly displayed a comprehension of autonomous driving as defined by "official" descriptions, so for instance by SAE (SAE International 2014) – respondents identified their future role in the vehicle as passengers or bystanders, whereas the vehicle does everything it needs to get from point A to point B by its own. On the other hand, 25% of the respondents saw themselves only partly supported in the driving function by the computer systems – meaning that they also implied being engaged themselves in driving functions in one way or another or having to take over whenever the system requests them to. A very small proportion of 2% had the notion that autonomous driving meant some sort of remote- or externally-controlled function, and 31% of the statements had no (or no recognizable) reference to the role of a human in an autonomous vehicle – this could mean that these respondents had no idea at all what autonomous driving is, that they confused it with something else (e.g. car sharing) or that they could not make clear what they really referred to (cf. Fraedrich *et al*. 2016, pp. 42-43).

When requested to state in more detail the characteristics that they attributed to the vehicle, those respondents that were assigned the specific case of "Vehicle on Demand", were not very positive. Only 38% of statements had a positive connotation. The word cloud (figure 1) graphically displays the (paraphrased and summarized) statements in relation to the frequency of their occurrence. Many attributes are emotionally connoted and a relatively high share of respondents did not have any conception of what precisely was meant by this kind of 'car'.

Figure 1. Characteristics ascribed to "Vehicle on Demand" – paraphrased, reduced, and generalized (Fraedrich *et al*. 2016, p. 45)

Hand in hand with the general uncertainty about what the autonomous car will be goes a very low differentiation between respondents by conventional characteristics such as gender, age or level of formal education. We only found some very weak or weak correlations for gender concerning the required fulfillment of mobility needs such as independence, freedom from stress, comfort or safety by a fully automated vehicle or a vehicle on demand. But we did not find any clear hints in favor or against the autonomous car following socio-demographic characteristics. We tentatively interpret this finding as an indication that involvement in and examination of the topic of autonomous driving by the "average Jane or Joe" is still very low.

5. EXPECTED MODE CHOICE BEHAVIOR AND TRAVEL TIME USE IN THE SELF-DRIVING CAR

5.1 Expected Mode Choice Behavior

Although the topic of autonomous driving is still very fresh and not common to today's users of the transport system, we assumed that once people get in contact with the issue they also start to think how this may affect them personally.

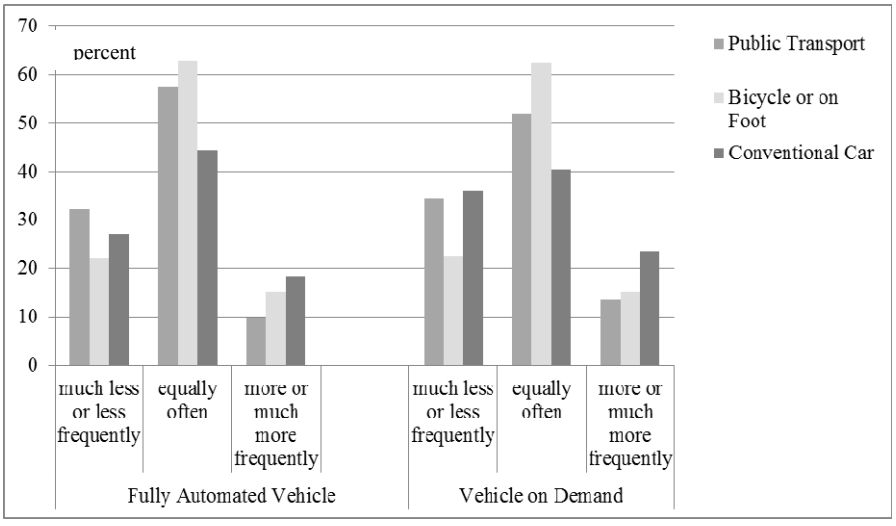

Figure 2. Expectations towards mode choice behavior for use cases "Fully Automated Vehicle" (N=250) and "Vehicle on Demand" (N=250)

There are in fact several reasons that could make the autonomous vehicle particularly attractive compared to those means of transport which we know today, so for instance door-to-door travel without any need to care for parking and new options for time use given that the car is self-driving (cf. Cyganski 2015).

Our survey addressed the question of potential change in mode choice by directly asking respondents if they expect any impact on their future mode choice once the self-driving car would be available. Although these expectations must be taken as a snapshot of what people can express at this very moment, they provide at least a tendency indicating on the hand that the majority of respondents do not expect a substantial change in their mode choice. However, if change happens, then public transport and the 'conventional' car will be those transport modes where a reduction is most evident (figure 2).

5.2 Travel Time Use Today and Tomorrow

To address various aspects of how people spend 'mobility time', the survey contained questions on current as well as anticipated future time use while traveling. First, the respondents were asked in which activities they were generally engaged in while traveling by car, local public transport, or train, the latter being defined as interregional train for distances of 100 km or above.

Naturally and not surprisingly, focusing on the ride and the route is the main activity reported while driving a car. Driving is often accompanied by listening to music or chatting with other passengers: around 80% of the car drivers stated they often or always listen to music, the corresponding shares for chatting amount to about two-thirds (62%). Also, more than half (56%) of the respondents reported always or often enjoying the ride and the scenery. Already now, the car is used at least sometimes as mobile office by 7% of the car drivers – potentially by means of making phone calls, for example. However, over 90% stated never to work while driving a car. Social networking, such as using the phone, mailing or sending text messages, was similarly uncommon with over 80% of the survey participants reporting never doing it (Fraedrich *et al*. 2016, p. 68).

By far the most mentioned activity pursued often or always in public transport and long-distance trains is enjoying the landscape and the journey (50% for public transport, 66% on trains), closely followed by conversations with fellow travelers (43% and 49%). These findings seem very in line with those reported by Lyons *et al*. (2007). In their study on the activities conducted by British rail users, window gazing was also – especially on short trips – the most mentioned activity on train trips.

Listening to music, reading or relaxing is another oft-mentioned activity, especially on train trips. Interestingly high are the shares of people stating they often or always concentrate on the trip – in both variants of mass transportation by almost 40 %. The low share of our survey respondents stating that they use the time for social networking purposes is also noticeable (Fraedrich *et al*. 2016, p. 69). The same is true for working while riding on trains or in public transport: 77% of respondents say they never work during public transport trips. On long-distance train trips, this share is down to 69%, contrasted by 6% of the interviewees often or always working on the go. Here, socio-demographic factors had a statistically significant effect on whether people are productive while travelling or not – especially the variables gender, income, education level, household size, and the presence of children in the household (see Cyganski *et al*. 2015 for details).

In the course of the survey, respondents were then asked what advantages they would perceive in using a vehicle from one of the four use cases. Answering options were given parallel to the ones provided for current time use; in the following we refer only to the use cases "Fully Automated Vehicle" and "Vehicle on Demand". The particular advantages most respondents could agree with were the enhanced possibility of enjoying the trip and the landscape as well as the chance of talking to fellow travelers. In both cases, about a third stated they considered this in large measure or strongly an

advantage of the corresponding autonomous vehicle type. Relaxing and sleeping options were other activities that a high share of respondents mentioned positively (figure 3).

It is worth noting that a large proportion of respondents did not expect to use their time in an autonomous car by activities like surfing the internet, watching movies or social networking. Disagreement went up to 51% for the case of watching movies in Highway Pilot. While using Vehicle on Demand 21% welcomed the option to surf the internet, but still 34% thought they would not engage in this activity even though they are no longer active for driving (Fraedrich *et al*. 2016, p. 71).

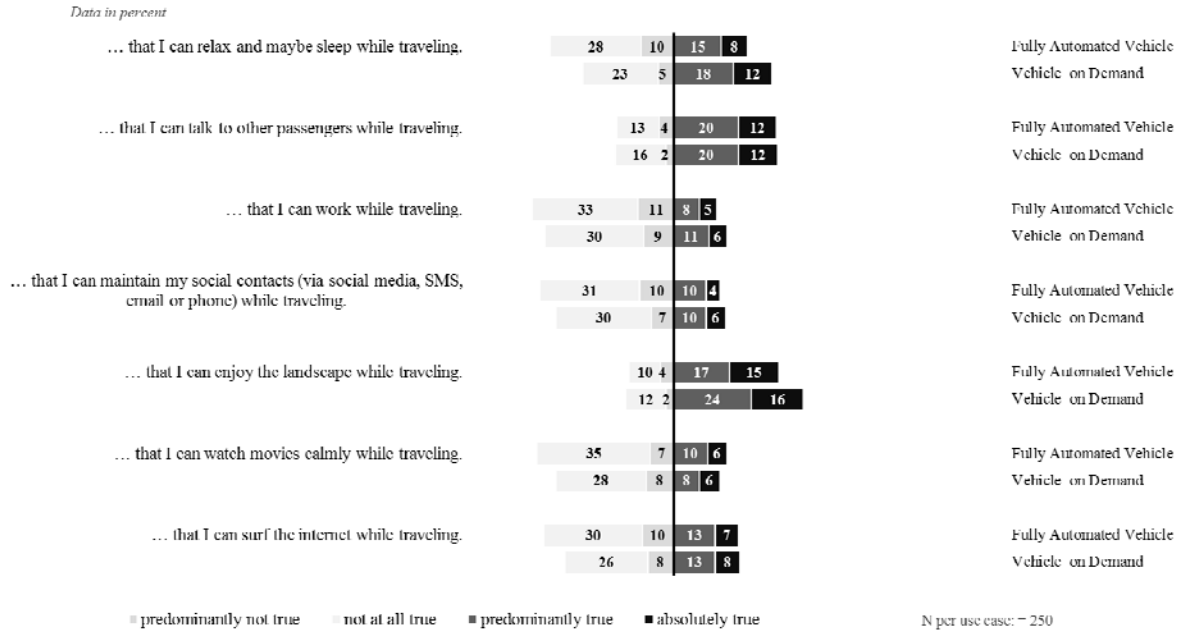

Figure 3: Anticipated time use for the use cases "Fully Automated Vehicle" (N=250), and "Vehicle on Demand" (N=250)

Working enjoyed the least reception among all options of activities to be done while traveling in a self-driving car. When asked if they perceive the option to work as an advantage of autonomous driving the disagreement for Vehicle on Demand was 30%. At the same time, 17% of participants felt that working while traveling in a Vehicle on Demand would be a good option for them. For Fully Automated Vehicle, the corresponding share amounted to 13 %. The notion of wasted, unproductive time being turned into (economically) valuable time is one of the most dominant arguments in the debate on autonomous driving. In Cyganski *et al*. 2015, we used an ordered probit model to further identify the factors influencing the decision to work in an autonomous car. We found current time use to be an important predictor of the perception and evaluation of the option to work while traveling whereas socio-demographics showed only minor importance: the more frequently respondents spent time working, the more likely they were to consider working possibilities as an advantage of autonomous vehicles. On the other hand, the more people spend their time enjoying the landscape on longer trips today, the less likely they were to imagine spending their time working in the future. Our conclusion is that advantages of automated vehicles are predominately identified for those activities already favored in today's conventional cars. The only minor share of respondents that explicitly declared working while traveling to be a benefit of autonomous vehicles clearly shows that any assumption of people being eager to spend their travel time 'productively' while traveling has to be regarded with caution (Fraedrich *et al*. 2016, p.72).

6. CONCLUSIONS AND OUTLOOK

Although people have just started thinking about autonomous driving and its potential consequences for their personal life, the survey at hand revealed that a significant share of them is aware that the self-driving car could change their mode choice behavior; they even anticipate the direction this change may take. The other quite surprising result of the survey is that respondents do *not* anticipate major changes in travel time use, but – instead – assume that they will continue to carrying out those activities to which they are accustomed. These issues, mode choice and time use once the self-driving vehicle is on the road, will need much more attention in the future to understand those factors that are relevant for the appropriation of the autonomous vehicle, but also the appropriation process and its impact on the transport system. The particular contribution of empirical research to the issue of transport automation will lie in monitoring and providing a good foundation for projection.

7. REFERENCES

Cyganski, R. (2016) Automated Vehicles and Automated Driving from a Demand Modeling Perspective. *Autonomous Driving. Technical, Legal and Social Aspects*. eds. M. Maurer, J.C. Gerdes, B. Lenz, and H. Winner, pp. 233-253. Springer Open, Berlin, Heidelberg.

Cyganski, R., Fraedrich, E. and Lenz, B. (2015) Travel-time valuation for automated driving: A use-case-driven study. *Proceedings of the 94th Annual Meeting of the TRB.* 94th Annual Meeting of the Transportation Research Board, January 11-15 2015, Washington, USA.

Continental Mobilitätsstudie (2013). Continental AG, [online] http://www.continental-corporation.com/www/download/pressportal_com_en/general/ov_automated_driving_en/ov_mobility_study_en/ download_channel/pres_mobility_study_en.pdf [July 22, 2016].

Fagnant, D. J. and Kockelman, K. (2013) Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations. Washington D.C.: Eno Center for Transportation.

Fraedrich, E, R. Cyganski, I. Wolf and B. Lenz (2016): User Perspectives on Autonomous Driving: A Use-Case-Driven Study in Germany. Arbeitsberichte Geographisches Institut, H. 187, Berlin: Humboldt-Universität, [online] https://www.geographie.hu-berlin.de/de/institut/publikationsreihen/arbeitsberichte/download/Arbeitsberichte_Heft_187.pdf [July 25, 2016].

Fraedrich, E. and Lenz, B. (2016a) Societal and Individual Acceptance of Autonomous Driving. *Autonomous Driving. Technical, Legal and Social Aspects*. eds. M. Maurer, J.C. Gerdes, B. Lenz, and H. Winner, pp. 621-640. Springer Open, Berlin, Heidelberg.

Fraedrich, E. and Lenz, B. (2016b) Taking a Drive, Hitching a Ride: Autonomous Driving and Car Usage. *Autonomous Driving. Technical, Legal and Social Aspects*. eds. M. Maurer, J.C. Gerdes, B. Lenz, and H. Winner, pp. 665-685. Springer Open, Berlin, Heidelberg.

Litman, T. (2015) Autonomous Vehicle Implementation Predictions Implications for Transport Planning, vtpi, [online] http://www.vtpi.org/avip.pdf, [January 22, 2016].

Lyons, G., J. Jain and D. Holley (2007) The use of travel time by rail passengers in Great Britain. *Transportation Research Part A: Policy and Practice*, 41 (1), pp. 107-120.

OECD/ITF and CPB (2015) Urban Mobility System Upgrade. How shared self-driving cars could change city traffic, [online] http://www.internationaltransportforum.org/Pub/pdf/15CPB_Self-drivingcars.pdf, [January 22, 2016].

Schoettle, B. and Sivak, M. (2014) Public opinion about self-driving vehicles in China, India, Japan, the U.S., the U.K., and Australia. The University of Michigan, Transportation Research Institute, Report No. UMTRI-2014-30.

Silberg, G., M. Manassa, K. Everhart, D. Subramanian, M. Corley, H. Fraser and V. Sinha (2013) Self-Driving Cars: Are We Ready? KPMG, [online] https://www.kpmg.com/US/en/IssuesAndInsights/ArticlesPublications/Documents/self-driving-cars-are-we-ready.pdf [January 22, 2016].

Willumsen, Luis G. (2013): Forecasting the Impact of Self-Driving-Cars. What to do about them in our models and forecasts. Citilab Asia User Conference, Karon, Thailand, November 5, 2013.

Zmud, J., Sener, I.N. and Wagner, J. (2016) Consumer Acceptance and Travel Behavior Impacts of Automated Vehicles. Texas A&M Transportation Institute: PRC 15-49F.