VI-DAS

Vision Inspired Driver Assistance System

EUROPEAN COMMISSION
Innovation and Networks Executive Agency

Horizon 2020 Research and Innovation Programme
Grant Agreement Nr 690772

Societal and cultural aspects and ethics protocols for future ADAS development (final version)

Deliverable no.	D7.8
Dissemination level	Public
Work Package no.	WP7
Main author(s)	Martina Baumann (KIT), Claudia Brändle (KIT),
Co-author(s)	Margarita Anastassova (CEA), Thierry Bellett (IFSTTAR)
Version Nr (F: final, D: draft)	F
File Name	D7.8 Societal and cultural aspects and ethics protocols for future ADAS development (final version) V1.0.docx
Project Start Date and Duration	01 September 2016, 36 months

Project funded by the European Union's Horizon 2020 Research and Innovation Programme (2014 – 2020)

Document Control Sheet

Main author(s) or editor(s): Martina Baumann (KIT), Claudia Brändle (KIT),

Work area: WP7

Document title: Societal and cultural aspects and ethics protocols for future ADAS development final version)

Version history:

Version number	Date	Main author	Summary of changes
v0.1	05.01.2018	Finbarr Murphy (ULIM)	Table of contents
V0.2	14.02.2018	Martina Baumann (KIT), Claudia Brändle (KIT)	Chapters about societal and ethical aspects/protocols added
V0.3	21.02.2018	Thierry Bellett (IFSTTAR), Claudia Brändle (KIT), Martina Baumann (KIT)	Chapters on cultural aspects added , other chapters especially on elderly drivers improved
V0.4	26.02.2018	Margarita Anastassova (CEA)	Chapter on HMI and acceptance added
V1.0	27.08.2019	Claudia Brändle (KIT), Martina Baumann (KIT)	Update based on recently published literature

Approval:

	Name	Date
Prepared	Finbarr Murphy (ULIM)	26.02.2018
Reviewed	Thierry Bellett (IFSTTAR)	28.02.2018
Authorised	Oihana Otaegui	28.02.2018

Circulation:

Recipient	Date of submission
EC	28.02.2018

VI-DAS consortium	28.02.2018

Legal Disclaimer

Acronyms

3G	3rd Generation cellular networks
4G	4th Generation cellular networks
5G	5th Generation cellular networks
5G PPP	5G Infrastructure Public Private Partnership
API	Application Programming Interface
ASN.1	Abstract Syntax Notation One
C-ITS	Cooperative ITS
C2C-CC	Car-to-Car Communication Consortium
CAN	Controller Area Network
CPU	Central Processing Unit
DNN	Deep Neural Networks
DSRC	Dedicated Short-Range Communications
EC	European Commission
ETSI	European Telecommunications Standards Institute
EU	European Union
EXI	Efficient XML Interchange
FP7	EU Framework Programme 7
FPGA	Field-Programmable Gate Array
GA	Grant Agreement
GPU	Graphical Processing Unit
H2020	Horizon 2020
IDS	Intrusion Detection System
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent Transportation System
JSON	JavaScript Object Notation
KPI	Key Performance Indicators
LAN	Local Area Network
LDM	Local Dynamic Map
LTE	Long Term Evolution
LTE-A	LTE Advanced
PaaS	Platform-as-a-Service
MNO	Mobile Network Operator
PO	Project officer
QoS	Quality of Service
REST	Representational State Transfer
SAE	Society of Automotive Engineers
SDK	Software Development Kit
SoC	Software-on-a-Chip
TEAM	Tomorrow's Elastic Adaptive Mobility
TMP	TEAM Messaging Protocol
UART	Universal Asynchronous Receiver/Transmitter
UMTS	Universal Mobile Telecommunications Service
URL	Uniform Resource Locator
USB	Universal Serial Bus
UWB	Ultra-WideBand
V2C	Vehicle-to-Cloud
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VCD	Video Content Description
WAR	Web application ARchive
WAVE	Wireless Access In Vehicular Environments
WP	Work Package
WS	Web Service
QoS	Quality of Service

Table of Contents

Executive Summary

The following report contains a preliminary overview on and discussion of the opportunities and challenges ADAS driving represents on a societal, cultural and ethical level. After a brief introduction on the context and purpose of the report, the three aspects will be presented in two chapters. Accordingly, the second section will focus on the societal aspects of ADAS driving, with a closer view on the financial side of this technology as well as its role in urbanisation processes. Another important topic addresses the inclusion of parts of the population that are as of yet excluded from motorized individual transportation– namely the elderly as well as people with disabilities for whom ADAS technology might open up different and more self-determined types of mobility. A third focus lies on public acceptance of automatization of traffic, and the expectations and knowledge that people have of this innovation. Further hopes and fears of the public are related to safety and health aspects and the influence of automation of traffic on the job market. This section will also deal with the question how culture and ADAS acceptance influence each other and how these factors might be reflected in ADAS development. Topics here include the prevalence of a "joy of driving" as well as associations with cars with notions of freedom and privacy. The ethical considerations related to ADAS driving are subject of section four and concentrate on the question of moral responsibility, autonomy and justice concerning (semi-)autonomous driving. Instead of further exploring the related issues of liability and insurance, which are subject of the accompanying Deliverable D7.6., we will offer a brief introduction to several concepts that could potentially be used to address open ethical questions. For example, the concepts of responsible research and innovation (RRI), value sensitive design, and of ADAS as a social experiment can provide a way to deal with unknown effects and uncertainties surrounding its development and implementation process. In a concluding section, key points will then be summarized and preliminary recommendations outlined.

1 Introduction

Work-package 7 RISK: Underwriting, Legal, Ethical and Societal Analysis evaluates the effectiveness of the technical work packages (WP2-5) from the perspective of the insurance industry and civic society. The involvement of this important stakeholder group is key to the success of assisted driving technologies. The implementation of the technical measures will tend to decrease personal and fleet auto liability and possibly increase product liability and this WP will estimate the resultant risk profiles. The respective risk premium changes will have a significant impact on drivers, manufacturers and the insurance industry and also effectively act as useful monetary measure of risk reduction. A holistic liability analysis will be undertaken in the context of ethical and legal considerations. In addition to this focus on the insurance industry, which is discussed in D7.1 (auto and fleet liability), D7.4 (product liability) and D7.6 (legal considerations), further ethical aspects and the relevance of the technologies to societal challenges will be analysed, also in order to provide a better understanding of the prerequisites of successful and responsible innovation. In task 7.4 and this deliverable 7.8, we will analyse ethical aspects of the planned technological developments, their relevance with regard to major societal challenges, and their public perception, in order to provide a sound understanding of ethical aspects in the social context of innovation processes, as a basis on which VI-DAS can develop. To develop underwriting protocols around VI-DAS and develop a standardised approach to the insurance/underwriting of ADAS enabled automobiles (task 7.5) is discussed in D7.1, D7.3 and D7.6 and will not be covered here.

The development of HMI technologies raises some profound ethical issues. Among these issues are questions around moral responsibility, autonomy and justice considerations implicit in ADAS. In this task, the relevant discussions will be analysed and various approaches of ethical analysis will be applied, with regard to current developments, but also long-term perspectives. Furthermore, ethical analysis will be combined with a value-based design approach targeted at broader societal aspects and in line with core elements of responsible research and innovation (RRI). This will include analyses of the technological developments with a view to major societal challenges such as demographic change and urbanisation. Chances as well as risks will be scrutinised by means of a systemic and multi-stakeholder approach that will help define the elements of value-based and smart future mobility infrastructures. Cultural aspects that are crucial for innovation in this area will also be taken into account (e.g. private cars as powerful cultural symbols and mobile private spheres). Both in terms of public policy and the more general phenomena of societal acceptance, this analysis will also help sustain innovation processes following the development of VI-DAS.

1.1 Purpose of document

The aim of D7.8 is to provide an overview on the impacts, enabling and driving factors and barriers the implementation of ADAS driving can have on a societal, cultural and ethical level. ADAS impacts can both be an opportunity as well as a challenge for society. In the document, we therefore briefly explore concepts that could possibly be of use in predicting and addressing particular challenges of the innovation process. To that end, some concluding remarks and recommendations are expressed.

1.2 Linkage to other WPs and deliverables

The activities of this WP will be correlated with the advancements made by the other technical (WP2, WP3, WP4, WP5, WP8) and non-technical (WP1, WP7) work-packages. The present deliverable is strongly linked to Deliverable 7.5. (and D7.6. respectively) which will focus on questions of liability and insurance, and related ethical aspects of ADAS driving, and includes reflections both on D5.1 and D1.7.

1.3 Current limitations

General limitations of this report stem from the fact that ADAS technology is still a somewhat visionary innovation. Even though concrete steps have been taken, e.g. through wok done within the VI_DAS project, to bring about ADAS technology, there is still much potential for future development. As such, many of the possible effects on civil society and its potential ethical problems can only described in broad terms or as mere hypotheticals. There is also a lack of knowledge on how specific cultural aspects can play a role in the development and implementation of ADAS technologies as well as on their regulation and acceptance by different societies. This complicates the formulation of precise recommendations and requirements as a road map or ethics protocol. For this reason, the recommendations put together in this report are of a preliminary nature and meant to act as a starting point for discussion. It is important to keep a close eye on technological development as well as its scientific reflection in the future, especially from the standpoint of the social sciences and humanities. .

1.4 Intended audience

The dissemination level of D7.7 and D7.8 is public, and also intended for the Commission Services. This document is intended to be an internal guideline for all technical work packages.

1.5 Document organization

Section Fehler! Verweisquelle konnte nicht gefunden werden. is about societal and cultural aspects of future ADAS development.

Section Fehler! Verweisquelle konnte nicht gefunden werden. details ethical aspects of ADAS

Section Fehler! Verweisquelle konnte nicht gefunden werden. provides preliminary recommendations as a basis for future road maps and ethics protocols.

2 Societal aspects

Before we discuss societal aspects of future ADAS development, we want to make clear how we use terms for different levels of automation in this text. This is important as the different levels may differ in their societal implications.

- AVs are autonomous vehicles, that are either partly or fully autonomous (if not stated, fully) partly AVs are sometimes referred to as semi-autonomous driving within the text and refer to level 4, fully AVs to level 5 technology (SAE International 2016); this means no monitoring by a human driver in certain circumstances, for example on the highway, or no monitoring at all, which makes it possible to be a passive passenger, or pursuing other tasks or leisure activities
- ADAS cars are cars with advanced driver assistance systems, state of technology today, including level 3 where it is possible to take hands of the wheel (in certain situations) but required to monitor constantly
- VI-DAS wants to develop an ADAS car with functionality that goes beyond state of technology of level 2, but not necessarily in such a way that drivers can take their hands of wheel as in level 3; more advanced warning and helping functions shall be developed

In the following, we will provide some insight into the societal aspects of ADAS development as well as future AV development. Here, especially cost and access to this innovation and its potential for as of yet marginalised groups are important. In addition, possible interrelations of ADAS innovation and trends in urbanisation, demographic change, daily life and its environmental impacts etc. will be discussed.

2.1 Equity

2.1.1 Costs and access

Costs of ADAS technology are obviously a crucial factor when thinking about its societal impact. Considering current prices, ADAS cars/AVs are not accessible for many. This is twofold unfavourable, as first, below a critical market share the benefits of connected ADAS vehicles will not be achieved, and second, prices will not drop before the numbers of sold vehicles rise considerably (Litman 2019). The starting price of ADAS cars/autonomous vehicles might be of high relevance for its future prospects.

Numerous factors have to be taken into account to calculate saving potentials on the one side and additional costs of ADAS cars and usage on the other side. Besides the costs of the car itself, fuel consumption, repair and accident/insurance costs might change. On a societal level, investment in infrastructure will be required to bring ADAS to its full potential (by vehicle to infrastructure communication (VtoX) and special roads). Examples are HD maps, positioning supports for specific areas with positioning problems; safe harbors on some roads or for trucks, quick snow removal etc. (Kulmala et al. 2019). To illustrate potential costs: In 2013, the autonomous driving system of Google cost about $150,000 (Howard 2014). Also, from 2013 Toyota Prius, which starts at around $24,000, is optioned up with a $75,000 to $80,000 Velodyne LIDAR system, visual and radar sensors estimated to cost about $10,000, and a nearly $200,000 GPS array. Costs of the driving computer and software are still excluded[1].

Costs may be considerably lower for ADAS, and also depend on the sensing technologies used. Laser technology is relatively cheap, which was used already in 2013 to fit a car retrospectively with ADAS for 5,000 pounds[2]. In 2016, a Honda LC Civic Sedan equipped with ADAS was released for a relatively small price of $ 20,000[3]. For comparison, an Audi A8 level 3 car (with an autonomous mode for a speed up to 60 km/h, thus called traffic jam pilot), is available for around € 90,000[4]. Overall, estimates and announcements by carmakers still range widely, from $ 8,000 - $ 300,000 for an autonomous car. LIDAR technology is at the time the most cost-sensitive equipment part, though cheap versions of high-end sensors are being developed. A substitution with camera technology would be very favourable for the price of future AVs and ADAS cars, but the feasibility of this approach is still unclear[5].

Not surprisingly, a study by Howard et al. found that wealthier people are more likely to be interested in self-driving cars than those with lower income and that over two-thirds of respondents of all demographic groups cited that costs are a concern. It concluded that reductions in the cost of this technology may increase demand over all income groups (Howard and Dai 2013). In another study, 22% of the respondents did not want to pay more than $ 0 for a fully automated driving system, whereas 5% indicated they would be willing to pay more than $ 30,000 for it (Kyriakidis 2015). Although 40% expected that a fully automated car would cost $ 5,000-9,999 on top of the costs for a regular car, more than 71% would not be willing to spend more than $ 4,999 to purchase it. (Kyriakidis 2015) So there is clearly a

---

[1] Tannert, C. (2014). Well you ever be able to afford a self-driving car?. https://www.fastcompany.com/3025722/will-you-ever-be-able-to-afford-a-self-driving-car
[2] https://www.theguardian.com/technology/2013/feb/14/self-driving-car-system-uk
[3] http://safecarnews.com/honda-sensing-adas-added-to-my2016-civic_o6193/
http://fortune.com/2016/03/14/self-driving-car-honda/
[4] https://spectrum.ieee.org/cars-that-think/transportation/self-driving/the-audi-a8-the-worlds-first production-car-to-achieve-level-3-autonomy
[5] https://qz.com/924212/what-it-really-costs-to-turn-a-car-into-a-self-driving-vehicle/

great gap between projected actual costs and the additional money future users are willing to pay at the moment.

However, as mentioned above, cost reductions, especially due to reduced crash risk, might lead to an amortisation of car costs over the lifetime of the vehicle. A study estimated the cost savings through crash reduction in relation to additional equipment costs for Forward Collision Warning (FCW), Blind Spot Monitoring (BSM) and Lane Departure Warning (LDW) and found a net benefit (Harper 2015).

ADAS cars may be even more successful in this respect, by further reducing crashes and resulting in lower personal and societal costs (for social/health insurance). These savings will of course only benefit the individual driver (thereby further incentivising buying an ADAS car), if they are distributed via tax reductions. Fuel consumption reduction by automated smooth and intelligent driving styles may have a direct positive effect on costs.

Additional costs for full automation in the future as well as potential cost savings are more difficult to predict, and lead to different estimates accordingly.

In another study, AV technology was projected to have a price premium of US$7000 to $10 000, and so drop ten-fold from today’s prototype costs. Mass adoption might reduce the price premium further. Decreases in insurance and parking costs, and time saved, could amount to around US$3000 per year per vehicle, meaning that a cost of US$10 000 would be amortized in three years (Greenblatt and Shaheen 2015).

This and similar calculations (Wadud 2017) bear two big uncertainties: first, the price drop over time, and also the time gained for AV users, which is taken as having a monetary value. In this vain, a very interesting result of a study was that among private users, households with the highest income will benefit more from automation because of their higher driving distances and higher perceived value of time, and less costs of automation in relation to higher baseline car costs (Wadud 2017). They would save more than 1,000 pounds per year, while lower income families/households would pay more than before.

Costs are not only a factor for private owners to consider, but also for fleet owners. Studies about this topic show heterogeneous results. It seems that autonomous taxi fleets are cheaper than driver-operated taxis, but more expensive than car-sharing.

Another interesting finding is that the benefits from automation for commercial applications like taxi fleets are much larger than those for personal use (Wadud 2017). Consequently, one could propose (company-owned, for-profit) robotaxis as a solution to the high cost and resulting access problem. However, another study came to the conclusion that still, using a self-driving taxi instead of a self-owned old car would mean an increase in costs per mile[6]. The authors came to the conclusion that capacity utilization rates would need to improve by nearly 100% and margins lowered by 37% for autonomous vehicles to achieve cost parity with their conventionally driven counterparts (Nunes/Hernandez 2019). Cost per kilometre is only one influencing factor for mobility choices (besides comfort and time of travel) (Bösch 2018). However, it will significantly affect the choice between robotaxi/shared manually driven car, and owned vehicle, and thus also the future of traffic.

High uncertainty remains even with regard to the cost factors which have to be taken into account in such calculations. Nunes/Hernandez (2019) take into account costs for the remote supervision/control of fully AVs, which might be needed to ensure safety and traffic flow (e.g., take over in case a white line has to be overridden for safety reasons or to go on). With regard to the driving environment, some experts think that predictability has to be increased to a certain extent by adapting it to the capabilities of AVs, e.g. minimising the possibility for animals to enter the road and other unlikely events[7].

Taken together, the findings seem to suggest that investments in public transport fleets of AVs might be an option to increase access in an economically sound way. The downside of this option is of course the loss of jobs for bus and taxi drivers (see also section 2.4 of this deliverable). In addition, the car-sharing trend might alleviate the cost problem, but on the other hand, small selling numbers will keep the price per car high.

Apart from the car itself and its use, another cost factor that has to be taken into account from a societal perspective is infrastructure. First, for traditional infrastructure, i.e. streets, for which costs could fall or rise, depending on overall development of car numbers, distances travelled, number of passengers per vehicle, and the distances to other cars (that might become less with automated driving). Second, special kinds of infrastructure elements might be needed for ADAS cars that are connected with each other and the infrastructure. The resulting “intelligent” infrastructure is supposed to send cars information related to traffic density or construction sites to plan routes and warn the driver more timely than possible based on the cars sensors alone. From an equity perspective, measures should be taken in order to bring benefits of ADAS also to the socioeconomically weaker parts of population. Money needed for infrastructure might lead to raising taxes or might be taken from the budget for alternative

---

6 https://ftalphaville.ft.com/2019/04/29/1556557142000/Scoop--the-questionable-economics-of-autonomous-taxi-fleets/

7 https://hbr.org/2018/08/to-make-self-driving-cars-safe-we-also-need-better-roads-and-infrastructure?referral=03758&cm_vc=rr_item_page.top_right

infrastructures such as public transport and should therefore benefit all.

Taken together, prices of ADAS cars might be a barrier to access, especially for socioeconomically weaker parts of the population, and will make it difficult to reach the full potential of safety and other benefits of this technology for all of society. Prices may decline with adoption rates, but this adoption related decline may be hampered too much by initially high prices to make this happen. It's a “chicken and egg problem” (Litman 2019). Poorer people drive older and less saver cars already today, producing a safety gap based on economic power, and ADAS cars should rather reduce than further increase this inequality. For developers, a trade-off between comfort and affordability might help to make safety increasing ADAS available to a bigger part of the population. Public agencies should take great care to make sure that infrastructure investments from tax money benefit society as a whole and not only the happy few who can afford ADAS and AVs.

2.1.2 Inclusion of people with disabilities

There are big hopes in parts of the disability community that assisted or autonomous driving might give them the opportunity to fully take part in social life that is only possible with increased mobility, especially in rural areas. However, legal questions have to be answered first and universal design would have to be embraced as a central pillar of carmakers' philosophy. From the technical viewpoint, caution should be taken with regard to promises and calls for universally accessible cars. Rather, there should and could be a range of vehicle designs which meet the needs of various segments of the disability community[8]. Current regulations in California have been criticized to delay the deployment of self-driving cars, “particularly disadvantaging people with disabilities who would benefit from using this technology to perform everyday tasks that often cross municipal boundaries such as commuting, shopping or visiting their doctor.”[9]

In the US, the legal situation might however still be more favourable for the community of people with disabilities, as the Vienna convention was not ratified there. In countries of the EU, the Vienna convention was ratified which states that “every driver should possess the necessary physical and mental ability and be in a fit physical and mental condition to drive”. “Driver” hereby means a person, who is able to control the vehicle at all times, which also

[8] http://secureenergy.org/wp-content/uploads/2017/01/Self-Driving-Cars-The-Impact-on-People-with-Disabilities_FINAL.pdf

[9] http://www.sfchronicle.com/opinion/openforum/article/Disability-community-Don-t-slow-testing-of-10528350.php#photo-11729964

includes the ability to switch off an autonomous driving mode in case it cannot handle a situation. A blind person, or a person with a muscle disability not able to move accordingly, is thus as of yet not allowed to drive an ADAS car or a partly AV. In the context of the EU, the Vienna Convention would have to be changed to make driving of an ADAS car with autonomous driving mode on e.g. a highway possible for people with disabilities.

Safety is of course an issue for this mode of inclusion of people with disabilities in mobility, as some forms of disability might make it impossible to take over control or push an emergency button. Thus, besides the legal solution that is still pending, driverless cars for people with disabilities would need prior public acceptance of computer-controlled empty cars.

From an ethical perspective, there is a dilemma between the obligation to provide inclusive mobility to people with disabilities, and safety for all other traffic participants and themselves. At least where fully AVs are concerned, the idea that safety does not always trump freedom and autonomy (see also Bundesministerium für Verkehr und digitale Infrastruktur 2017) can also be applied to disabled drivers who are unequally affected by the current mobility restrictions (e.g. monitoring duties in autonomous driving modes) when compared to abled drivers. Thus, if in the future fully autonomous driving were possible, it might not necessarily be correct to keep with current legislation, as it would deny people with disabilities significantly improved mobility and an increased ability to social participation. A practical, though not unproblematic solution to this problem might be to provide a means of oversight like in aviation, where traffic controllers are able to intervene in case of emergencies, if neither the machine nor the driver is able to handle a situation (Bradshaw-Martin 2014). In similar fashion, fully remote controlled autonomous vehicles are presented as a solution for people with disabilities[10]. Such systems have already been proposed to manage autonomous cars and bring them to a “safe harbour” in case of control issues, but have obviously their own privacy and also safety issues. Also,

There was a now famous Google demonstration with a blind man in a self-driving car back in 2012, which was probably heavily scripted, but seemingly still gave hope to other blind or people with bodily disabilities. Car companies should be careful not to overpromise nevertheless, as some people with disabilities are terminally ill and too unrealistic expectations unfair[11].

While autonomous driving that can also be used by e.g. blind people seem to still be a very

[10] https://www.v2c2.at/gtc2018-2/
[11] https://www.2025ad.com/latest/driverless-cars-for-people-with-disabilities/

visionary concept, ADAS cars can have the potential for some impairments to be eliminated as barriers to driving. For example, visual aids could help to highlight lane markings and detect pedestrians and thus blur the boundaries of disability and ability[12]. Possibly, also the definition of "being in a physical condition to drive" might change for a highly automated car, where one can rest e.g. ones arms most of the time.

Principles of universal design are needed for ADAS and AV development in order to include people with disabilities from mobility[13]. ADAS and AV should be developed with the inclusion thought at its heart, and not as an afterthought in order to comply with anti-discrimination laws or to increase selling numbers after the market is sated, like it happened with many technologies before (Bradshaw-Martin 2014), or as an argument to foster support in the face of safety concerns. The federal highway traffic safety agency e.g. tries to help developers with this challenge[14].

The United Nations' Convention on the Rights of Persons with Disabilities gives a definition of universal design. „Universal design" means the design of products, environments, programs and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. Since both the European Union as well as their Member States (except Ireland) are parties to the UN Convention, they are committed to undertake or promote research and development of universally designed goods, services, equipment and facilities, which should require the minimum possible adaptation and the least cost to meet the specific needs of people with disabilities (Sieberns 2018). This should be an ethical obligation as transport provides people, including those with disabilities with access to education, work, healthcare, cultural and leisure services, and is thus a prerequisite for taking part in social life. Those with severe disability can use currently available cars only with expensive adaptations, or are not able to drive at all. In addition, their need to park closer to their destination is more and more difficult due to the increasing number of cars and decreasing number of parking places, especially in the cities. Thus, in order not to further broaden this gap in accessibility for the weakest in society, special care should be taken to take universal design into account for ADAS as early as possible. Aspects to consider include both physical accessibility (wheelchair users (also as passengers) should have easy access), and HMI accessibility. Communication of the position of the car, duration of the trip etc. should be available in

[12] http://www.bbc.com/news/magazine-21720318
[13] https://www.cdc.gov/ncbddd/disabilityandhealth/disability-strategies.html#UniversalDesign
[14] http://www.sfchronicle.com/opinion/openforum/article/Disability-community-Don-t-slow-testing-of-10528350.php#photo-11729964

braille/audio for deaf and blind people.

The redesign of the in-car interaction is an important factor for AV and ADAS diffusion, and this challenge relates not only to current drivers, but also to potential new drivers who were not previously able to use cars (Ferati 2018). Considering that currently 85% to 95% of sensory cues while driving are visual, this should not be the case with the type of interaction inside the car, as older persons and persons with disabilities often have deterioration in visual and auditory functions (Ferati 2018). Personalization of multimodal HMI could take into account that some users have quite differing preferences from the “normal” population, which is not only a question of convenience and acceptance, but highly safety relevant (Ferati 2018).

Potentially, ADAS could also have benefits for people with children with disabilities who need special attention during a trip, and deaf drivers who are not able to lipread when they have to pay attention to the road[15].

A final point we want to mention is that though there is a high potential for ADAS and AV to make life of people with disabilities much better, it is very important not to exclude or underfinance alternative inclusion strategies like public transport, barrier free access, and assistive technology that might enable public transport use. Examples are wheel chair ramps and bays at public transport stations and inside busses and trains, and other solutions for blind people to enable them to use public transport. Especially in cities, this might be the cheaper option. However, in rural areas autonomous vehicle fleets might be the only option for people with disabilities to increase their autonomy. Still, it might not be possible to replace the human factor completely by autonomous cars, as people might need help to get into and out of the car (Hancock 2019). In addition, social interaction during transport is removed, and actually might lead to further isolation in some cases[16].

As shown, the question how people with disabilities might be affected by ADAS and AV development is quite complex. Though some scenarios or issues described in this section are more relevant to AV development or not in the hand of manufacturers but legislators and local agencies, they are also relevant for ADAS development in VI-DAS. Care should be taken to design HMI in a way that is accessible also for people with disabilities while at the same time not overselling promises for this group of drivers. In the development phase of AV and ADAS, a strong partnership between stakeholder organizations for people with disabilites,

---

[15] https://medium.com/@mobility4eu/disabled-people-spoke-about-their-benefits-and-requirements-on-autonomous-cars-232cdb73f197

[16] https://www.2025ad.com/disability-talks-our-community-debates-the-driverless-gamechanger-1

researchers and manufacturers as well as standard bodies is recommended for ADAS development (Claypool et al. 2017). There is a danger that otherwise, ADAS cars with unsuitable HMI systems do not benefit people with disabilities, and thus a great potential is lost. Evaluation of driving capability in persons with disabilities is complex, and cognitive and motor skills have to be taken into account in a situative manner (Heikkilä et al. 2005), which makes it difficult to predict for which kinds of disabilities current and future ADAS functions will be helpful. As ADAS is generally thought to reduce cognitive load, and also offers possibilities for resting times when the car is in autonomous mode, it could be a game changer for big number of people with disabilities, giving them the opportunity to get a driving license.

2.2 Urbanisation and demographic change

The impact of ADAS and AVs goes far beyond increased comfort and safety of trips for individuals using it, but as the last section shows, might be a “game changer” for some parts of society. In the following, we will discuss the potential of ADAS and AVs for mobility of elderly as well as its (long-term) impacts on overall mobility, urban planning, job opportunities and our daily activities.

2.2.1 Inclusion and safety of elderly and novice drivers

During the last few decades, increasing attention has been devoted to the issue of elderly drivers. Older drivers are usually experienced and careful drivers (Langford, Methorst, & Hakamies-Blomqvist, 2006) with a high concern for respecting the safety rules when driving their car (Classen et al., 2010). However, although involved in few crashes in terms of absolute numbers, elderly people represent the part of the population with the highest risk for crashes with serious injury and death per number of drivers and per distance travelled (Koppel, Bohensky, Langford, & Taranto, 2011). This is both related to their greater fragility and with the decline in their physical, sensory, and cognitive capacities (Langford & Koppel, 2006; Li, Braver, & Chen, 2003). Vrkljan and Miller-Polgar (2005) indicated that changes due to age in the visual and cognitive systems may reduce the ability to drive a car safely. Physical abilities, like neck flexibility, can also negatively affect various aspects of driving performance. Audition is also affected by aging, notably pure tone detection and speech comprehension. Koppel, Charlton, and Fildes (2009) also observed that the processing speed of elderly drivers decreases as cognitive load increases. Another set of studies also showed negative age effects on drivers’ Situation Awareness (SA). In the frame of car driving activity, SA corresponds to a mental representation of the road environment, as perceived and understood by the driver (Bellet et al, 2009). Using a simulator experiment, Bolstad (2001) showed that, due to age-related declines in perceptive and cognitive functions, older drivers' mental models of road environments are less complete than SA formulated by younger experienced drivers. Similar results were also found by Bailly (2004) under normal driving conditions, and more recently by Kaber et al (2012) for hazardous situations: old age negatively impacts the content and adequacy of SA, especially for complex driving situations with high attentional demands. Faced with the complexity of certain traffic situations, elderly drivers may have greater difficulty in perceiving and integrating all the relevant pieces of information required to make the right decision. This results in higher involvement in certain types of accidents, typically in situations requiring complex interaction with other road users, like at intersections crossing, merging, or lane changing in dense traffic (Alexander, Barham, & Black, 2002; Clarke, Ward, Bartle, & Truman, 2010; Langford & Koppel 2006; Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998; Skyving, Berg & Laflamme, 2009). The older the driver is, the more the risk is increasing. Braitman, Kirley, Ferguson, and Chaudhary (2007) reported that in more than half of the crashes involving drivers +80 and older in the US failure to yield was found to be the cause..

Despite these risks, there is a societal challenge to keep elderly drivers at the wheel as long as possible. Facing the demographic forecasts, the number of older people who drive increased dramatically in Europe during recent decades. A large part of the population will be 65 or over in the next coming years (For instance, in France, it will be the case for the third of the population in 2030). In addition, the vast majority of elderly people in European countries use cars to ensure their mobility. Reducing driving can impinge heavily on older people's autonomy and thus reduce accessibility to important services and activities. Two out of three German retirees use their car daily and being mobile and traveling are very important in their life (Diepold 2017). There is clearly a need for ADAS in the elderly population to better enable them to take part in social life and be mobile.

Moreover, several researches point out the correlation between driving cessation and cognitive decline's speed up for seniors (Marottoli & al. 1997; 2000, Edwards et al, 2009; Pochet, 2003, Dickerson et al., 2007). Therefore, allowing older people to drive safe as long as possible in a safe way can be considered as an important societal issue, and preserving the autonomy and the individual mobility of this part of the population becomes an important challenge for the European countries.

One challenge is that elderly seem to be a little bit more cautious and having less trust than younger age groups when it comes to partly or fully autonomous driving (Robertson 2016, Kyriakidis 2015). Another challenge is that the special needs of elderly have to be considered carefully when designing user interfaces in ADAS and autonomous cars (Frison 2017). For

SAE level 4 and 5, for example, auto manufacturers are developing systems that give drivers only seconds to prepare to re-engage to avoid collision, and will pull to the side of the road if re-engagement is not detected. Experts say such systems may not be optimal, also for younger drivers, but especially for those who take some medications or may have difficulty reorienting themselves[17].

In a recent study implemented in France (Bellet, Paris, Marin-Lamellet, 2018) elderly drivers' expectations were ranked regarding existing and/or future ADAS from their respective perceived utilities. The main findings of this study are that older drivers were familiar with several ADAS and are actual users of a part of them (more particularly men). It also shows that they have a generally positive attitude towards advanced driving aids and vehicle automation, and that men and women have quite similar expectations towards driving aid functions and similar preferences in terms of HMI modalities (informative or warning systems being generally preferred than ADAS based on vehicle automation). Older drivers' acceptance and interest toward Highly Automated Driving (HAD) and Autonomous Cars are generally positive as well: they were interested in this idea, and considered that it could be a highly suitable solution for ensuring the self-mobility of certain elderly persons in their circle. They also considered it for themselves in the future, as they become older, or in case of impairments of their cognitive or physical capacities. These findings are of importance for car manufacturers. Indeed, elderly people are one of the most important groups of drivers liable to buy new and expensive cars in Europe. In addition, a large part of them – and more particularly men – have, use and are highly interested by innovative systems in cars (compared to other technologies like computer or smartphones, which are much more appreciated by young people, the ‘‘real geeks for ADAS” are more frequently the older men). With the increasing of life expectancy and for keeping their safe mobility, older drivers could be the main target group of the future autonomous car market.

A comparative study based on these results and this method, but dedicated to young novice drivers, was specifically implemented for VI-DAS. The results are presented in D5.1 (Strachan et al. 2017). This target group is maybe less interesting from an economical point of view as it is not growing, and less in need for inclusion in mobility as public transport is an easier option (at least in cities). But novice drivers are also a high-risk subpopulation. In the UK, this high risk in fact leads to an exclusion from automobility in some cases, as insurance premiums may

[17] https://www.nytimes.com/2017/03/23/automobiles/wheels/self-driving-cars-elderly.html

be very high[18].

2.2.2 Environmental impacts

Autonomous vehicles could reduce energy consumption in transportation by as much as 90%, or increase it by more than 200%, according to research from the Department of Energy (DOE)[19]. Other predicted ranges are even broader, from 40% to 300% (Stephens 2016). These numbers show that there is a lot uncertainty about the effects of autonomous driving on fuel consumption, which is not only related to costs for users, but also the environmental and health impact of AVs, especially in urban areas. As more than a quarter of greenhouse gas emissions come from the transportation sector, according to the Environmental Protection Agency (EPA) (Worland 2016), a reduction of energy consumption and emissions will be a considerable step for environmental protection, improving air quality and delaying climate change, one of the biggest societal challenges at the time.

AVs might have a reduced environmental impact, but possibly only through a synergy with on-demand mobility (Greenblatt and Shaheen 2015). The crucial factor with regard to fuel consumption and greenhouse gas emissions is of course the development of the overall amount of driving. In this regard, either a doubling or halving of vehicle-miles traveled through the use of (semi-)autonomous driving is deemed possible (Wadud 2016). Similar to other technological advancements in motorized mobility, the development and widespread implementation of AV technology could lead to so-called rebound effects (Jackson 2009) as well and increase the number of vehicle-miles and its respective impacts on the environment (Brändle/Grunwald 2019) for a variety of reasons. Complexity arises due to a combination of factors with unknown dynamics. Social factors like behavioural changes, e.g. increased use by those unable to drive, a shift away from public transit, introduction of self-parking/-fueling, longer commutes, and unoccupied trips to pick up passengers, are especially difficult to predict. Agent-based and activity-based models to simulate possible changes in travel demand, vehicle ownership and other environmental indicators, such as energy consumption and emissions, is needed to make more valid predictions (Milakis 2017). Very different scenarios are possible, depending also on cooperation of private sector and policy makers e.g. regarding speed limits, liability regimes, subsidizing of different modes of autonomous driving and business models (shared fleets, private) (Wadud 2016).

---

[18] Young drivers have been called an uninsurable generation in the last 10 years in the UK, as premiums continually rose in a disproportionately high amount for this driver group, see: https://www.standard.co.uk/news/new-driving-generation-becoming-uninsurable-7277109.html

[19] https://www.nrel.gov/docs/fy13osti/59210.pdf

The same problems arise for ADAS technology, as it is difficult to quantify and combine a multitude of impacts ADAS cars may have on the environment. It is important to gain insight into these impacts in order to enable ADAS development and implementation to fulfil its beneficial environmental potential. In the following, we will provide an overview of potential effects of ADAS technology and its societal impacts on energy consumption.

A first possibility to save energy would be platooning of vehicles, which is already considered for trucks[20](Greenblatt and Shaheen 2015). Second, automated vehicles are able to reduce fuel consumption and emissions by optimizing driving style, either autonomously or by providing feedback as a component ADAS[21] (Greenblatt and Shaheen 2015). Computers respond more smoothly to the need to accelerate and brake, and may anticipate traffic situations and avoid traffic jams through intelligent routing. To make the vision of perfectly inter-coordinated vehicle travel come true, manufacturers will have to work out common standards so that cars can communicate safely and reliably. A recent study predicts that reduced traffic and parking congestion, and thus resulting energy conservation and pollution reductions, will only be significant when AVs become common and affordable, probably in the 2040s to 2050s (Litman 2017). A mix of traditional and self-driving cars sharing the road will make this task even more difficult, as human communication and behaviour is sometimes difficult to understand and predict for machines, e.g. a human standing at a crosswalk but not crossing the street, or a handsign from another driver. Also, real traffic differs from how traffic is supposed to work according to legal regulations, e.g. for a Google car tested in the US which famously became trapped while trying to turn across traffic, with the self-driving vehicle's program judging it unsafe to try to fit into the small gaps in traffic or force its way in (Torvey 2016).

Energy savings and emission reductions are also uncertain, as estimates depend on a variety of uncertain variables related to mobility behaviour, like car resizing and the above mentioned rebound effects (Stephens 2016, Greenblatt and Shaheen 2015) due to increases in driving comfort and safety. The possibility to work and rest while traveling, if only for a part of the drive like in partly AVs, may make longer drives more attractive. An increase in automobile travel may then reduce usage of both local and long-distance public transport travel, leading to a vicious circle in which less demand for public transport leads to less investments and a further reduction of public transport attractiveness (Victoria Transport Policy Institute 2017, p. 4). In a study with Canadian drivers, 20% of commuters said they would switch to AVs if they were

[20] https://www.eutruckplatooning.com/About/default.aspx
[21] https://www.fueleconomy.gov/feg/driveHabits.jsp

available, so that declines in public transport use can be anticipated (Robertson 2016). With fully autonomous cars, even sending a vehicle driving around the block, rather than pay or search for an urban parking space might become a common behaviour. Travel by populations that are traveling seldom by car today, like kids without licenses, people with disabilities, or older people no longer capable driving, may increase fuel consumption and emissions considerably.

On the technical side, automated cars might be able to travel faster (and still safely) than human-driven vehicles due to faster reactions, which matters because fuel economy typically decreases at speeds over 50 miles per hour[22]. ADAS might however also decrease speeding by humans, either by giving feedback or by having an automatic function for holding the speed limit, though one has to take into account that disengaging the autopilot will still be an option for drivers who wish to travel at speeds above the allowed limit.

A last point we want to consider here is weight. In the past, anti-lock brakes, air bags and laminated glass have made driving much safer while also increasing the weight of vehicles. ADAS technology may have a similar effect to a vehicle's weight, as electronics and cables put further weight on cars. In the future however, the trend could be reversed when ADAS cars or AVs are so much safer that weight can be reduced by decreasing coachwork material strength. On the other hand, for wealthier users, AVs might become a type of mobile home, with possible environmental downsides from their much larger size (Greenblatt and Shaheen 2015). Such second order effects impacting life-cycles of infrastructure and vehicles and thus their environmental footprint are even more difficult to predict than fuel use. Besides impacts on vehicle material, one could imagine material use decreases due to less parking facilities, narrower/fewer streets due to increased capacity (platooning) (Wadud 2016).

Taken together, future ADAS and AV technology has the potential to preserve the environment and health of people, and reduce running costs of cars. Still, there are technological challenges in order to reach this potential as well as prevailing uncertainties regarding the adoption and use of the technology by society. Overall, study results are unclear with regard to the question if autonomous driving would have a negative or positive impact on the environment (Crayton 2016).

2.2.3 Influence on urban area use

Increased comfort and safety might influence not only the mileage driven or the driving

[22] https://www.fueleconomy.gov/feg/driveHabits.jsp

behaviour and style, but even decisions of people about where to live and work. When time in a vehicle does not have to be spent on driving-related tasks, but instead permits other activities, users might not only consider further away destinations for their daily journeys and also their longer-term residential location decisions. Scenarios consider that ADAS and even more autonomous driving might make commuting more attractive. More people might move to the suburbs or even countryside when working in the city. This has an effect not only on overall car use and energy consumption (as discussed in the last section), but also on the population distribution in rural and urban areas. (Though currently, it is not clear how strong motion sickness might influence the attractiveness of longer rides considerably, and thus also the impact on triggering urban expansion (Wadud 2017).

Also, implications for urban infrastructure design can be imagined. A far-reaching scenario with AV would lessen the importance of the traveling time factor as a constraint for urban planning (Heinrichs 2015). Regarding urban area use, it is very difficult to predict the overall space requirements for a change from manual to autonomous driving, and we will only give two examples for both a reduction and an increase in space needed for cars. On the one hand, special lanes might be needed and result in less remaining space for other modes of transport. On the other hand, some manufacturers are already testing autonomous parking in parking houses (Audi 2012) and developers of parking robots (which take cars and bring them to their parking lot) think that there could be up to 60% more parking spaces on the same area through the reduction of space needed for humans to get out of the car and intelligent “packing” of cars of different sizes (Kowalewski 2014). There are other estimates which predict a reduction of parking space requirements up to over 90% (Milakis 2017). If less parking areas would be needed, especially in crowded urban areas more space for the citizens, e.g. children’s playgrounds would have space.

All the described developments are much less likely to occur with ADAS, or only on a much smaller scale.

2.2.4 Impact on daily activities, work-life-balance and stress

Another potential advantage of automated driving consists in gaining high-quality time. Time spent for certain daily activities might change when fully or partial autonomous driving becomes available. Driving may be exchanged for resting or sleeping, searching for parking might become unnecessary and used for activities that are more related to joy. The car as a living room with diverse seating positions and entertainment systems is already promoted as the future of driving[23]. An important target group for ADAS will be working commuters for whom fully automated driving, also if only available in certain circumstances like on the highway or in traffic jams, could provide flexibility in working hours and chosen living area. More time with the smart phone might be a very attractive option especially for the younger generation[24]. There are however, also potentially negative changes in daily activities, like having the possibility and felt obligation to work in the car instead of listening to the radio and talking to other passengers. Participants in a study said it was less likely to accompany kids to activities when they had an AV (Robertson 2016). A reduction in physical activity might result from door-to-door transportation by AVs (Pettigrew 2017). Automated/autonomous driving itself might also be more stressful than anticipated by manufacturers (Robertson 2016).

2.3 Societal expectations, knowledge and acceptance

The acceptance issue is central when discussing ADAS from a societal and ethical perspective. Societal expectations and knowledge of ADAS are also crucial to know in order to be able to implement generally accepted technology successfully.

It is important to think about how the public can anticipate, understand, and appreciate the impacts of an innovation like ADAS and autonomous driving. A current problem is still that personal inexperience make that difficult. The question is then, on what basis the public judges the value of ADAS and autonomous driving (Hancock 2019). Many assumptions developed by the consumption of media accounts may be misleading. All involved professionals should disseminate their work and clearly articulate the limits of ADAS technology. Consent of the public currently is largely implicit, which makes it very vulnerable for unexpected failures like the fatal Uber crash (Hancock 2019). It may be incorrect to frame the question about ADAS safety as a “Machines are better at vs. Men are better at” type of question. Rather, it should be communicated that it is a cooperative achievement to improve safety in traffic (Hancock 2019). However, this cooperative endeavor also creates new problems. First, on the level of manually driven-autonomously driven car cooperation (or pedestrian/cyclist-autonomous car cooperation or communication), and second, within an ADAS car, where the human driver is still in the loop.

[23] Fahrendes Büro und Wohnzimmer. Rinspeed zeigt die Zukunft des autonomen Fahrens. http://www.trendsderzukunft.de/fahrendes-buero-und-wohnzimmer-rinspeed-zeigt-zukunft-des-autonomen-fahrens/2014/02/18/

[24] A survey conducted by Carnegie Mellon University found that passengers say they would spend most of their time in a driverless car looking at their mobile devices (http://nymag.com/selectall/2016/10/is-the-self-driving-car-un-american.html)

The first relates to capability attribution errors, e.g. attribution of human-like rationality and motivations, but also the perceptual world. This is very different between humans and LIDAR/RADAR/Camera based AVs with regard to the sensitivity for certain aspects of the world (Hancock 2019). For example, a stop sign can be made unrecognizable for machine vision while it is still clearly a stop sign for humans (Hancock 2019). Overall, traffic rules are to a certain extent a social convention that also differs between countries/cultures. These difficulties are a problem both with regard to safety and acceptance.

2.3.1 Safety and functionality expectations vs. reality

There is an ongoing discussion about trust and acceptance of AVs, especially related to accident dilemma situations, privacy and hacking risks, and the general problem of not being in control of the vehicle constantly. Before discussing the issue of human-machine interaction in more detail, we will briefly discuss a question that is less often discussed: how much do future users know about ADAS and AVs, what are their expectations, and how might this affect their use of, and on a larger scale, the societal impact of the technology? There is one exceptionally interesting study on this issue: Robertson et al. found that among some of their study participants, limitations of current automated driving technology are not well known. 16% think it is unnecessary to pay attention in a partly AV, many would sleep, drink, text, and drive fatigued, or distracted. Some would also drive above the speed limit and disengage the automatic mode of the car if necessary, e.g. to run red lights in emergency situations. These findings indicate that inadequate driver behaviour and (mis)use of ADAS cars and AV might destroy some anticipated safety benefits or even aggravate certain safety risks of driving. While most drivers think that a manual or lessons are needed to be able to use an AV, some do not agree. Robertson et al. conclude that more education about the limitations and functions of partly AVs is needed (Robertson 2016, p. 27), as especially early adopters might overestimate functionality and drive risky with this technology.

2.3.2 HMI acceptance

There is also a lot of ongoing work on drivers' acceptance and trust in advanced HMI in AVs. Acceptance and trust are crucial, since they will partially determine whether AVs will actually be adopted on a broad scale.

HMIs in AVs can be roughly divided into two groups as far as acceptance and trust are concerned. The first group of HMIs is based on monitoring functions and vehicle actuation capable of adequately supporting drivers when facing difficulties, near-misses or when making dangerous errors while driving. Privacy-compliance and protection, as well as over- and under reliance in the system are the main determinants of drivers' acceptance for this group of technologies and functions. The second group of advanced HMIs are based on Highly Automated Driving (HAD) designed to reduce the risk of deliberate violation of traffic laws by harmonizing driving behaviors and enforcing these laws. For this group of technologies, the notions of driver's control and autonomy are crucial for driver's acceptance.

A number of recent online surveys have shown contrasted attitudes as far as trust and acceptance of HMIs in AVs are concerned. Schoettle and Sivak (2014), based on an online survey with 1533 participants aged 18 years or older from the UK, USA and Australia, concluded that the majority of participants thought HMIs in AVs are acceptable as they are potentially useful in collision reduction. However, it also showed a number of concerns such as potential HMIs failures, and limited driver's control. Furthermore, older participants seemed more concerned than younger ones regarding these points. Also, females were less convinced by AVs than males. The same tendencies have been observed in surveys in Austin, USA, based on the participation of 347 adults (Bansal et al., 2016); 1661 adults in Great Britain (Smith, 2016), and 4886 adults from 109 countries (Kyriakidis et al., 2015).

Thus, a multidimensional approach focused on a number of factors (e.g. age, gender, different psychological constructs such as fear of loss of control, and ethical values of autonomy and privacy) should be adopted and promoted to both study and foster acceptance and trust in HMIs in AVs. This is important to ultimately reach the aim to increase safety and at the same time respect users autonomy and privacy.

2.4 Influence on the job market

Job losses are often discussed in relation to automation in general, and for autonomous and automated driving specifically. Jobs in the car repair and maintenance sector are at stake if ADAS and AV adoption is accompanied by a trend to share cars (Litman 2017). Economic benefits from automation for commercial fleets might push the replacement of bus and taxi drivers by robots, though this is likely dependent on achieving fully AVs. There is already a 30% shortage of skilled truck drivers in the UK, making full automation very attractive for this sector (Wadud 2017). In a future scenario with autonomous vehicle fleets, other public transport modes might be used less frequently and drivers of e.g. trains could lose their jobs. Participants of a study said they would use taxis and other transport modes less often if they had an automated car (Heinrichs 2015). This result is probably at least partly based on the optimistic assumption that automation means that there will be fully autonomous cars that one can use when too tired or drunk and not able or allowed to drive anymore (Robertson 2016). For a near future world with broad adoption of ADAS cars, the decline in taxi and public transport use and the related consequences for driver jobs will most probably not be that severe. It could also be somewhat influenced on the number of elderly and disabled persons enabled to drive their own car by ADAS or AV technology, and how many of them regularly used taxis so far.

2.5 Public health

Autonomous driving has been embraced by some public health experts (Pettigrew 2017). There may be both direct effects, e.g. through reduced crash risk, and indirect effects, e.g. related to effects on employment in certain sectors, which has an effect on psychological health. Mobility options had always had a big influence on public health. In the horsecar era, horse manure was a risk factor for infectious diseases. With the introduction of streetcars, population dispersed into suburban locations, which reduced infectious disease risk and air quality in the cities. Increasing automobile use contributed and today still contributes considerably to non-communicable diseases like obesity, and while laws against impaired driving, seatbelts and unleaded gasoline improved safety, injuries and death from driving are still a big issue from a public health perspective. In addition, air pollution is a growing issue, especially in big cities (Crayton 2016).

Some health relevant implications of ADAS cars and AV adoption where already shortly discussed in the previous sections: the influence on stress levels, daily activities related to well-being, air quality, and social inclusion. Optimistic accounts predict that ADAS will increase spare and high-quality time; potentially improve air quality, especially in cities; help elderly and people with disabilities to take part in social life; reduce stress resulting from driving in difficult situations like traffic jams and under difficult weather conditions. All these undoubtedly desirable impacts are, however, relatively uncertain and increased automated/autonomous driving may even be realized with reversed effects. For example, further social exclusion may result if ADAS cars where unaffordable for some parts of society; traffic load may increase due to higher comfort and safety (rebound effect); working hours may go up above a healthy level for commuters who are able to work during their trips; and door-to-door-transport may reduce exercise. Obviously, a reduction in fatal accidents and injuries would be the most important health-related effect of AVs and ADAS cars adoption and has an additional potential to lower public health costs and reduce suffering. It is however, at the current state of technological development, impossible to quantify this impact. The fact that more than 90% of accidents are caused by human errors is frequently cited (e.g. Kockelman 2015) when predictions are made about the reduction of accidents through a change of control from human to machine. The World Health Organization estimates that 1.25 million people die in road accidents every year and more than 20 million are injured globally and that for those aged 15–29 years road accidents are the leading cause of death (WHO 2015). Motor vehicle safety was ranked among one of the past decade's great public health achievements in the US, comparable to tobacco control and prevention and control of infectious disease[25]. New kinds of machine errors, the challenges of mixed traffic, and unintended interaction with and use of ADAS by humans may however reduce the maximum achievable impact considerably.

2.6 Cultural aspects

Cultural aspects of driving are not only an interesting topic for sociologists but have practical implications for acceptance and use of ADAS cars. We can only briefly touch upon this topic in this deliverable but hope this will suffice in giving an idea about the importance of this aspect.

Intercultural differences of needs and preferences have to be taken into account when a product is to be successful on different national markets. In Germany, there are no speed limits on some highways. A car that is capable of driving perhaps 80km/h autonomously may be a smaller success in this country than in a country where speed limits of 80-100km/h are the norm. Another speculation is that testing of ADAS cars in US/California or France successfully may not mean that the model will be of any use in, for example, India, which can be attributed to legal reasons, as traffic regulations differ, but seems to be mostly a problem of driving culture.

Additionally, different meanings and values may be attributed to driving and cars by rural vs. urban population in the same country. Rural inhabitants, be it in the US or Germany, associate cars and driving with the freedom to go where they want, an option also having to do with growing to adulthood[26]. In the cities, the lack of mobility is not that pronounced or absent altogether for young people. Though practical attractiveness is higher for the rural population exactly due to this reason, emotionally charged meanings of the car might be a barrier for ADAS or partly autonomous driving in rural areas[27]. Having that in mind, ADAS development options or features like automatic routing, or personalized routing to shops with special offers as a means to increase sales of shops might be not as desired by some users as developers think.

Joy of driving may also be valued differently in different countries or subpopulations, and associated more with the practical value of getting from A to B and having a good time with

---

[25] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5343691/?report=reader
[26] http://nymag.com/selectall/2016/10/is-the-self-driving-car-un-american.html
[27] Ibid.

any activity (like working or reading while driving), or with being in control of the car.

Being in control of the car has also to do with independence from technology. Dependence from technology is often rejected and may give people a bad feeling if they are reflective about it, especially in the early adoption phase. This dependency on technology can also be seen as a general risk factor, similar to other technological solutions, e.g. energy supply, on which critical infrastructure relies on (Grunwald 2016). A value-sensitive design approach could take these retentions seriously and implement ADAS functions in a way that allow for high safety without denying users the feeling of control. This approach is however ethically questionable if the feeling of control was a mere illusion to trick users to acceptance.

Our last point here is that many users consider the car to be essentially a private room. This has implications for the prospects of car sharing, which is often discussed as a trend further enabled by autonomous driving, but may be hampered by the crucial point that people like to be in private in the car, and also like the idea of owning a car, due to practical and social status reasons. The point is also highly relevant in regard to the preservation of data privacy and in view of the in-car monitoring functions of ADAS cars. People might behave differently when monitored, whether data are actually safe from unauthorized access or used as a means for crime investigation, or not.

The three cultural aspects or functions and meanings of cars and driving described here (freedom and joy of driving, independence from technology, and the car as a private room) are closely related to the ethical aspects autonomy over ones actions (or moral agency), autonomy from technology, and privacy or data autonomy. In addition, the cultural aspects are often researched implicitly and indirectly in acceptance studies, though it may not be explicitly labelled as cultural studies.

3 Ethical aspects

3.1 Current Ethical Landscape

Apart from the legal, societal and cultural aspects of ADAS driving discussed above, there are a number of open ethical questions that need to be addressed before ADAS driving can be successfully implemented. The following pages are therefore meant to provide a comprehensive but succinct overview on these broad ethical questions. In this context, it may be necessary to differentiate between the vision of fully autonomous cars, where the vehicle occupant is completely relieved of any driving duties, and the pre-stages of semi-autonomous driving with varying levels of advanced driver assistance systems. As the latter are already in the development stage, e.g. in the context of the VI-DAS project itself, ethical challenges related to this technological stage are arguably more pressing than the more visionary questions that arise with fully autonomous driving. However, at least where ethics is concerned, the contrast between these different development stages might be smaller than expected. The overarching ethical themes seem to apply to both cases with only minor differences. These overarching themes – as they are discussed both in academic literature as well as in the general media – seem to be the following:

Responsibility

Who is responsible for the “actions” of a (semi-)autonomous car, e.g. in a crash situation? How should a (semi-)autonomous car decide in an eventual dilemma situation and what are the right (moral) criteria for its decision-making process?

Autonomy

What implications does the widespread use of (semi-)autonomous cars have on the autonomy of its occupant? These include issues of data privacy and control, but can also expand to general effects of increasing dependence on highly complex socio-technical systems.

Justice

Innovative technology can both be a chance for furthering justice and fairness between members of a society, but can just as well result in further cementing existing inequalities: (How) Is this the case for (semi-)autonomous driving?

3.1.1 Moral responsibility in automated driving

While the expected steep increase in traffic safety is one of the major advantages brought forward in the debate about automated driving, accidents will likely still occur, especially in the transition phase with mixed traffic involving vehicles without and with ADAS up to level 3 automation. This leaves open the question of who is responsible if an accident happens, that for example involves (fatal) injuries to persons.[28] The car itself can surely be seen as causally responsible, since it did make the decision to follow a certain action plan. However, awarding the vehicle moral responsibility seems to be misplaced: A vehicle as a technical artefact is not something that can be reasonably held accountable for its "actions". Indeed, it is questionable if the vehicle "acts" in the purest sense of the word: It does what it is programmed to do.[29] This leads us to the programmer or – more broadly – the manufacturer of a car with ADAS as the most likely candidate who can or should be held accountable for the harm their product causes. Hevelke and J. Rümelin (2015) arrive at the same preliminary conclusion, but go on to argue against exclusively burdening manufacturers with the responsibility for accidents. Manufacturers should certainly be held accountable for their products insofar as they are designed with a strong emphasis on safety (Ibid.) and for accidents that are clearly caused by malfunctioning technology. But a general moral responsibility for any and all accidents seems counterproductive as it could lead to an overall worse ethical outcome: If cars with ADAS in fact do have a positive impact on the numbers of injuries and fatalities in traffic, than there seems to exist a moral obligation to bring about the development and implementation of such technologies. Such further innovation would be severely hindered if manufacturers were the only ones shouldering the responsibility for any harm through (semi-)autonomous vehicles (Ibid.).

Not only accidents caused by unforeseen circumstances are a challenge for manufacturers, the same holds for foreseeable traffic situations that involve a need for the (semi-)autonomous vehicle to make a (moral) decision. This raises the question what general (moral) criteria should be implemented in a (semi-)autonomous car to ensure (morally) adequate decision-

[28] The question of moral responsibility for harm and damage caused by (semi-)autonomous vehicles is closely related to the open question of liability that is often raised in debates about this technology. For an in-depth discussion of the different liability issues of ADAS cars see also Deliverable 7.6. "Legal responsibility and ethical considerations".
[29] This of course is a very succinct and somewhat controversial characterization of a broad philosophical debate about the status of autonomous systems in general. This debate focuses on the question whether autonomous systems based on applications of machine learning and artificial intelligence can be described as moral agents and, if yes, what kind of moral agents they are. Popular accounts of autonomous systems as (artificial) moral agents e.g. include: Anderson/Anderson (2011), Wallach/Allen (2009), Moor (2006), Misselhorn (2018). Even if these accounts ascribe some kind of moral agency to autonomous systems, this does not include the ability of such moral machines to "take responsibility" for the outcomes of their decision-making processes in a sense akin to human moral accountability. For a general overview on the philosophical debate about autonomous systems, see: Misselhorn 2018.

making. This challenge is widely discussed in popular media in its more extreme cases of dilemma situations:

Should the (semi-)autonomous vehicle, after a short calculation phase, spare the group of people appearing in front of it and swerve on the next lane instead – thereby killing a single person? How should it decide when the death of either an older person or a child is inevitable? There are countless possible combinations of these so-called trolley problems (based on thought experiments by Foot (2002)). It is easy to see how what once was a thought experiment designed to bring our moral intuitions regarding Kantianism and Utilitarianism to the foreground, gained traction with the continuing development of autonomous driving: Here this thought experiment seems to become a painful reality and to answer this philosophical puzzle likewise turns into a pressing issue. While there is no defining answer to the question in sight, whether Kantianism, Utilitarianism or some other ethical concept is – in fact – the right one to implement in such vehicles, these questions need to be dealt with one way or another before ADAS driving can be responsibly implemented. With this general difficulty spelled out, it seems obvious that manufacturers or even individual programmers and developers should not be burdened with the task to answer these difficult and potentially unsolvable questions on their own. Instead, a public discourse about societal values with regard to ADAS driving and about the proper way to deal with accidents, difficult traffic situations and potential dilemma-situations needs to take place as a basis for clear legal and political regulations. Such regulations could provide a framework for manufacturers and innovators to work in and would also make a differentiation possible between cases where manufacturers are to be held responsible and those where they are not, e. g. for harm caused by the implemented course of action in a dilemma-situation.

Pointing to society at large and political or legal regulators specifically where the moral responsibility for harm caused by ADAS cars is concerned can also be important for another likely candidate to award moral responsibility to: The user of an ADAS car. The question if and if yes, why and how, the user of such a (semi-) autonomous vehicle might reasonably be held accountable for accidents, revolves around the users' ability to intervene if an accident is likely to occur. If a user has the ability to actually intervene and reduce the number of accidents by overriding the decisions of an autonomous vehicle or a semi-autonomous vehicle in autonomous mode, than this could mean that there is a moral obligation or a "duty to intervene" (Hevelke, Nida-Rümelin 2015, p. 623f.). Even though such a duty would reduce the appeal of an autonomous car and could only be used when at least one occupant could overtake the vehicle in critical situations, it could be a users' responsibility to pay attention during the drive (Ibid.). But the possibility of such an ability to intervene is questionable for two reasons: One being that a great number of accidents are not predictable enough to ensure a save transition from autonomous to manual driving (Ibid.). Additionally, it is highly unlikely that the user of an autonomous car is "able to keep up the necessary attention" to effectively intervene (Hevelke, Nida-Rümelin, also Bainbridge 1983, Goodall 2014). The same is likely true for the case of emergency transitions to manual vehicle operation in the case semi-autonomous driving (level 3 and 4).[30] Under this notion, users of (semi-)autonomous cars are hardly the right candidates to be held responsible of harm caused by (semi-)autonomous vehicles.

This is not to say that the users of (semi-)autonomous vehicles – much like its manufacturers – bare no responsibility for accidents caused by such vehicles: As users, they are the ones introducing these vehicles, and the risks associated with their use, into traffic in the first place. A reframing of the question of (moral) responsibility for harm caused by (semi-)autonomous vehicles can be helpful here. (Semi-)autonomous driving can be framed as socio-technical system with a multitude of relevant stakeholders: manufacturers, users, insurance companies (see also Baumann et al. 2018) as well as political and legal regulators who are mutually responsible for insuring a safe implementation of (semi-)autonomous driving. This idea will be revisited in section 4.2.

3.1.2 Autonomy in ADAS Driving

In the following pages, we take a closer look at the impact ADAS driving might have on the autonomy of its users: The impact on privacy and data autonomy, on autonomy to free decision-making and on autonomy as a contraposition to (technological) dependency.[31]

Of these different impacts on autonomy, concerns about privacy, data autonomy and protection belong to the most discussed topics where ADAS driving is concerned and with good reason: Since for this technology to actually function, high amounts of data, among them also sensitive personal data of the vehicle users, other road users and bystanders, needs to be collected and processed. These high amounts of data can – with the wrong goal in mind or in the wrong hands – pose a serious threat to a person's autonomy. It is therefore important

[30] An interesting question is, whether a user of a semi-autonomous car is responsible for accidents occurring at the time of planned transition phases, e.g. when transitioning from autonomous driving on highways to manual driving in municipal areas. Here the individual case needs to be considered to determine who is accountable for harm or damage done. For a general discussion of the ethical and legal challenges of HMI in the context of transition phases in semi-autonomous driving, see also Bellet et al. 2019.

[31] See also the German the ethics committee on automated and networked driving (Bundesministerium für Verkehr und digitale Infrastruktur 2017), where these aspects of autonomy in relation to autonomous driving are addressed.

to provide answers to a range of difficult questions: Who is in control of personal data collected and processed for ADAS driving? Can the amounts of personal sensitive date be reduced without compromising basic functions or the safety of the vehicle? How can sensitive data best be protected from improper use? Should there be the possibility to opt out of (semi-)autonomous driving in general?[32]

The latter question touches upon another way ADAS driving can have morally relevant effects: It can be seen as an obstacle for personal decision-making. Driving in autonomous mode is by definition a state, where there is no human driver necessary as the vehicle itself acts as the driver, the human having the status of a mere occupant. Any reactions made in traffic are therefore decisions programmed into the machine and at least in fully autonomous vehicles the vehicle occupant has no way of interfering with or overriding this automated process. This inability to decide freely about which particular course of action to take can be a problem for our personal autonomy. We can't, for example, freely decide to act somewhat irrationally, e.g. to drive faster than allowed if the situation calls for it – a decision that responsible citizens are entitled to make (Bundesministerium für Verkehr und digitale Infrastruktur 2017). This lack of influence would also be the case for other and much more morally difficult decisions on which action to take, e.g. the decision to prioritise one's own life and the lives of one's passengers in the event of an imminent accident that the machine on the basis of preceded ethical deliberation was not programmed to make. Although this is not a general argument against the implementation of (semi-)autonomous driving per se, it can be an argument against mandatory traffic automatization. The moral obligation to use the means necessary to make road traffic safer and thereby saving many people's lives cannot outweigh a persons' right to autonomy in personal-decision making. People should thus be fundamentally able to choose if they want to use an autonomous vehicle with the accompanying condition to hand over critical decisions to the machine or if they opt out of such technologies (Ibid.). This seems to be the right ethical choice even if this would mean to retain mixed traffic, which is arguably a lot more challenging to program and develop..[33]

---

[32] For an in-depth discussion about data privacy with a special focus on cars with ADAS see also Deliverable 1.7., especially section 2.1.. Deliverable 7.5. will also include information on the issue of data privacy.

[33] Introducing fully autonomous driving specifically on the streets without the necessity of a capable human driver can in some cases also benefit the autonomy of a person: This is for example the case for the elderly of people with disabilities in general that are not able to drive a car themselves. As indicated in sections 2.1.2 and 2.2.1.of the present report, this technology can be used to enable this group of the population to increase their independence and social participation thereby furthering their personal autonomy.

Another reason for enabling mixed traffic despite the accompanying difficulties is the risk of an increasing dependence on a highly complex socio-technical system that a purely or partly automated traffic system would represent. It is an open question what impacts an increasing dependence on such a complex technological system might have on a society of autonomous persons. Similarly to the aspect discussed above, turning autonomous driving into a mandatory system for the benefit of increased traffic safety, many people likely won't be comfortable at the thought of giving up their autonomy and their control over their own reactions and decisions to instead rely on a complex technological system that can be susceptible to failure. The risks associated with such a system failing, e.g. through deliberate sabotaging actions like hacking or through malfunctions of the system, seem to be very high and could have very disrupting impacts on public live (Grunwald 2016). Large quantities of citizens losing the ability to drive ("atrophying of skills") or a general inability to switch to manual driving can therefore be seen as a risk factor to be avoided (Ibid.). At the same time, this challenge is not limited to ADAS driving. We already are heavily dependent on complex systems, such as our energy supply. A clear answer to the question on how to balance the ability of personal autonomy with the dependency on technological systems seems not available in the foreseeable future and will likely depend on factors such as: how high the expected benefit of such a system would be and how safe such a system could be designed. Such systemic vulnerabilities inherent in a complex socio-technological system can be seen as morally justifiable from a utilitarian point of view, if the risks associated with the system can be considered to be low (Bundesministerium für Verkehr und digitale Infrastruktur 2017). Still, measures to avoid the susceptibility of system failure due to hacker attacks should be taken, e.g. by promoting IT security by both manufacturer and the state (Ibid.).

3.1.3 Considerations of Justice in ADAS Driving

A topic that tends to be minimized in the discussion about the ethics of autonomous driving or is relegated purely to the societal aspects of this technology are justice considerations. Especially in light of the possibility that cars with ADAS might become not only optional but mandatory, questions arise how ADAS driving can be designed affordable for the masses (see also section 2.1.1.): Who has access to this technology? How much will it cost and who is able to pay the price for cars with ADAS?

Putting a focus on affordability of ADAS driving can be the right thing to do in order to enable a majority of people to benefit from this innovation, especially people who are not yet able to independently take part in motorized personal travel such as elderly people or people with disabilities preventing them from driving. In addition to enabling previously excluded groups of people into personalized traffic, other justice considerations can be used as an argument to favour affordability. This includes the impact of ADAS driving on issues of liability and insurance: Under the notion that (semi-)autonomous driving is overall safer than other forms of non-automatized driving, this could lead to incentivizing the use of cars with ADAS by offering insurance contracts that are more attractive. On the other side, if cars with ADAS were to stay very expensive, they are only reasonably available for the already wealthy. People with a lower socio-economic background and less material means could then be even further marginalised, e.g. by paying comparably higher insurance premiums on top of not being able to enjoy the benefits of ADAS technologies like increased safety in the first place (Baumann et al. 2018). While this threat of further cementing existing injustice can be a reason to further the development of affordable ADAS, other reasons might count against it. One such reason can for example relate the underlying design principles followed when developing cars with ADAS like a “safety trumps all” approach that ensures that autonomous vehicles operate as safe as possible in traffic with as little accidents as possible. To ensure such a maximum safety approach can entail using more high-tech solutions and could increase the overall price of a car with ADAS (as previously discussed in section 2.1.1.). Here both ethical and practical questions arise: How safe is “safe enough”? How can the need for safety and the need for affordability be balanced in a morally acceptable way?

Another aspect indeed of consideration when implementing ADAS cars concerns fair risk allocation. Because of their speed and size, motorized vehicles like cars and trucks, are already introducing risks into traffic as is. As described in section 3.1.1. on the responsibility for accidents, the same can be said of (semi-)autonomous vehicles, even though the general hope is to reduce the risk of accidents happening or to minimize the harm caused by accidents. Here, however, there is an important distinction to be made between different stakeholders who may be affected by these risks in differing and morally relevant ways. One stakeholder group are the vehicle occupants themselves or the users of the car with ADAS, the second stakeholder group are other road users: users of manually driven motorized vehicles, but also cyclists and pedestrians (Grunwald 2016). As described in the previous section, at least as long as autonomous driving is not yet mandatory, people can freely decide if they want to use, a semi-autonomous or a manually driven motorized vehicle. Some members of the second stakeholder group, cyclists and pedestrians, lack a similar choice: While they can choose between using a motorized vehicle or not taking part in public traffic at all, this seems a disproportionate choice to burden them with as this would result in strong limitations and restrictions in personal mobility (Ibid.). At the same time, motorized vehicles, including cars with ADAS, pose a serious safety risk in particular for vulnerable road users like cyclists and pedestrians. For example, collision accidents between motorized vehicles and cyclists or pedestrians often lead to much more severe harms and even fatal outcomes for the latter group (Statistisches Bundesamt 2016). This means that with the implementation of autonomous vehicles on the street could be accompanied by a strong moral imbalance. There would be a group of stakeholders, namely the users of such autonomous vehicles, which would not only benefit from the advantages of autonomous driving (more safety, higher level of comfort), but would at the same time bear hardly any of the risks of this technology (Grunwald 2016, see also Baumann et al. 2018). It is the most vulnerable road users instead that are burdened with the majority of the risks associated with the technology without benefitting from it. Such an unequal distribution of risks and benefits seems unfair to us. This injustice leads us to the above-mentioned topic of moral responsibility and how a morally appropriate handling of this challenge could look like. An open question remains whether there should be a general rule or regulation that principally prioritizes the safety of vulnerable road users over the users of such autonomous vehicles.

How to prioritise the safety of all road users and other ethical questions of ADAS driving is something that needs to be part of the design and implementation process in general. Here it is important to take such justice-based considerations in account and ensure that there is a kind of procedural justice as well. This is also an issue when algorithms based on self-directed and therefore opaque machine learning are used, as there may be the possibility that algorithms develop discriminatory decision-making criteria, without the knowledge or even a general inability to identify and correct these criteria (The Royal Society 2017). How to prevent such potential system-immanent injustice is an open question that needs to be addressed as part of the regulations and conditions preceding the introduction of (semi-)autonomous vehicles onto the streets.

3.2 RRI, value-sensitive design and autonomous driving as a social experiment

As described in the three sections above, the development and implementation of ADAS driving will have morally relevant impacts on society and individuals alike, e.g. were personal autonomy is concerned. In addition, there is an as of yet open question of who needs to take responsibility if the technology causes harm. As is the case with many new and emerging technologies, furthering innovation of ADAS driving is confronted with a large deal of uncertainty: many of the ethical issues described above are merely hypotheticals – while likely to happen, it is unclear when, if at all or to what extend some ethical problems will occur. Moreover, there are potentially a great number of unknowns – effects and impacts of ADAS driving on individuals and society on an ethical level that are non-predictable (see: Grunwald 2016). This leaves the question of how to deal with these challenges adequately.

One way to address these challenges is to turn to concepts such as responsible research and innovation (RRI), an advanced version to constructive technology assessment (cTA) (Grunwald 2011). One definition of RRI describes this concept as a “transparent, interactive process” that brings together the different stakeholders (“societal actors and innovators”) involved with or affected by the innovation of a specific technology with the goal of mutual responsiveness to ensure that the technology in questions is acceptable, sustainable and societally desirable (von Schomberg 2011). Owen et al. (2012) summarises the features of RRI as ““science for society”, “science with society” and “reframing responsibility”. To further the ethical acceptability of the technology, as well as its societal desirability, in line with RRI principles it can be useful to turn to an older approach: Value Sensitive Design. According to Friedman et al. 2008 “Value Sensitive Design is a theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner throughout the design process.” (Ibid.,p. 70). To do so, the concept of Value Sensitive Design takes into account three distinct but necessary aspects: “conceptual, empirical and technical investigations” (Ibid. p. 72). In the conceptual investigation, a closer look is taken at the different stakeholders who are either directly or indirectly affected by the technology and its design in varying ways. This includes an analysis of the impact of design on values as well. Questions that for example address potential “trade-offs among competing values […] (e.g., autonomy vs. security, or anonymity vs. trust)” or the question whether moral values principally outweigh non-moral values, are part of the conceptual analysis process (Ibid., p. 72.). The findings of the conceptual investigation can then be complemented by empirical studies that draw on the experiences of social science and employ both qualitative or quantitate research methods (Ibid.). The third aspect of the Value Sensitive Design process focusses on the specific technology and includes technical investigations on how the “technological properties and underlying mechanisms support or hinder human values” (Ibid., p. 73) and how technology might be designed to support the important values discovered in the two analysis approaches mentioned prior. In section 4.6., Friedmann et al. (2008) offer an overview on the practical implementation of the Value Sensitive Design concept. This includes e.g. the suggestion to “identify direct and indirect stakeholders” (p. 87), “to identify benefits and harms for each stakeholder group” (p. 88) and link them to the according values, etc.

In practice, Value Sensitive Design and RRI have a lot in common and while both offer a great way to approach the ethical issues surrounding ADAS driving, they also have a common drawback. Both concepts are of an anticipatory nature with a strong focus on a pro-active design “to reduce the uncertainty in the early phases of technological development” (van de Poel 2016, p. 669). Unfortunately, “anticipation has its limits” (Ibid., p. 670) as it is highly unlikely that every unknown can be anticipated and every uncertainty can be addressed in the early stages of technology development (Ibid.). To still be able to control the development process and ensure a safe and ethically sound implementation alternative or additional approaches can be necessary.

One such promising approach to the ethical challenges posed by ADAS driving is to present the development process of this technology for what it is: a social experiment. Describing ADAS driving as an experimental technology takes into account that in order to advance the technology to its necessary functionality, the technology has to be tested under real conditions – in actual traffic. The reason for this is that a great number of use cases are unknown and will only emerge during actual traffic situations. Additionally, the quality of the solutions to many of the various use cases that can actually be anticipated can again only be tested under real conditions, since some of these cannot be adequately recreated in a safer test setting. As such, autonomous driving can reasonably be called an experimental technology and a social experiment (van de Poel 2016, Stilgoe 2017). With this status as a (social) experiment, however, risks on both an individual and a collective level arise, some of which we already touched on briefly in the sections above. Accordingly, an ethical framework for these kinds of technological social experiments needs to be established and adapted to the case of autonomous driving in order to minimise risks and ensure the development process to be carried out in an ethically justifiable fashion. In his 2016 article, author Ibo van de Poel tried to design such an ethical framework for technological innovations. As a basis, van de Poel relied on the so-called „bioethical principles of non-maleficence, beneficence, respect for persons (autonomy) and justice“(Ibid., p. 668) that are generally used in medicine to properly deal with human test subjects. Van de Poel processed and generalized these principles to fit for technological innovations. Two of these aspects – autonomy and justice – were already discussed in the sections above and indicate that such an ethical framework might be beneficial for the case of ADAS driving (van der Poel, 2016 also mentions autonomous driving as an example for this ethical framework). The other ethical aspects beneficence and non-maleficence were addressed, too, albeit only indirect and under the label „moral responsibility“ that discussed who should be held responsible for failing to live up to certain moral obligations.[34] In the following, we provide a short overview of the sixteen conditions to be met

[34] Van der Poel (2016) comments on „moral responsibility“ as well, stating that there is no need to add it explicitly as a fifth ethical value since it does not add anything substantial to the debate. It is only of

for technological social experiments on the basis of these four moral obligations to minimize harm, set ethically sound goals and respect autonomy and justice of the people involved in the experiment:

Table 1: An ethical framework for experimental technology

1	Absence of other reasonable means for gaining knowledge about risks and benefits
2	Monitoring of data and risks while addressing privacy concerns
3	Possibility and willingness to adapt or stop the experiment
4	Containment of risks as far as reasonably possible
5	Consciously scaling up to avoid large-scale harm and to improve learning
6	Flexible set-up of the experiment and avoidance of lock-in of the technology
7	Avoid experiments that undermine resilience
8	Reasonable to expect social benefits from the experiment
9	Clear distribution of responsibilities for setting up, carrying out, monitoring, evaluating, adapting, and stopping of the experiment
10	Experimental subjects are informed
11	The experiment is approved by democratically legitimized bodies
12	Experimental subjects can influence the setting up, carrying out, monitoring, evaluating, adapting, and stopping of the experiment
13	Experimental subjects can withdraw from the experiment

importance to the question of who should be responsible of ensuring that the four basic moral obligations are respected.

14	Vulnerable experimental subjects are either not subject to the experiment or are additionally protected or particularly profit from the experimental technology (or a combination)
15	A fair distribution of potential hazards and benefits
16	Reversibility of harm or, if impossible, compensation of harm

Source: Table modelled after Van de Poel 2016, table 3, p. 680

The sixteen conditions Van de Poel lists in his 2016 article can be an interesting starting point for reframing the development process of ADAS driving and enable innovators to take the multitude of ethical challenges that arise with the further implementation of cars with ADAS into traffic into account.

4 Conclusions and recommendations

In the following, we will give some recommendations for an ethically informed road map for future development of ADAS. The recommendations summarized here are based on the societal and cultural aspects and the current ethical landscape discussed in this deliverable. Open questions regarding privacy in ADAS applications, as well as insurance and liability issues are discussed in more detail in deliverables D7.4 and D7.6 “product liability” and “legal responsibilities and ethical considerations” respectively.

Reviewing the potential societal implications of VI-DAS the topics inclusion of elderly (and to a smaller extent, people with disabilities) and public health turned out to be the most relevant. VI-DAS could advance the state of technology of level 2 or level 3 cars to improve safety and make driving easier and safer especially for the elderly. Costs, potential cultural losses and acceptance difficulties are lower for ADAS than for partly and fully AVs. Also, many other (both negative and positive) societal prospects are more relevant for future developments of level 4 or level 5 cars, like enabling blind and disabled people to drive, and implications for urban planning and daily activities.

From a both economic and ethical point of view, it is important to consider who benefits from and who pays the price for introducing ADAS driving into traffic, or more elaborately spoken, analyse the risk constellation for automated driving (Grunwald 2016). Not only the chapter on equity, but also all others in this deliverable are to some extend concerned with the just distribution of costs and benefits. There are a great number of uncertainties regarding almost all possible impacts on the societal and cultural level, which makes it difficult to “solve” or rather find the “equation of ADAS benefits and costs”. Monetary costs and safety gains are only part of this equation. It also features benefits like social inclusion and equity, and costs like environmental pollution or the endangerment of a cultural heritage, source of joy and freedom, according to car-lovers. The interplay of a new technology and society with all its different actors is complex. Societal acceptance, adoption rates and user behaviour have to be taken into account e.g. when planning a future infrastructure for car traffic. In turn, any infrastructure situation will also influence the mobility choices of people as well. Nevertheless, one should not avoid these considerations in early stages of the development of ADAS cars in order to design the technology in a way that is most beneficial for society as a whole, at the same time not forgetting equity aims like e.g. improving autonomous mobility for people with disabilities and the elderly. Sometimes, various benefits are exclusive, or some developments will inevitably have downsides that cannot be minimized by technology as such (e.g. ADAS for everyone means more safety and convenience, but high monetary investments which might be needed somewhere else, and a bigger strain on the environment, e.g. by potential rebound effects.

From an ethical point of view a variety of open questions present itself with ADAS driving and the advancement towards fully autonomous driving. Three key points were discussed in the present paper: ADAS driving and moral responsibility for crashes, its' impacts on personal autonomy and justice considerations related to this innovation. As mentioned above, the latter aspect is closely related to the allocation of benefits and costs/risks. Apart from balancing the different societal needs, keeping personal autonomy intact is also an important ethical requirement. This concerns matters of privacy and data security, but also freedom to personal decision-making and a choice to partake in technological innovations or to reject them. The question of who exactly should take responsibility for harm caused by ADAS driving seems to be a central open question. As with the other ethical considerations, this question needs to be addressed on a societal level and include the views of the different stakeholders affected by this technological innovation. To that end, several concepts were explored that could help deal with this challenge to ensure an ethically acceptable implementation of the technology. From those the RRI related concept of Value Sensitive Design and especially the idea of ADAS innovation as a social experiment seem promising. Here the "ethical framework for experimental technologies" (van de Poel 2016) might prove helpful. In the following, we will give some recommendations that should be considered in a roadmap for future ADAS development.

Responsibility

- What can developers and manufacturers of ADAS cars be reasonably held accountable for:
  - Accidents than can clearly be based on malfunction of technology, manufacturing errors that are in conflict with regulations
  - Responsible for ensuring that technology functions and adheres to the high standards put in place by politics as an actor for society as a whole through laws and regulations
  - Also potentially responsible to inform regulators if during their practical work they learn something new or gain knowledge of other necessary conditions.

<u>Expectations and knowledge</u>

- Make clear what the limitations and risks of ADAS cars are

Equity/Justice

Costs for ADAS and associated infrastructure

- For developers, a trade-off between comfort and affordability might help to make safety increasing ADAS available to a bigger part of the population
- Public agencies should take great care to make sure that infrastructure investments from tax money benefit society as a whole and not only the happy few who can afford ADAS and AVs.

Environmental and air quality-related health impacts:

- Ethical obligation to find ways of ADAS development and implementation that may help to reach the positive potential in this respect, in order to make ADAS also a beneficial option for non-drivers. E.g., raise awareness for a manner of ADAS usage that helps fuel reduction.

Risk allocation

- Prioritize the safety of other vulnerable road users and bystanders
- Figure out, eventually with the help of a societal discourse, what an ethically acceptable balance between safety measures and cost of the technological system can be
- Take special care in test situations in real traffic conditions. Lead questions can be: Who are (in)voluntary test subjects in the development phase? How can they be best informed about potential risks? How can they consent to take part in a social experiment? How can risks to them be minimised?

Autonomy

Mobility improvements for people with disabilities

- Car companies should also not to overpromise
- Principles of universal design need to include and not further exclude people with disabilities
- Do not exclude/underfinance alternatives like public transport barrier freeness

Inclusion of elderly

- Ethical obligation to improve mobility of elderly through user-centred design of ADAS

The car as a private room/data autonomy

- Data autonomy and privacy should not be compromised in ADAS cars

Freedom and autonomy over ones actions

- Routing according to other interests (advertising) may endanger autonomy of choice, e.g. practices like nudging, especially if they are intransparent

Intercultural differences

- Promote a culture of driving where safety comes first, not adventurous/high speed driving

References

Alexander, J., Barham, P., & Black, I. (2002). Factors influencing the probability of an incident at a junction: Results from an interactive driving simulator. Accident Analysis and Prevention, 34(6), 779–792.

Anderson, M.; Anderson, S. L.: 2011.Machine ethics. Cambridge, MA: Cambridge University Press. https://doi.org/10.1017/CBO9780511978036.

Audi 2012: Automatisch ins Parkhaus,
available online: http://blog.audi.de/2012/09/21/automatisch-ins-parkhaus.

Li, G., Braver, E. R., & Chen, L. (2003). Fragility versus excessive crash involvement as determinants of high death rates per vehicle-mile of travel among older drivers. Accident Analysis and Prevention, 35(2), 227–235.

Bailly, B. (2004). Conscience de la Situation des conducteurs: aspects fondamentaux, méthodes et applications pour la formation des conducteurs. Doctoral dissertation. University of Lyon 2, France.

Bainbridge, L. 1983. Ironies of automation.Automatica19:775–779.

Bansal, P., Kockelman, K.M., Singh, A., 2016. Assessing public opinions of and interest in new vehicle technologies: an Austin perspective. Transport. Res. C: Emerg. Technol. 67, 1–14.

Baumann, M. F., Brändle, C.; Coenen, C.; Zimmer-Merkle, S. 2018.Taking responsibility: A Responsible Research and Innovation (RRI) perspective on insurance issues of semi-autonomous driving. Transportation Research Part A: Policy and Practice. https://doi.org/10.1016/j.tra.2018.05.004.

Bellet, T., Bailly-Asuni, B., Mayenobe, P., Banet, A. (2009). A theoretical and methodological framework for studying and modelling drivers' mental representations, *Safety Science*, 47, pp. 1205–1221.

Bellet, T., Paris, J. C., & Marin-Lamellet, C. (2018). Difficulties experienced by older drivers during their regular driving and their expectations towards Advanced Driving Aid Systems and vehicle automation. *Transportation research part F: traffic psychology and behaviour*, *52*, 138-163.

Bellet, T., Cunneen, M., Mullins, M., Finbarr, M., Pütz, F., Spickermann, F., Brändle, C., Baumann, M. F. (2019). From semi to fully autonomous vehicles: New emerging risks and ethico-legal challenges for human-machine interactions. *Transportation Research Part F: Traffic Psychology and Behaviour*. 63, 153-164. https://doi.org/10.1016/j.trf.2019.04.004

Bolstad, C. A. (2001). Situation awareness: Does it change with age? Proceedings of the human factors and ergonomics society 45th annual meeting, Minneapolis, Minnesota, USA, 272–276.

Bösch, Patrick M.; Becker, Felix; Becker, Henrik; Axhausen, Kay W. (2018): Cost-based analysis of autonomous mobility services. In: *Transport Policy* 64, S. 76-91. DOI: 10.1016/j.tranpol.2017.09.005.

Braitman, K. A., Kirley, B. B., Ferguson, S., & Chaudhary, N. K. (2007). Factors leading to older drivers' intersection crashes. Traffic Injury Prevention, 8, 267–274.

Bradshaw-Martin H., & Easton C. (2014) Autonomous or 'driverless' cars and disability: a legal and ethical analysis", 20(3) Web JCLI.

Bundesministerium für Verkehr und digitale Infrastruktur (2017) Ethik-Kommission: Automatisiertes und Vernetztes Fahren, report: http://www.bmvi.de/SharedDocs/DE/Anlage/Presse/084-dobrindt-bericht-der-ethik-kommission.pdf?__blob=publicationFile, last accessed: 31.08.2017

Chris Hendrickson (PI), Corey Harper (2015): Safety and Cost Assessment of Connected and Automated Vehicles. Carnegie Mellon University, University of Pennsylvania.

Clarke, D. D., Ward, P., Bartle, C., & Truman, W. (2010). Older drivers' road traffic crashes in the UK. Accident Analysis and Prevention, 42(4), 1018–1024.

Classen, S., Winter, S. M., Velozo, C. A., Bédard, M., Lanford, D. N., Brumback, B., & Lutz, B. J. (2010). Item development and validity testing for a self- and proxy report: The Safe Driving Behavior Measure. American Journal of Occupational Therapy, 64, 296–305.

Henry Claypool, Amitai Bin-Nun, Jeffrey Gerlach (2017): SELF-DRIVING CARS: THE IMPACT ON PEOPLE WITH DISABILITIES. Online verfügbar unter http://secureenergy.org/wp-content/uploads/2017/01/Self-Driving-Cars-The-Impact-on-People-with-Disabilities_FINAL.pdf, zuletzt geprüft am 07.08.2019.

Crayton, Travis J.; Meier, Benjamin Mason (2017): Autonomous vehicles: Developing a public health research agenda to frame the future of transportation policy. In: *Journal of*

Transport & Health 6, S. 245-252. DOI: 10.1016/j.jth.2017.04.004.

Edwards, J. D., Lunsman, M., Perkins, M., Rebok, G. W., and Roth, D. L. (2009). Driving cessation and health trajectories in older adults. *The Journals of Gerontology Series A : Biological Sciences and Medical Sciences*, 64(12) :1290–1295.

Ferati, Mexhid; Murano, Pietro; Anthony Giannoumis, G. (Hg.) (2018): Universal Design of User Interfaces in Self-driving Cars. Advances in Design for Inclusion. Cham: Springer International Publishing.

Daniel Howard, Danielle Dai (2014): Public Perceptions of Self-driving Cars: The Case of Berkeley, California. Transportation Research Board 93rd Annual Meeting, Washington.

Di Bucchianico, Giuseppe; Kercher, Pete F.; Ferati, Mexhid; Murano, Pietro; Anthony Giannoumis, G. (Hg.) (2018): Universal Design of User Interfaces in Self-driving Cars. Advances in Design for Inclusion. Cham: Springer International Publishing.

Dickerson, A. E., Molnar, L. J., Eby, D. W., Adler, G., Bédard, M., Berg-Weger, M., Classen, S., Foley, D., Horowitz, A., Kerschner, H., et al. (2007). Transportation and aging : A research agenda for advancing safe mobility. The Gerontologist, 47(5) :578–590.

Diepold, Katharina; Götzl, Kerstin; Riener, Andreas; Frison, Anna-Katharina (2017): Automated Driving: Acceptance and chances for elderly people. In: Andreas Löcken, Susanne Boll, Ioannis Politis, Sebastian Osswald, Ronald Schroeter, David Large et al. (Hg.): Proceedings of the 9th International Conference on Automotive User Interfaces and Interactive Vehicular Applications Adjunct - AutomotiveUI '17. the 9th International Conference. Oldenburg, Germany, 24.09.2017 - 27.09.2017. New York, New York, USA: ACM Press, S. 163-167.

Foot, Philippa (2002): The Problem of Abortion and the Doctrine of the Double Effect. Virtues and Vices: and other essays in moral philosophy. Oxford University Press. DOI: 10.1093/0199252866.003.0002

Friedmann, Batya; Kahn Peter H., Borning, Alan (2008): Value Sensitive Design and Information Systems (2008). The handbook of information and computer ethics, Page 69-101

Frison, Anna-Katharina, Aigner, Laura, Riener, Andreas; Wintersberger, Philipp (2017): Senior Drivers. Using the Benefits of Automated Driving for the Elderly

Goodall N.J. (2014): Machine Ethics and Automated Vehicles. In: Meyer G., Beiker S. (eds)

Road Vehicle Automation. Lecture Notes in Mobility. Springer, Cham DOI: 10.1007/978-3-319-05990-7_9

Greenblatt, Jeffery B.; Shaheen, Susan (2015): Automated Vehicles, On-Demand Mobility, and Environmental Impacts. In: *Curr Sustainable Renewable Energy Rep* 2 (3), S. 74-81. DOI: 10.1007/s40518-015-0038-5.

Grunwald, A. (2011): Responsible innovation: Bringing together technology assessment, applied ethics, and STS research. Enterprise and Work Innovation Studies 7, 9-31

Grunwald, A. (2016): Social risk constellations for autonomous driving. Analysis, historical context and assessment. In: Autonomous driving. Technical, legal and social aspects (eds. M. Maurer, J.C. Gerdes, B. Lenz, H. Winner), pp. 641-662, Springer Open, Heidelberg DOI 10.1007/978-3-662-48847-8_30

Hancock, P. A.; Nourbakhsh, Illah; Stewart, Jack (2019): On the future of transportation in an era of automated and autonomous vehicles. In: *Proceedings of the National Academy of Sciences of the United States of America* 116 (16), S. 7684-7691. DOI: 10.1073/pnas.1805770115.

Harper, Corey D.; Hendrickson, Chris T.; Samaras, Constantine (2016): Cost and benefit estimates of partially-automated vehicle collision avoidance technologies. In: *Accident; analysis and prevention* 95 (Pt A), S. 104-115. DOI: 10.1016/j.aap.2016.06.017.

Harper, Corey D.; Hendrickson, Chris T.; Mangones, Sonia; Samaras, Constantine (2016): Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions. In: Transportation Research Part C: Emerging Technologies 72, S. 1-9. DOI: 10.1016/j.trc.2016.09.003.

Heather Bradshaw-Martin, Catherine Easton: Autonomous or ‘driverless’ cars and disability: a legal and ethical analysis. Available online: http://webjcli.org/article/view/344.

Heikkilä, Veli Matti; Kallanranta, Tapani (2005): Evaluation of the driving ability in disabled persons: a practitioners' view. In: *Disability and rehabilitation* 27 (17), S. 1029-1036. DOI: 10.1080/09638280500052740.

Heinrichs, Dirk; Cyganski, Rita (2015): Automated Driving. How It Could Enter Our Cities and How This Might Af fect Our Mobility Decisions. In: disP - The Planning Review 51 (2), S. 74-79. DOI: 10.1080/02513625.2015.1064650.

Hevelke, A. Nida-Rumelin, J. (2015): Responsibility for crashes of autonomous vehicles. An ethical analysis. Science and engineering ethics, 21 (3), 619-630. DOI:

10.1007/s11948-014-9565-5

Howard, Danial; Dai, Danielle (2013): Public Perceptions of Self-driving Cars: The Case of Berkeley, California. 93rd Annual Meeting of the Transportation Research Board, 01.08.2013, zuletzt geprüft am 07.08.2019.

Kaber, D., Zhang, Y., Jin, S., Mosaly, P., & Garner, M. (2012). Effects of hazard exposure and roadway complexity on young and older driver situation awareness and performance. Transportation Research Part F: Traffic Psychology and Behaviour, 15(5), 600–611.

Kyriakidis, M.; Happee, R.; Winter, J.C.F. de (2015): Public opinion on automated driving. Results of an international questionnaire among 5000 respondents. In: Transportation Research Part F: Traffic Psychology and Behaviour 32, S. 127-140. DOI: 10.1016/j.trf.2015.04.014.

Koppel, S., Bohensky, M., Langford, J., & Taranto, D. (2011). Older drivers, crashes and injuries. Traffic Injury Prevention, 12(5), 459–467.

Koppel, S., Charlton, J., & Fildes, B. (2009). Distraction and the older driver. In M. A. Regan, J. D. Lee, & K. S. Young (Eds.), Driver distraction: Theory, effects and mitigation (pp. 579–601). Florida, USA: CRC Press.

Kowalewski, S. (2014): Überlassen Sie das Parken Ray. Deutschlandradio Kultur. Available online: http://www.deutschlandradiokultur.de/technologie-ueberlassen-sie-das-parken-ray.2165.de.html?dram:article_id=290092.

Kyriakidis, M., Happee, R., de Winter, J.C.F., 2015. Public opinion on automated driving: results of an international questionnaire among 5000 respondents. Transp. Res. Part F: Traffic Psychol. Behav. 32, 127–140.

Fagnant DJ, Kockelman K. Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. Transp Res Part A Policy Pract. 2015; 77: 167–81.

Langford, J., & Koppel, S. (2006). Epidemiology of older driver crashes – Identifying older driver risk factors and exposure patterns. Transportation Research Part F: Traffic Psychology and Behaviour, 9(5), 309–321.

Langford, J., Methorst, R., & Hakamies-Blomqvist, L. (2006). Older drivers do not have a high crash risk: A replication of low mileage bias. Accident Analysis and Prevention, 38(3), 574–578.

Litman, T. (2017) Autonomous vehicle implementation predictions. Implications for transport planning. Victoria transport policy insitute.

Litman, Todd (2019): Autonomous Vehicle Implementation Predictions. Implications for Transport Planning. Hg. v. Victoria Transport Policy Institute, zuletzt geprüft am 06.08.2019.

Marottoli, R. A., De Leon, C. F. M., Glass, T. A.., et al. (2000). Consequences of driving cessation decreased out-of-home activity levels. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 2000, vol. 55, no 6, p. S334-S340.

Marottoli, R. A., Mendes de Leon, C. F., Glass, T. A., and Williams, C. S. (1997). Driving cessation and increased depressive symptoms : prospective evidence from the new haven epese. *Journal of the American Geriatrics Society*.

Milakis, Dimitris; van Arem, Bart; van Wee, Bert (2017): Policy and society related implications of automated driving: A review of literature and directions for future research. In: *Journal of Intelligent Transportation Systems* 21 (4), S. 324-348. DOI: 10.1080/15472450.2017.1291351.

Misselhorn, C. 2018. Maschinen mit Moral? Grundfragen der Maschinenethik. Stuttgart: Reclam.

Moor, J. A. 2006. The nature, importance, and difficulty of machine ethics. IEEE Intelligent Systems 21:18–21.

Nunes, Ashley; Hernandez, Kristen D. (2019): Autonomous Vehicles and Public Health: High Cost or High Opportunity Cost?

Owen, R., Macnaghten, P., Stilgoe, J. (2012): Responsible research and innovation: From science in society to science for society, with society. Science and Public Policy, 39(6), 751–760, https://doi.org/10.1093/scipol/scs093DOI: 10.1093/scipol/scs093

Pochet, P. (2003). Mobilité et accès à la voiture chez les personnes âgées: Évolutions actuelles et enjeux. *Recherche - Transports - Sécurité*, Volumes 79–80, April 2003, pp 93–106.

Preusser, D. F., Williams, A. F., Ferguson, S., Ulmer, R., & Weinstein, H. B. (1998). Fatal crash risk for older drivers at intersections. Accident Analysis and Prevention, 30(2), 151–159.

Pettigrew, Simone (2017): Why public health should embrace the autonomous car. In: *Australian and New Zealand journal of public health* 41 (1), S. 5-7. DOI: 10.1111/1753-6405.12588.

Risto Kulmala, Juhani Jääskeläinen, Seppo Pakarinen (2019): The impact of automated transport on the role, operations and costs of road operators and authorities in Finland. Hg. v. Traficom, zuletzt geprüft am 06.08.2019.

Robyn D. Robertson, Shawna R. Meister and Ward G.M. Vanlaar (Traffic Injury Research Foundation (Toyota)) (2016): Automated vehicles: driver knowledge, attitudes and practices. In: Highway Capacity Manual. Online verfügbar unter https://trid.trb.org/view.aspx?id=1440348.

Schoettle, B., Sivak, M., 2014. A Survey of Public Opinion About Autonomous and Self-Driving Vehicles in the US, the UK, and Australia. University of Michigan Tansportation Research Institute, Ann Arbor, MI.

Sieberns, Anne: Universal Design and Human Rights: The UN Convention on the Rights of Persons with Disabilities (CRPD)

Skyving, M., Berg, H.-Y., & Laflamme, L. (2009). Older drivers' involvement in fatal RTCs. Do crashes fatal to them differ from crashes involving them but fatal to others? Safety Science, 47(5), 640–646.

Smith, M., 2016. Majority of public would be scared to take a ride in a driverless car. London: YouGov. Available at: https://yougov.co.uk/news/2016/08/26/majoritypublic-would-be-scared-take-ride-driverle/

Statistisches Bundesamt (2016): Unfallentwicklung auf deutschen Straßen 2015, Wiesbaden: https://www.destatis.de/DE/PresseService/Presse/Pressekonferenzen/2016/Unfallentwicklung_2015/Pressebroschuere_unfallentwicklung.pdf?__blob=publicationFile, last accessed: 31.08.2017

Strachan S., Senat T., Anastassova M., Panëels S., Schouten P., Paris J.C., Bey C., Bellet T., Richard B., Banet A.,, Van Elslande P. (2017). Specifications of the user-interface and information exchange between driver and vehicle, VIDAS Deliverable 5.1, pp. 105-118

T.S. Stephens: ANL; J. Gonder and Y. Chen: NREL; Z. Lin and C. Liu: ORNL; D. Gohlke: USDOE: Estimated Bounds and Important Factors for Fuel Use and Consumer Costs of Connected and Automated Vehicles, zuletzt geprüft am 06.08.2019.

SAE International. 2016. Standard J3016.Taxonomy and definitions for terms related to on-roadmotor vehicle automated driving systems.

Stilgoe, Jack (2017): Machine learning, social learning and the governance of self-driving cars.

Social Studies of Science, p. 1-32, DOI: 10.1177/0306312717741687

Strachan S., Senat T., Anastassova M., Panëels S., Schouten P., Paris J.C., Bey C., Bellet T., Richard B., Banet A.,, Van Elslande P. (2017). Specifications of the user-interface and information exchange between driver and vehicle, VIDAS Deliverable 5.1, 130 p.

The Royal Society. 2017. Machine Learning: the Power and Promise of Computers that Learn by Example. https://royalsociety.org/-/media/policy/projects/machine-learning/publications/machine-learning-report.pdf, last accessed: 26.08.2019

Torvey, A. (2016) Think self-driving cars could mean an end to traffic jams? Think again...http://www.telegraph.co.uk/business/2016/07/19/think-self-driving-cars-could-mean-an-end-to-traffic-jams-think/

Van de Poel, Ibo (2016) : An Ethical Framework for Evaluating Experimental Technology. Sci Eng Ethics 22, p. 667-686, DOI : 10.1007/s11948-015-9724-3

Von Schomberg, R. (2011): Prospects for technology assessment in a framework of responsible research and innovation. In: Technikfolgen abschätzen lehren: Bildungspotenziale transdisziplinärer Methoden (eds. M. Dusseldorp and R. Beecroft), pp 39-61, VS Verlag, Wiesbaden, DOI: 10.2139/ssrn.2439112

Vrkljan, B. H., & Miller-Polgar, J. (2005). Advancements in vehicular technology: Potential implications for the older driver. International Journal of Vehicle Information and Communication System, 1, 88–105.

Wadud, Zia (2017): Fully automated vehicles. A cost of ownership analysis to inform early adoption. In: Transportation Research Part A: Policy and Practice 101, S. 163-176. DOI: 10.1016/j.tra.2017.05.005.

Wallach, W.; Allen, C.. 2009. Moral machines: Teaching robots right from wrong. New York: Oxford University Press.

Worland, J. (2016) Self-Driving Cars Could Help Save the Environment—Or Ruin It. It Depends on Us. Time online. http://time.com/4476614/self-driving-cars-environment/