



University of Bergen  
Department of Linguistic, Literary and Aesthetic Studies

DIKULT350  
Master's Thesis in Digital Culture  
Fall 2018

Social and ethical implications of Automated Vehicles. Understanding virtualization  
and dematerialization of the human driver in Smart Mobility scenarios

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## Abstract

This study focuses on gathering and mapping the effect of vehicle automation presented in scenarios of Smart Mobility and automotive industry stakeholders. The main perspective used in the thesis is rooted in the social constructivist framework which implies the social development of technological artifacts and put against technocentric views often represented by the advocates of vehicle automation. The study reviews the technology of Machine Learning as the main enabler of vehicle automation, and possible corresponding effects of digitization processes such as automation, dematerialization, and virtualization of users of traffic systems. The thesis also studies human interaction with interactive technology e.g., Automated Vehicle interfaces from the current perspective of Digital Culture, Ethics, and Interaction Design.

## Sammendrag

Følgende avhandling fokuserer på å samle og kartlegge påvirkningen av kjøretøyautomasjon som er presentert i scenarioene av Smart Mobility og bilindustriens interesser. Hovedperspektivet i avhandlingen er forankret i sosial konstruktivisme som antyder sosial utvikling av teknologiske artefakter, noe som blir testet mot teknosentrisk synspunkt ofte brukt av representater av kjøretøyautomasjon. Avhandlingen også gjennomgår maskinlæring, teknologien som er ment til å muliggjøre kjøretøyautomasjon i tillegg til andre tilsvarende digitaliseringsprosesser som automatisering, dematerialisering, og virtualisering av brukere av trafikksystemer. Avhandlingen ser også nærmere på menneskets interaksjon med interaktiv teknologi, som for eksempel diverse løsninger for brukergrensesnitt i automatiserte kjøretøy, med nåværende perspektiv i Digital Kultur, Etikk, og Interaksjonsdesign.

Keywords: vehicle automation, automated vehicles, virtualization, dematerialization, digitization.

Nøkkelord: kjøretøyautomasjon, selvkjørende biler, virtualisering, dematerialisering, digitalisering.



## Table of Contents

Abstract.....	3
Sammendrag.....	3
Introduction.....	6
Topic of the thesis.....	6
Structure of the thesis.....	8
Theoretical framework.....	9
Terminology and definitions.....	20
Reception and implementation of Automation Levels.....	24
Legal framework for Automated Vehicles.....	27
Summary.....	30
Cultural and historical aspects of Automated Vehicles.....	30
New challenges to the ethics of technology.....	33
Basic ethical approaches.....	35
Discussing ethics of automotive industry.....	36
Social perception of Automated Vehicles.....	38
Intelligent Agents.....	40
Case study of Automated Vehicle Scenarios .....	43
Introduction to the selected material .....	43
Basic principles of Smart City and Smart Mobility.....	46
Daimler’s scenario – Smart Vision EQ Fortwo .....	48
Expansion of Daimler's vision through Car2go services.....	52
Scenario presented by Waymo .....	55
Waymo's Early Rider Program.....	57
Benefits of Automated Mobility on Demand.....	62
Discussion.....	65
Safety and ethics of Automated Vehicles enhanced with Artificial Intelligence.....	65
Cognitive implications of Smart Mobility scenarios.....	73
Results and Conclusion.....	85
Summary of Findings.....	85
Conclusions and future of the field.....	87
Bibliography.....	88

# Introduction

## *Topic of the thesis*

According to the most recent reports, urban areas experience exponential growth on a global basis, where urban population of the world has grown rapidly from 751 million in 1950 to 4.2 billion in 2018 and is expected to increase by additional 2.5 billion people by 2050 (UN, 2018). Considering demographics, power requirements and territorial challenges, the way it has been designed during 20<sup>th</sup> century, the current transport sector cannot provide sustainable and efficient service for society in the 21<sup>st</sup> century. In this regard, there are some innovations that may provide possible solutions to existing structural deficiencies of the automotive sector. In the following work, I will attempt to discuss how emerging technologies developed by both automotive industry and Smart City, offer realistic, or less realistic scenarios for future mobility. The relation between automotive industry and Smart City transportation scenarios, has become more intertwined during the last years, as Smart City visions provide a “framework, predominantly composed of Information and Communication Technologies (ICT), to develop, deploy and promote sustainable development practices to address growing urbanization challenges” (Gemalto, 2018). Smart City scenarios have stimulated in various ways the automotive industry which has adopted some of its ideology e.g., to include automated driving as a technology that could improve the quality of life in urban areas.

The following work aims to explore from the perspective of key issues in Digital Culture the relation between visions of the Automated Vehicles (AVs), Smart Mobility and automotive industry and their possible influence on the role, behavior, and construction of a human driver. These three visions, each in their own way, have been fueling technological development and industrial ambitions which calls for a closer revision and analysis of the benefits and challenges, that some scenarios derived from these visions may bring to society. In order to concretize this approach, I will present and analyze selected theories and scenarios that refer both implicitly and explicitly to views on various digital technologies, ethics and society.

Central actors have expressed their visions in various narratives in form of scenarios and prototypes, with particular emphasis on automation and autonomous technologies as potential solutions to address existing societal and environmental problems. By gradually replacing or removing human driver behavior as a variable, industrial and societal advocates of vehicle automation, develop an argument that is present in many scenarios - that technology will be able to offer new mobility opportunities, better safety and efficiency, resulting in e.g., further reduction of

traffic accidents or the time people spend in traffic jams. However, these scenarios may not only generate above-mentioned positive effects but also pose new challenges to the whole transportation sector and to the configuration of urban areas e.g., safety and reliability issues, disappearance of jobs for people who used to make their living as professional drivers, adapting city infrastructure to the new technology. In order to assess how several central actors and stakeholders in Smart Mobility and in the automotive industry address such issues and challenges, a close reading of various narratives of vehicle automation will be required. An analysis of the arguments presented in several key documents released by leaders of the automotive industry, such as white papers, vision statements and reports, may possibly reveal both converging and diverging discourse strategies which will be used to compare Smart Mobility visions with the views expressed in documents provided by automotive industry. Furthermore, there is a need to establish to what degree, supporters of vehicle automation, aspire to modify the lifestyle of individuals through total product design and what impact such approach may have on the notion of the driver or user of a vehicle. Some versions of these visions, may imply substantial changes to the ownership of the object (e.g. the 'car' or the 'vehicle') and to services connected to transport (e.g. carsharing<sup>1</sup>, ridehailing<sup>2</sup>, ridesharing<sup>3</sup>). These changes may lead to the emergence of new transportation and mobility behaviors replacing the individual by collaborative consumption. The development of new types of services linked with the automated driving technology re-actualizes and concretizes the broader theme of dematerialization and corresponding virtualization of traditional, physical mobility, which could be compared to many other economic sectors becoming digital e.g., logistics, communication, education or finance. The creation of 'weightless' (virtual) companies, shows how “products and services are merging in the digital economy; products become merely platforms for delivering services to consumers” (Heiskanen et al. 2001, 9). This has led to a new idea that economy and ecology can be combined in a new way with a particular focus on environmental discourse (ibid, 9). This narrative turn has attracted new interest groups to participate in the debate about the future transportation and mobility systems, may have both positive and negative outcome to the further development.

Arguments advocating vehicle automation<sup>4</sup>, predominantly promote the vision that large benefits could be expected in dense urban areas, considering e.g, pollution and traffic which have a direct negative impact on quality of life of citizens. In my analysis, I will evaluate and discuss, which versions of the visions presented by both Smart Mobility and automotive industry, take into account

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1 Carsharing – model of car rental focusing on short term usage e.g, commuting.

2 Ridehailing – ordering a transportation via an application on mobile device e.g, Uber, Lyft.

3 Ridesharing – services connecting people who wish to carpool e.g, Waze Carpool

4 Vehicle automation – Partial/total replacement of human driver direct inputs with a control of the digital system

the configurations of matching 'smart infrastructures', physical or digital, which may lead to the creation of smarter urban spaces, as advocated in various Smart Mobility visions e.g. fleets of autonomous electric vehicles reducing traffic and pollution while increasing accessibility and productivity. Furthermore, one may explore to what degree, suggested Smart Mobility scenarios, actually promote benefits to quality of life as a main goal for their projects taking into account all possible costs and results of such change to society. Unresolved tensions and open questions justify the need for confronting specific automation and mobility scenarios with theoretical views on technology – e.g. various actors provide narratives about how Artificial Intelligence (AI) or vehicle automation may be exploited to achieve their goals. Overall, combining such innovative and advanced technologies tends to generate uncertainty about their potential to modify human behavior. In that sense, the visions and scenarios about vehicle automation, not only call for addressing and discussing ethical and legal issues that may result from deploying technologies of Smart Mobility, but also, for conducting a critical discussion about the views on digital technologies.

### ***Structure of the thesis***

Since the presented topic is extensive and reaches across many fields such as the theory and philosophy of technology, society and ethics, with special focus on automation, I will be dealing with sources that were not necessarily meant to interrelate explicitly. As these heterogeneous sources are sometimes converging, sometimes clearly discordant, and also operate with different levels of rhetorical significance, I will concentrate on collecting themes that exhibit obvious commonalities, while seeking to highlight incompatibilities, and possibly contradictions, between various approaches. I will also attempt, where possible, to assess to which degree the automotive industry and Smart Mobility documents to be discussed in this thesis tend to operate with separate visions of digital technologies and social realities while identifying possible zones of convergence. The overall approach will be guided by current debate in the Digital Culture about how technology, society, and individuals interact.



## Theoretical framework

To understand better the processes of dematerialization and virtualization inside the automotive industry, one may attempt to describe and interpret the world it operates within – e.g., what are the aspects, concepts, or components which may characterize it. The following chapter is going to deal with defining key concepts in fields briefly introduced in the previous section, as well as recognizing and introducing different approaches to the terminology of actor, stakeholder, notion of the driver, user and operator of the vehicle.

A few definitions may contribute to clarify the theme. Users of transportation systems are individuals or groups of individuals who benefit from transportation but do not take any *direct* action in applying the changes to the product or the system. Respectively, a stakeholder, is an individual or a group of individuals with a direct or indirect interest in certain products or infrastructures. A clear distinction between stakeholders and actors happens when a person, a group or an organization, attempts to influence the total infrastructure by exerting pressure on specific requirements, laws and restrictions. automotive industry is one of the largest industries but due to the intense competition, it is difficult for companies to achieve high profit margins. Additionally, the industry depends on various stakeholders in different domains of the long processes of designing, producing and promoting a vehicle or a mobility lifestyle. The multilayered nature of the automotive industry, creates an extremely complex network based on different interacting subdomains. With such complexity in mind, it is necessary to understand that each stakeholder may have different visions – and with the introduction of a new, possibly disruptive technology of Automated Vehicles, the complexity and diversity of stakeholders grows, and by analogy, the diversity of scenarios for implementing the Smart City infrastructures increase as well.

Automotive industry, being a part of a much larger landscape of interconnecting fields of global economy, e.g, logistics, trade and manufacturing, has constructed a capacity for further development which would not be realizable without the support from political and economic stakeholders. Nevertheless, subject to technological and societal change, the automotive industry continues its expansion into new domains while absorbing the best practices from them. The rising level of cooperation between automotive industry and other fields, e.g., software engineering or actors within urban mobility, has come to reality only recently, when technology convergence has led to reevaluation of standards applying to when designing cars. The theme of the Digital

Revolution<sup>5</sup> could serve as a model for phase/shift that may explain many of these converging events. As a result, concrete developments within information science have led to the significant changes e.g., Automation, Artificial Intelligence, Machine Learning and software engineering have become significant forces pushing the development of not only Automated Vehicles but also contributing to a new understanding of the concept of *mobility*.

In order to understand better the ongoing evolution of vehicle automation one needs to approach it as an “innovation process” that is influenced by many factors such as “actors and actor networks, institutional frameworks, and technological developments both inside the innovation system and external to it” (Schreurs and Steuwer 2016, 168). As the development around the automated technologies increases, it is expected to see the emergence of new stakeholders – as the sector is slowly shifting from a traditional industrial approach to one that focuses on software and data management contributing to virtualization and digitization. This shift calls for a much wider spectrum of actors to be involved in the development of new technologies. Companies which until now have been small suppliers have suddenly gained much larger importance for the final product. More concretely, the automotive industry is progressively merging with ICT, aeronautical, and defense industry involved in the design and production of visual detectors and processors such as radars and LiDARS<sup>6</sup>.

When looking for indications of such change, one could examine various automotive market reports, evaluating the current state of the industry. E.g., Navigant's publication, “Navigant Research Leaderboard Report: Automated Driving” (2017) describes a substantial expansion considering the number and diversity of contributors to the market in comparison to the previous research done in 2015.

The transition phase of the automotive industry to a more modern and service oriented structure, induces new challenges, opportunities, and risks, e.g., the strong position of the oil industry in transportation is now being challenged by alternative, sustainable solutions resulting in growing interest in electric vehicles. Several countries – the UK, France, Norway and China, have publicized plans to 'phase out' and eventually end sales of gas and diesel cars in the next 15-20 years (Zimmermann, 2018). New regulations and legal constrains add yet another layer of stakeholders that need to be considered e.g., opening the roads for Automated Vehicles and building charging infrastructure for electric vehicles will depend on each specific city, region, or country, the production of batteries and the development of Artificial Intelligence specific for AVs will happen

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5 Digital Revolution (Third Industrial Revolution) – shift from analog and mechanical based devices to the digital technology.

6 LiDAR – (Light Detection and Ranging) technology used for measuring distances, which demand has highly increased together with the development of AVs.

on a global basis. The forces that act upon the automotive industry are a part of a larger dynamic of change that unfolds both within technologies e.g., expectation related to digital lifestyle, and between technology and society. Some actors and stakeholders might have both overlapping and diverging objective interests and share common challenges but oppose in other areas. I will try to explore these schemes, focusing on tensions and common interests between them.

The rising importance of software production and data processing has attracted new actors which have the potential to increase the growth and possibly change the direction of the industry to a more service oriented sector. During the last decade, automotive industry has experienced the introduction of several new concepts, often originated from the outside of the industry itself e.g., services of car- and ridesharing, development of automation, and an increasing pressure to produce safer, cleaner and more efficient vehicles. The reaction from the well-established part of industry has been rather uncertain and needed some time to make adjustments. From my analysis so far, it should be clear that automotive industry (including most of its components e.g., vehicle designs, energy and drivetrain solutions, business models, approach to social and environmental aspects) has entered a phase of transition – where human driver might no longer be required to the same degree as before. How this transformation is going to be solved depends mostly on the current debate that should include every field contributing to the development of Automated Vehicles. It is important to remember that these vehicles, if introduced, still will have to work within certain rules such as legal, social, economic or technological frames – and each one of them is being represented by a group of agents and stakeholders. In my thesis I intend to look closer at these dimensions created by mentioned groups represented by both automotive industry and Information and communication technology, and establish problems and tensions between them, and how they may affect the creation of future notion of the human driver.

In order to produce an exploitable mapping of vehicle automation, it may be necessary to establish the landscape of theories considering views on relation of human and technology, and definitions, that could enable one to relate social and cultural construction around the role and lifestyle of the driver to the activities or behaviors that are strictly connected to the practice and skills of driving – both professional and recreational. Since the language we operate with, tends to reflect and possibly shape our reality, there is a need to examine critically the notion or the representation of the driver – an evolving notion that could be profoundly transformed by the adoption of Automated Vehicles and express societal, technological and cognitive changes.

From a strictly technical point of view, a driver is someone who “operates a motor vehicle”. As a consequence, a driver may be defined as a person, agent, or a function who or which “perform[s] an

action or to influence” but also as a subject or program who or which “provide[s] an impulse or motivation” (Cambridge dictionary, 2018). Hence, there is much more to driving, than just controlling a vehicle on a basic level – e.g., driving involves many layers of “operations”, “actions” and “motivations” that can be performed to and with the vehicle.

A perspective provided by the field of Interaction Design might be useful as it focuses on “theory research, and practice of designing user experiences for all manner of technologies, systems, and products” (Preece et al. 2015, 8). This multidisciplinary approach draws from and cooperates with Human-Computer Interaction, Cognitive Science and Engineering, and Social Sciences which allows to put a broad framework around the AV technology in relation to the notion of the driver with surrounding phenomena. One of the main themes in Interaction Design is cognition which studies human abilities of e.g., “attention, perception, memory, learning, reading, speaking, and listening, problem solving, planning, reasoning, and decision making” (ibid). These activities constitute the basis for user experience, which is a significant area of designing interaction with any virtual or physical system. There are several cognitive frameworks that might be useful when discussing the interaction with Automated Vehicles e.g., mental models, information processing, distributed and external cognition that all provide different structures to learn how people develop the knowledge of how to interact with systems and how they work.

Further discussion would require a closer look at Activity Theory (AT), originally formulated by Lev Vygotsky and developed by his student Aleksei Leontyev, which proposes two kinds of processes that contribute to the development of given activity – first, processes based on historical development and secondly an ongoing process “which is constantly transformed” (Kern, 2008, 124). Additionally AT distinguishes between three levels of action: (1) *activity* – unconscious motivation of the individual, (2) *action* - individual plans and strategies based on conscious objectives; and (3) *operations* - the practical conditions performed as a habit. While this model is rather simple and tends to disregard several complicating aspects, it is also closely related to Rabardel's model of instrumented mediated activity. According to Rabardel instrumented mediated activity is based on three elements with *human activity* as a unifying concept – (1) the *subject* being, in our case the user, or a driver, (2) the *instrument* being an artifact such as tool or machine (a vehicle in our case) and the *object of the action* (driving, in our case). Rabardel's model, briefly described above, could be further expanded, there are several conditions that describe human instrumentation, e.g., by stating that an artifact becomes an instrument when a subject uses it as a means to the action (ibid, 125) which implies that the instrument is being composed of two parts: *artifact* and *schemes*. Rabardel, by linking these two elements, stresses the importance of developing the utilization schemes, that convey social, cultural and personal meaning and integrate

the instrument into the wide framework of the activity. Utilization schemes can be developed both in private and social dimensions and may involve both physical or logical artifacts e.g., algorithms. The key notion proposed by Rabardel is a concept of mediation where instrument “becomes a mediator of various relationships between the subject and the object” (ibid, 129) which includes understanding, transforming and controlling the object:

The production of technical knowledge is fully linked to that of artifacts: the action of designing a new technical object engenders the process of transforming and producing technical knowledge. Affirming that artifact design activities give rise to the production of technical knowledge means accepting that the production of technical knowledge is based on specific characteristics of these design activities. (Rabardel 2002, 17)

Activity Theory, as introduced by Vygotsky, Leontyev and further developed by Rabardel and Engeström (1999) will serve as a tool when I will discuss and analyze in more detail, various visions and scenarios suggested by Smart Mobility and automotive industry stakeholders (page 76). As Automated Vehicles employ more digital technologies e.g., Artificial Intelligence, the complexity of interaction with such system increases, which may suggest the need for more extended tools of analysis. When discussing the idea of driving in regards to Automated Vehicles, one may keep in mind that a variety of scenarios may open for numerous interpretations and definitions about how particular vehicles will be designed, how humans will interact with vehicles, and how the interface may impact the evolution of the mediation between the vehicle, and in which aspects of various interfaces may impact the evolution of the mediation between the vehicle. Activity theory, as formulated by Victor Kaptelinin, stresses the importance of “how the activities are being re-shaped by using the technologies as mediating means (mediation)” when analyzing “the effects of certain technologies on human cognition” (Kaptelinin 2012, 33). This observation may become particularly useful when analyzing various interfaces proposed in specific driver automation projects of automotive industry.

It is important to point out that within the general phenomenon of vehicle automation one may distinguish several fragmented and heterogeneous trends and visions about the configuration of the final product and about the nature and function of the driver. Currently, different approaches are competing to define the way Automated Vehicles will or may be designed. Such competing approaches actualize the main question raised earlier: How will particular conceptual and industrial designs impact drivers, passengers, or for that sake, any kind of user of transportation systems? Even a brief review of prototypes of AVs will reveal that visions of the driver’s environment may differ widely across various vision statements. One could assume that there exists a general functional, aesthetic or cognitive relationship between the level of automation (see e.g., the SAE

document explaining levels of automation discussed on page 16), the hypothesis being that the more disruptive the interiors of cars may be in terms of functional and aesthetic design. The higher the level of automation (implying lower implication on the driver as to perform driving tasks) the more likely it is that interiors of cars necessarily will, for functional, legal, cognitive, and cultural reasons, lose the tools connected to “conventional” – non-automated driving, e.g., the historical “steering wheel” or mechanical “pedal box”. These artifacts may no longer be required as possibly unfunctional and unsafe – where new configuration of interfaces may replace them.

In prototypes of Automated Vehicles, one could observe that earlier mechanical, electronic or digital interfaces have been replaced by other types of controls that would allow users to interact with the vehicle. More fundamentally, the disappearance of a direct or indirect physical mediation between human and machine will be made possible because of the replacement of physical function, by means of delegation (logical and virtualized mediation of a physical mediation) to embedded virtualized functional system. E.g., some current designs suggest systems based on touch screens, or on users' own smartphone, or on inputs based on voice-activation, or on fetching a vehicle with a key-ring device. Artificial Intelligence (AI) imposing itself as a common denominator for a number of automated systems offers promises of further improvements in productivity, efficiency, and reliability, is also suggested to become “one of the primary means to automate and aid interaction with information” (Russel et al. 2016 p. 34). In many cases, AI by implementing Machine Learning, becomes a proxy of information processing between humans and the rest of the world (ibid). One should therefore discuss which tasks may and should be taken over for human benefit when speaking of automated driving scenario.

New interaction schemes may open for new design possibilities creating new aesthetic and functional conceptualizations e.g., arranging the cabin in a completely new way. Indeed, some projects presented by car makers exhibit interiors that remind of compartments in luxury trains or first class planes – where rows of seats are facing each other changing the dynamics of the cabin (see Illustration 1 below). When faced with the possibility of fully automated driving system, many instruments may be perceived as superfluous and as an obstacle to a more pleasant, lounge-like concept of the interiors. Close-production vehicles, exhibit cabins where steering wheel loses its importance as a functional artifact. In such designs the steering wheel is either retracting into the dashboard when automated mode is engaged, or non-existent – encouraging other activities, unrelated to the actual tasks of driving, e.g, checking email or using virtual reality experience generated in real time, to make the daily commute experience more pleasant.



*Illustration 1: Matthias Mueller, the CEO of Volkswagen, inside the VW Sedric, showing the OneButton control which fetches the automated vehicle. (Copyright AP Images. 2017)*

All those possible solutions create a situation where the already existing “driving activity”, which includes pre-existing schemes, will most expectably need to be renegotiated. This is not a totally new situation, as several technological, functional and schematic disruptions have already occurred since the early stages of automobiles, e.g., there were many solutions and layouts of pedals and levers that would control the vehicle and, it is possible to map how current car manufacturers have implemented different visions of how to design an ideal interface that would work with automated vehicle.

A closer look at the theory of social constructivism and methodology of Social Construction of Technology (SCOT) discussed by Wiebe Bijker and Trevor Pinch (1987) could be helpful when revealing the continuous cycle of designing an artifact. “In SCOT the developmental process of a technological artifact is described as an alternation of variation and selection” which results in a “multidirectional model” (Bijker and Pinch 1987, 28). This leads to “interpretative flexibility” arguing that the “successful stages in the development are not the only possible ones” (ibid, 28). Social constructivism offers a more expanded view on various stages of development, implementation, acceptance and final (often unexpected) outcome of given technology. This model

might be highly relevant when analyzing the development of Automated Vehicles as it proposes an interesting view which emphasizes the importance of actor-network theory, bringing multiple factors in creating social-technological relations.

The opposing view that needs to be considered is the theory of technological determinism, which reduces and simplifies technological schemes, replacing them with more historical and systematic rhetoric. This view claims that the technology is the source of an independent force and power that can constitute the development of the society. In order to achieve a complete overview of the visions presented by the Smart Mobility stakeholders, one must consider a wide range of social structures and cultural values that would constitute the often mentioned social impact of technology. In order to do that, one should discuss the impact on anthropological factors such as psychological, cognitive, cultural, political or intellectual changes when given scenario of technology is introduced. In that way, the answer to the question regarding the notion and construction of the human driver and human passenger in a perhaps virtualized manner may be revealed. There is a possibility that a strong technocentric view may be one of the main obstacles to the development of a “people-first” design – the idea that by improving technology and changing physical space around people, their decisions and choices may be altered and reshaped to some extent. Accordingly, the technocentric view that is often visible among automotive industry, includes a certain belief that the technology has the ability to address not only strictly technological problems, but also address issues of society, economy or politics. The view discussed by Howard Rheingold that while technology is capable of solving some social problems, the issues that are rooted in human nature require social and political will to be changed (Rheingold 2001). Similarly, the idea that “a tool is not the task” (ibid) must be considered when developing and interacting with Automated Vehicles. My observations in Case study section will focus on finding that discussion in the chosen texts from Smart Mobility.

In that sense, even such decisions that were intended to have minimal effect on the driver, may have significant impact on the notion of the (former) driver and future user of a system. Characteristic to the recent transition from a low-automation to a high-automation situations, the virtualization and take-over of formerly crucial driving tasks by the system, is going to be a key concept contributing to the implementation of automation offered by vehicles at different stages of evolution. There are numerous documents and projects that represent various visions for concepts of both conventional and automated driving. However, not many of these actually ambition to and manage to collect and narrate all aspects and levels of automation into one complete document– such total industrial vision statement is currently not feasible, due to technological, social, cultural, and legal constraints.



In order to sort out regulations and standards, SAE International (Society of Automotive Engineers), global association gathering engineers and technical experts, has elaborated a document that could serve as a reference point for the automotive industry - “Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles” (also called the SAE standard J3016). Guidelines included in the SAE document have been accepted and validated by the US Department of Transportation (DOT). The document provides useful insight into core definitions of Avs and more importantly, offers definitions of levels of vehicle automation. Recommendations presented by SAE also take into account three primary actors in driving: “the driver, driving automation system and other vehicle systems and components” (SAE 2016), which opens for reading this document from the perspective of Activity Theory. Furthermore, the cited definitions may serve as a platform for discussing automated driving systems and, additionally related aspects of vehicle automation to Smart City implementation (see below page 43).

According to SAE's website, the mission this organization is providing focuses on a “neutral forum for the benefit of society” while “promoting, developing and advancing” technologies connected to “aerospace, commercial vehicle and automotive engineering” (SAE 2017). For the purpose of establishing and creating an appropriate framework for the debate, the SAE guidelines and definitions currently constitute the most exploitable platform to discuss and analyze car automation. The taxonomy provided by the SAE is supposed to be “descriptive and informative rather than normative” (SAE 2017) which may raise critical questions pertaining to the claims to produce an objective description of car automation. Keeping this in mind, SAE is fundamentally an association of engineers – which entails that the knowledge and concepts SAE is producing express vision of an engineering character<sup>7</sup>, than, e.g., a societal, cultural, or lifestyle vision.

The critical discussion that follows will expand on the overview provided in the theoretical section and concentrate first on the most crucial actor, the user of a vehicle – what are the clear distinctions between a driver and passenger, depending on existing level of automation. Definition provided by the SAE standard, explains a driver as a “*user* who performs in real-time part or all of the *DDT*<sup>8</sup> and/or *DDT* fallback for a particular *vehicle*” (SAE 2016). However, the SAE distinguishes between a conventional and a remote driver. A conventional driver must manually perform a Dynamic Driving Task (DDT) from a driver's seat using a conventional driver-interface, through “in-vehicle input devices (steering wheel, brake and accelerator pedals, gear shift) accessible to a (human) *driver*” (SAE 2016). The difference between a conventional and a remote driver is that the

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7 As explained on the SAE's website: “The Board [of Directors] supports the Society's mission of serving a global network of mobility engineers by providing industry standards and life-long learning, networking and career-development opportunities. (...) The Board is responsible for redefining SAE's strategic direction.” (SAE 2018)

8 Dynamic Driving Task (DDT) - “All of the real-time operational and tactical functions required to operate a vehicle

remote driver is not required to be seated in a particular position in order to perform the same actions as the conventional driver is performing e.g., manually provide inputs. Today's technology already allows individuals to control a vehicle by using smart phones or special keys in order to park a car, by combining semi digital, or fully virtualized inputs.

The next step that might be useful in supporting an expanded and updated definition of a driver is to establish key activities of DDT which include both “operational actions” (steering, braking, accelerating and monitoring the vehicle and roadway) and “tactical actions” (responding and determining actions), the terms operational and tactical originating in the SAE standard. A dynamic driving task, does not include the strategic aspects such as determining way points and destinations.

With the history of automobiles in retrospect, car drivers actually have already, not once, but repeatedly, been relieved from many tasks by using various automation technologies, e.g., automatic wipers reacting to rain, headlights adjusting the type of lights to the outside conditions or automatic braking systems applying brakes when detected an obstacle in front of the vehicle. Most of the technological solutions were meant to make the “driving experience” more comfortable and safe, e.g., saving the driver from distractions and “burdens” of managing the vehicle. Technology has already been supporting some operational activities which might change with an introduction of full automation where the most important action of DDT can be fully replaced by automated system with no intervention of a human driver.

The standard presented by the SAE, distinguishes between six levels of vehicle automation:

- No Automation (Level 0): The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems.
- Driver Assistance (Level 1): The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.
- Partial Automation (Level 2): The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.
- Conditional Automation (Level 3): The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene.
- High Automation (Level 4): The driving mode-specific performance by an automated driving system

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in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints.” (SAE 2016)

of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene.

- Full Automation (Level 5): The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver. (SAE 2016)

As stated in the SAE standard, the term Automated Driving System (ADS) refers to “the hardware and software that are collectively capable of performing the entire *DDT* on a *sustained* basis, regardless of whether it is limited to a specific *Operational design domain (ODD)*<sup>9</sup>; this term is used specifically to describe a level 3, 4, or 5 *driving automation system*” (SAE 2016). Following that definition, a clear distinction between conventional and ADS-Dedicated Vehicle (ADS-DV) – which is a “vehicle designed to be operated exclusively by a Level 4 or Level 5 ADS for all trips” (SAE 2016). This means that ADS-DV does not require any conventional nor remote driver. Following this model, users of Automated Vehicles that operate above Level 3, actually stop being drivers and become passengers. Users of such Automated Vehicles capable up to Level 3 may require an operation from a human – in case of a system failure or when a vehicle simply reaches the limits of its *Operational Design Domain*. It is extremely important to point out that even though a Level 3 vehicle is capable of performing the entire DDT, it may not be capable of performing any DDT-fallback<sup>10</sup>. This may lead to dangerous situations and defining to know exactly what is *operational design domain* will be crucial in educating users of AVs. In theory ODD is a set of tasks that given vehicle is capable of performing, which in practice, might be “expressway merging, high-speed cruising, low-speed traffic jam, etc.” (SAE 2016).

At this point, Level 3 Automated Vehicles require attention to monitor the situation on the road and if the vehicle recognizes it cannot manage the situation it demands an action from the user. The biggest difference between Level 3 and 4 is that vehicles above Level 3, while ADS is engaged, are carrying passengers and by definition can only prompt them to take action. However, this action is optional as the vehicle can perform DDT-fallback on its own as it is a part of a system design. If a user decides to take action and operate vehicle to “minimal risk condition”, then s/he becomes a driver. Many car manufacturers and analysts claim that this particular transition between Level 3 and 4 where vehicle may require human assistance at any time is going to be an issue and needs to be solved as soon as possible for user safety. From the perspective of Rabardel's model, it may be interpreted as a dissonance in creating mediation schemes – an instrumental conflict that should be

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9 Operational Design Domain (ODD) - the specific conditions under which a given driving automation system or feature thereof is designed to function, including, but not limited to, driving modes. (SAE 2016)

10 Dynamic Driving Task Fallback - “The response by the user or by an ADS to either perform the DDT or achieve a minimal risk condition after a DDT performance-relevant system failure or upon ODD exit.” (SAE 2016)

a clear sign for car companies to redesign key features. Additionally, the SAE standard, chooses to ignore the instrumentalization processes between artifacts and society. In the next sections I will discuss the results of this neglect by the industry and relate them to other events and trends inside of the automotive industry that might provide clues to research questions.

### ***Terminology and definitions***

In the following section, I will clarify some key concepts in order to avoid further misuse and misinterpretation. It is important to point out some terms used in public debate, often influenced by media or car companies themselves, that do not offer precision in that discussion. Automated and Autonomous – those terms are often used interchangeably, and equally with “driverless” or “unmanned”. As the technology of Automated Vehicles is under development, the definition and use of these terms is not fixed. Nevertheless there are certain standards and definitions that could help one to outline the correct and useful terminology. The term Automation describes a field that focuses on reducing (not necessarily eliminating) the need of human intervention. In the context of Automated Vehicles, this term is the only one precise enough to describe systems that performs driving. Autonomous on the other hand, implies the “ability and authority to make decisions independently and self-sufficiently” that with time has grown to decision making of the whole system, meaning full automation. This level of independence from human intervention has not been reached yet, and by strict definition, may never be, as the ultimate level of autonomy, by definition presupposes self-governance, and at a minimum a technical-logical “self” dissociated from human force and acting as a decision-making agent. Precise and clear distinction is strongly related to the discussion about responsibility and risk to the automated systems, which will follow in the Discussion section (page 65). Decision making and planning in traffic requires inputs from outside, where communication and cooperation is crucial. Another point against the imprecise use of adjective “autonomous” is that even most advanced driving systems are going to rely on software produced by humans as well as commands provided by users. In the same manner, statements such as “self-driving”, “driverless” or “unmanned” do not explain the exact interaction between user and vehicle or do not provide the explanation for level of automation of a vehicle either. Considering the wide range of documents analyzed, the most suitable solution for this thesis would be to follow the standards recommended by SAE. However, the variety of authors rather requires to use their own terminology as a citation. While most of them recognize the five levels proposed by SAE, depending on the region or institution, documents operate with different terms such as “self-driving”, “driverless”, “robo-taxis” or create additional distinctions and levels to “automated” and “autonomous”. In order to create a clear presentation of knowledge I will use terms specific to each author and text as a citation to avoid dissonance between my understanding and the purpose of a

certain text.

Another set of terms that are often used in a mistakenly interchangeable manner is Transportation and Mobility. A simple definition of transportation as provided by a dictionary, is: “the movement of people or goods from one place to another” ; “a vehicle or system of vehicles (...) for getting from one place to another” (Cambridge Dictionary 2018). In contemporary and common usage, transportation often implies a “motorized” element. Mobility, on the other hand, suggests a more open approach and as a field, is not restricted to motorized vehicles, including any type of movement of people or goods. Other than that, the differences are mainly rhetorical in order to achieve a certain political effect. Replacing the term “transportation” by “mobility” has become a widespread rhetorical tactics used by several actors and stakeholders. The effect of such terminological replacement would be to suggest a more “environmentally friendly” approach. By doing so, some documents may consciously attempt to enhance their rhetorical value by removing negative connotations of the term “transportation” to vehicles, e.g. unfavorable character of oil industry, air pollution or traffic congestion.

Having briefly exposed the basic components of the automotive landscape, considering industrial and engineering viewpoints, it might be beneficial to integrate knowledge from a field of social sciences. More precisely, the theoretical framework of New Mobilities which draws upon “anthropology, cultural studies, geography, migration studies, science and technology studies, tourism and transport studies, and sociology” (Sheller 2004, 207) is prone to integrate new dimensions, among these lifestyle dimensions. Mimi Sheller, in her paper “The New Mobilities paradigm” discusses the need of the new approach to look at people and their relation to technology as many domains of people's lives have gone through a transformation. The new paradigm, includes a broader look at physical movement – including the physical movement “enhanced by technologies” e.g., cars. Such approach is, indeed, highly valuable for this study as it encourages a discussion about the processes that mediate between human and technology while in movement – as opposed to existing research which prioritized the static “*sedentary* theory” in which humans are supposed to “reside or to stay, to dwell at peace, to be content or at home in a place” (ibid, 208). According to Sheller, existing theories have failed to “consider how the car reconfigures urban life, with novel ways of dwelling, traveling, and socialising in, and through an automobilised time-space” (ibid, 209). By using the approach presented among others, by Sheller, reviewing selected scenarios of Smart Mobility and Automated Vehicles, will be situated in a new perspective – e.g., the perspective of the dynamics of the urban spaces.

Additionally, Sheller describes automobility as a sociotechnical system that forms “gendered

subjectivities, familial and social networks, spatially segregated urban neighborhoods, national images and aspirations to modernity, and global relations ranging from transnational migration to terrorism and oil wars” (ibid). Furthermore, it is necessary to acknowledge the fact that this systems is “interconnected with other mobile systems that organize flows of information, population, petroleum oil, risks and disasters, images and dreams” where a car, or more precisely 'personal vehicle' has become a primary target to develop and apply the mobility visions (ibid). Additionally, there are several viewpoints that are presented by Sheller that should be considered in the following analysis of Smart Mobility visions – the perspective on traveling as an activity. While chasing to reduce the amount of time spent traveling (often perceived as “dead time”) some may overlook the fact that “activities occur while on the move, that being on the move can involve sets of 'occasional activities” (Sheller 2004, 213 referring to Lyons and Urry, 2005). Following that theory, it may be helpful to look for the definition of travel, trip or movement in general that is proposed by various mobility actors in order to understand the larger scenario suggested by them.

As previously discussed, current automotive industry could be characterized as entering a phase of substantial changes which may pose fundamental challenges to many structures of the system. In that case, the theory introduced by Pierre Bourdieu needs to be considered, which described some key concepts that might be helpful with understanding the nature of change and resistance to change during the phase of transition. As described in the article “Habitus, Hysteresis, and Organizational Change in the Public Sector” (McDonough and Polzer 2012, 359), *hysteresis* “is a term that Bourdieu employed to indicate a cultural lag or mismatch between habitus and the changing “rules” and regularities of a field” during a transition phase. The idea of hysteresis could be linked with the notion of *habitus*, which, inspired by Bourdieu is described as “a system of dispositions or forms of know-how and competence with emotional, cognitive, and bodily dimensions — that generates practice (McDonough and Polzer 2012, 362 referring to Emirbayer and Johnson 2008, 27). Habitus is also defined as the “ensemble of schemata of perception, thinking, feeling, evaluating, speaking and acting that structures all expressive, verbal, and practical manifestations and utterances of a person” (Walther 2014, 13 referring to Kraus 1988 1993, 169). Habitus is acquired by socialization, “constantly reinforced and modified by life experiences giving it a dynamic quality” (Walther 2014, 13 referring to Chudzikowski and Mayrhofer 2011). Habitus could be also characterized as “durable and transposable” operating largely below the level of consciousness and providing members of an organization a framework for accomplishing appropriate practice (McDonough and Polzer 2012, 362). The imbalance between habitus and any given field may lead to previously mentioned hysteresis – which creates a situation where participants of a field or an organization are “unable

(temporarily, at least) to recognize the value of new positions” (ibid). Originally, Bourdieu introduced these concepts of hysteresis and habitus to describe changes in social fields and organizations, e.g., sociocultural habitus. These concepts, may, however, be applied to drivers, pre- and post automation, as the habitus of a driver has been under the development for over 100 years. For that reason, my further analysis in the Discussion section (see page 81) will focus on searching for the aspects of the discourse showing how stakeholders of vehicle automation decide to convey (or not) these values in their texts.

Despite of the fact that this study is not focusing on evaluating or predicting future AV technologies, there are certain aspects of technological evolution that must be considered. When analyzed from the perspective of “Gartner's Hype cycle” for technology, one may note that the interest around the idea of automated driving is growing rapidly, resulting in higher activity in this domain e.g., frequent announcements and declarations about new projects and investments. Gartner recognizes five stages of hype cycle: (1) *Technology trigger*, (2) *Peak of inflated expectations*, (3) *Trough of disillusionment*, (4) *Slope of enlightenment* and (5) *Plateau of productivity*. (Gartner n.d).

Additionally, there are some features characteristic of each stage that could help determine the progress of attention to certain technology. When given a closer look, AV technologies have already been implemented in first generation products with high cost and custom design, as witnessed by early prototypes e.g., Google self-driving vehicle, and boosted by “mass media hype” and followed by “supplier proliferation” (as exemplified and discussed by Navigant (2017) research). All these factors may indicate that technology of AVs has just passed the phase of “technology trigger” and entered the stage of “inflated expectations” (ibid). Closer analysis of any technology that is reaching the stage of inflated expectations, may be additionally distorted as the real picture of the actual state of the development of this technology is influenced by the “noise” created by various stakeholders further enhanced by the mass media. As stated on Gartner's website, hype cycle research methodology helps to “separate hype from the real drivers of a technology's commercial promise” when analyzing emerging technologies (ibid). While this methodology is meant for evaluating risk in business, it gives useful context to the processes surrounding the implementation of new technology.

The progress of technological development depends on many factors, which is also the case of AVs – major aspects that could stimulate production of AVs would include: significant breakthrough in the field of Machine Learning (e.g., Deep Learning), rising competition among car companies, positive feedback and consumer demand from the public, and supportive legal framework. Many car companies are confident that the AI would be a key technology triggering the acceleration of the development of Automated Vehicles and reaching higher levels of automation quicker. However,

relying on one technology which historically has created high expectations but also, has gone through significant crises due to limitations overseen by early research, involves some risk. Advocates of AVs should consider also risks which could be transferred to consumers, implying a need for a thorough ethical debate.

### ***Reception and implementation of Automation Levels***

The standard released by the SAE, has proposed six levels of automation in order to clarify the automated driving scenario and provide some explanation to specifications and requirements considering the automated driving technology. However the SAE cannot predict when, or in which order certain levels of vehicle automation would be implemented. Observations of vehicles currently available on the market as well as those in phase of early public tests (ranging from Level 1 to Level 4 Automation) show that there are many areas lacking refinement and standardized solutions, e.g., creating smooth cognitive transitions for users or maintaining clear communication with users of transport system, in order to be considered a complete and safe product. By introducing the technology prematurely, a product that is not ready might result in strong public backlash. What conditions does a certain technology have to meet in order to gain trust from the society? A critical review of the most recent report titled “Great expectations”<sup>11</sup> on peoples' perception of automotive industry shows that, general trust towards “self-driving vehicles” has increased in all countries that have participated. The percentage of respondents that think “self-driving vehicles will not be safe” has fallen from 20%-30% within a year from the last survey (2017 as compared to 2018). Additionally, when asked about the type of company (traditional car manufacturer, new AV company/other, existing tech company) to be trusted about bringing the AV technology to the market, answers have varied significantly, depending on the localization. A majority of respondents in Western Europe and Japan, would trust the traditional manufacturers, while Southeast Asia including India would choose existing tech company to bring AVs to the market.

The observation of prototypes presented by car makers during the last decade, may show clear trends to improve safety and efficiency, without which AV is not viable. Trent Victor, senior technical leader of crash avoidance at Volvo, has commented that drivers need to “know when you're in semi-autonomous and know when you're in unsupervised autonomous” (Golson 2016) which shows the concern in creating new mediation schemes when operating the AV. He also points out that asking a driver to be ready to step in at anytime is not reasonable as the driver is

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<sup>11</sup> Survey “Great Expectations. Insights exploring new automotive business models and consumer preferences” has surveyed 22,000 people, across 17 countries, in early 2018 (Deloitte Insights 2018)



theoretically allowed to check email or watch a video - the moment of transition between fully-distracted and fully-concentrated on the situation, is the biggest issue as the analysis from accidents show. American company, Tesla, was one of the first on the market to claim that their vehicles, particularly hardware, was Level 5 ready and only limited by software updates. Their product, branded as an “Autopilot” was first offered in late 2014 and despite its promising name was able to perform tasks within Level 2 to Level 3 depending on the specification of the vehicle. A full version of Tesla's Autopilot in 2018, according to their website, features: Adaptive Cruise Control, Autopark and Summon function, Autosteer+ and Speed Assist (Tesla 2018). When analyzed each of these systems separately, it is clear that the terminology of the technological solutions offered by Tesla, might be misleading – one may be left with an impression that systems installed in the vehicle are much more capable than they actually are.

Even though SAE standards claim that Level 2 Automation requires that the “driver must still always be ready to take control of the vehicle” (SAE 2017) reality shows that the illusion of automation is created by a situation in which a misunderstanding of technology through the interface disallows users to correctly develop the appropriate use schemes (instrumental conflict). As an answer to such a concern about safety, Volvo’s approach is to skip Level 3 Automation and take full responsibility on those “unexpected developments” (Golson 2016). Unlike Tesla’s “Autopilot” that shuts off when drivers fail to intervene, Volvo's system is designed to react to those extreme situations such as “people walking in the road, handling a crash or conflict situations” (Golson 2016). Similar concerns have been expressed by autonomous vehicle expert at Ford, Jim McBride, stating that their focus is on getting Ford straight to Level 4, since Level 3, which involves transferring control from car to human, can often pose difficulties and asking the driver to instantaneously intervene is “not fair proposition” (Reese 2016). As a number of vehicles on the roads that can be considered as automated is growing (especially in the US) – both used for private and commercial purposes, this discussion is still very much open.

Before further discussing issues that may be encountered during the implementation of AV technology, it is important to clarify a few definitions related to safety. There is, e.g., a need to define more precisely the difference between *crash*, *accident* and *collision*. The most commonly used term accident refers to “unexpected, undesirable and unfortunate happening resulting in harm, injury, damage, or loss; casualty.” (Cambridge Dictionary 2017). An accident, similarly to a crash, does not imply any personal involvement in the situation, meaning there may not be any person or group to blame. In order to avoid legal and insurance problems, it is agreed that the term *collision* offers a more precise definition of traffic situations where at least two vehicles are involved. Traffic collision implies absence of at least two parts where at least one is at fault and has the responsibility

for the accident. With that being said, determining the responsibility in a hybrid traffic scenario where there are conventional and Automated Vehicles is going to be a challenge where insurance companies, car manufacturers and legal regulators will have to get involved into that debate. In the light of recent accidents, where people lost their lives, as when Automated Vehicle was involved, this should be an indication that certain safety improvements need to be made. Closer look at the accidents, may be helpful as for establishing points to improve. One of the first serious accidents happened on the March 19<sup>th</sup>, 2018 when a “self-driving Uber Volvo” struck and killed a woman while she was crossing the street at night. At this moment, the full investigation report has not been released yet and deciding on who is to blame would be neither fair or accurate. However, there are a couple of circumstances that should be discussed further. At the time of the accident, the Uber Volvo was in a “self-driving” mode – as the state of Arizona allows “autonomous vehicle testing” provided that there is a human “supervisor” behind the steering wheel. This person, also termed “safety-driver” by Uber was not paying attention to the road – as the footage from the dashboard cameras shows, she was busy with her mobile phone at that moment. Additionally, safety systems that are standard equipment on the Volvo used by Uber, such as automatic braking or crash avoidance were disabled. The second accident happened on March 23<sup>rd</sup>, 2018 when a Tesla has crashed into crash attenuator while the “Autopilot” was engaged. According to the announcement on Tesla's website, the driver failed to response to “several visual and one audible hands-on warning” and “driver's hands were not detected on the wheels for six seconds prior to the collision” (Tesla 2018). Although these two accidents are very different, there are some conclusions that could be drawn from them – both people and technology have failed on many levels – the tendency to expect perfection from technology – to avoid any accident in this case, together with a lack of education and understanding of technology might have been a significant factor. At the same time, these two accidents confirm previously expressed doubts about qualitative differences between Level 2 and Level 3 automation, and about how people perceive the capabilities of Automated Vehicles. I will focus on these questions, further in the thesis – how car producers and service providers decide to lead that conversation and address these issues. After the crash, Tesla has released an announcement emphasizing the statistical (lower probability of morality) rather than the functional aspects of the problem: “It is worth noting that an independent review completed by the U.S. Government over a year ago found that Autopilot reduces crash rates by 40%. Since then, Autopilot has improved further. That does not mean that it perfectly prevents all accidents - such a standard would be impossible - it simply makes them less likely to occur.” (Tesla 2018). The concept of actual versus perceived safety of AVs is strongly influenced by the expectations created by the mobility scenarios and further transmitted to consumers.

Considering the presented factors and trends expressed by central mobility stakeholders, one could conclude a common scenario implying the emergence of a hybrid traffic system, that is, a system combining conventional and remote users of vehicles (including all automation levels). Companies involved in the development of the automated driving technology should participate more in the public discourse, providing quality and accuracy to the debate and education of other road users on how to interact with the new technology. I will cover these points later in the thesis, with particular focus on visions and available tools for interaction between the users and the products from certain car makers and service providers in relation to discussed theoretical frameworks.

## **Legal framework for Automated Vehicles**

To this point, I have focused on a brief introduction to standards and terminology as well as on establishing the conceptual background for the development of Automated Vehicles. In the following section I will attempt to map and discuss a highly important part of the automotive industry – political stakeholders dealing with legal and administrative work. AV projects depend on support from both international political organizations such as the European Union as well as local departments of transportation in different countries. As noticed by Schreur and Steuwer: “visions for autonomous driving are being shaped by various stakeholders who have their own interests in advancing particular framings” (2016, 152). With such a global-local span in mind I will dedicate this section to analyze and present how political stakeholders may influence the mobility scenarios which might have an indirect impact on users of Automated Vehicles.

For the purpose of this thesis I will use as an example three markets, that illustrate how political bodies and structures are contributing to development of the technology. I will look closer at the markets in the United States, Europe (mainly under European Union governance) and in parts of Asia (mainly China and Japan). These are the areas that recognize the need for and are willing to support the development of the AV technology. Both manufacturers and lawmakers are going to deal with the issue of the global adaptation of their products – even though their cars are made for the “global customer” they will have to be customized and approved in each country that will sell them. This particular issue goes beyond existing national and local constraints e.g., regulations, which consumers have faced to this point. For example, when ordering a Tesla, customers who want an option of a “Full Self-Driving Capability” will have to accept a disclaimer stating: “Please note that Self-Driving functionality is dependent upon extensive software validation and regulatory approval, which may vary widely by jurisdiction.” (Tesla 2018). These circumstances may affect users e.g., when traveling and crossing country or state borders in a vehicle capable of full

automation.

The US has worked out a set of legislative and regulatory rules that are related to automated driving technology, where both Department of Transportation (DOT) and National Highway Traffic Safety Administration (NHTSA) has produced a policy<sup>12</sup> in which they both state to support and encourage any technology that has a potential to save lives. The main point of that document is to ensure a “safe deployment” of Automated Vehicles. DOT and NHTSA agreed to allow testing of “up to 2,500 fully autonomous vehicles on the road for up to two years” (DOT, NHTSA 2016) and as of June 2017, most of the states has regulated and defined the use of Automated Vehicles and allowed testing them on public roads.

The described case when agencies of the government decided to support the AVs in the US is an example of political stakeholders accelerating the development of particular technologies (Schreurs and Steuwer 2016, 151). Similarly to nuclear or renewable energies, “e-mobility is a recent example of an attempt by policy-makers to help boost the implementation of a particular technology on a larger scale” (ibid). In most of the cases, rules of the market decide whether certain idea or technology “survives” and will continue to grow. However, as stated by Schreurs and Steuwer, changing the approach towards operations of transport and mobility sector on a larger scale will depend on public intervention (ibid, 152). As the technology of automated driving has the potential to change transport sector in many dimensions – social, environmental or even cultural, actions such as research funding, providing infrastructure or artificially creating a demand for a certain technology are proven to work as early boosters for many solutions (ibid, 168).

Another market that could be considered as one of the leaders of innovation in technology is Japan, and the document “Public-Private ITS Initiative/Roadmaps 2016” (ITS 2016) can only confirm that statement. In a document composed by The Strategic Headquarters for the Promotion of an Advanced Information and Telecommunications Network Society, researchers create a collective term – Intelligent Transport Systems (ITS) which means a “new road transport systems designed to integrate people, roads, and vehicles (...) to enhance the safety, transport efficiency, and comfort of road transport” (ibid, 3). In order to achieve these objectives, the main goal of the research was to stimulate both private and political stakeholders and encourage them to cooperate. Document clearly recognizes that ITS are mostly build upon Automated Driving systems and lists possible aspects of vehicle automation to analyze the potential benefits of AVs. According to the document, Japan's plan is to “build a society” based on two perspectives – social and industrial which support each other. Main goals are to achieve the “world's safest road transport by 2020” (ibid, 18) and by

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12 “DOT/NHTSA policy statement concerning automated vehicles” 2016 update to “preliminary statement of policy concerning automated vehicles”

2030, a transport system that will be considered the “smoothest”. At the same time, Japan's plan is to be the “global hub of innovation related to automated driving systems” (ibid, 18) by activating the public-private collaboration. In order to achieve these goals, their strategy is to “commercialize semi-autopilot systems on highways and realizing unmanned autonomous driving transport services by 2020” (ibid, 25). Additionally, the research recognizes multidimensional benefits of pursuing the development of Automated Vehicles, that are not restricted to the ones directly involving e.g., safer transportation, reduction in the traffic and expanding mobility for new groups of people, but also the indirect ones e.g., pushing forward the innovation and fueling other industries that are related to the production and design of Automated Vehicles. This would lead to “improved efficiency and innovation in the mobility/logistics industry and promote the application of automated driving technology to other fields related to automated driving technology (agriculture and mining)” (ibid, 10).

In order to evaluate the state of interest in automated driving in Europe, Schreurs has analyzed strategy documents and research projects that are related to visions of transportation. Most of the inspected legal documents are general in their statements and lack any concrete evaluations that could indicate particular interest in the technology of AVs. The main focus is channeled towards “green technologies, material substitution and ICT, and the optimization of intermodal transport” (Schreurs and Steuwer 2016, 155). The only area mentioned in documents that plans on further research is traffic management, information and transport systems that could fulfill the objectives of optimizing traffic flow and reducing congestion.

Schreurs and Steuwer also discuss the regulatory changes that would allow further development of AVs and influence the definition of the driver. The main obstacle created by the United Nations Convention on Road Traffic which stated that “drivers should be able to control the vehicle at all times” (1968 Vienna Convention on Road Traffic, 2013). In 2014, some substantial changes have been proposed to this requirements by adding several exceptions:

- a. The system operates in emergency situations, or
- b. The system operates in a manner that does not unduly surprise the driver, or
- c. The driver can regain full control whenever needed (by overriding or switching off the system), or
- d. The system is certified in accordance of existing legislation. (1968 Vienna Convention on Road Traffic, 2013)

In March 2016, the amendment has been accepted which allows the system of Automated Vehicle to perform all Dynamic Driving Tasks.

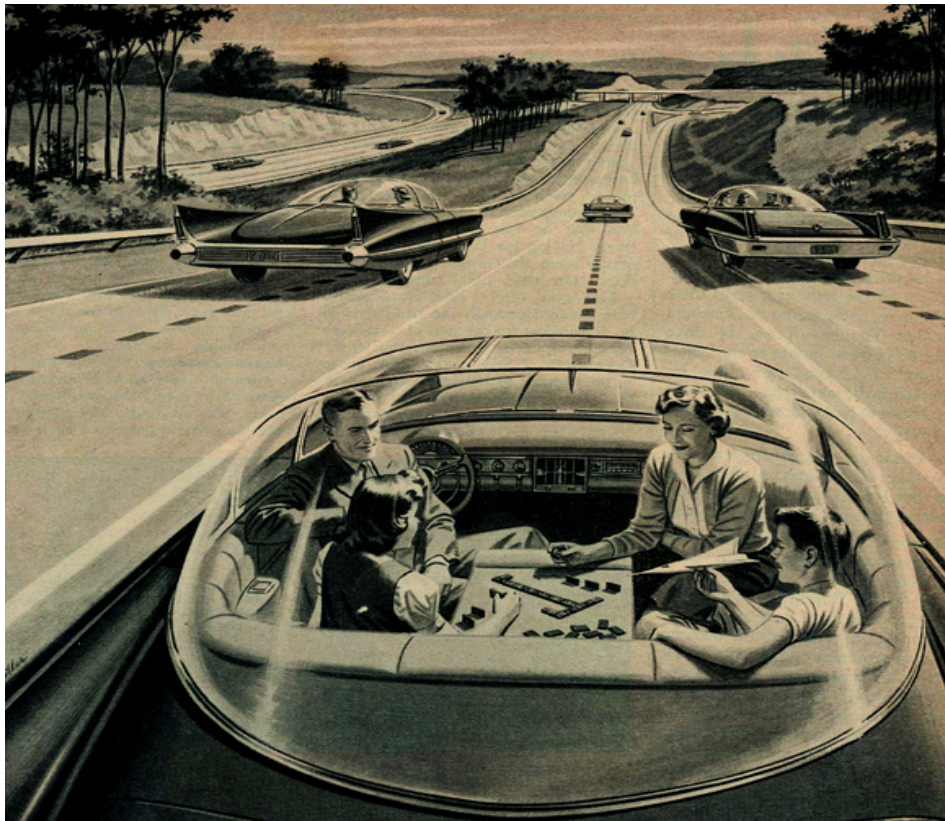
## **Summary**

Depending on the region, the discourse visible in the texts debating the Automated Driving is diverging – the discussion is based based on the needs of the market and shaped by mobility stakeholders. That is why, for example in the US, the main benefit that is attributed to this technology is expressed in a form of increased traffic safety e.g., numbers of accidents and rates of fatalities on roads are mentioned as important issue by various stakeholders represented in media and politics. At the same time, most European projects use environmental arguments as the main benefit of AV technology. Japan brings economic and industrial competitiveness as one of the main aspects connected to the development of Automated Vehicles.

## **Cultural and historical aspects of Automated Vehicles**

The vision of Automated Vehicles has been shaped in the automotive industry for almost 100 years and presented as a possible solution for reducing the number of accidents. In the first years of motorization in the US, only in 1920s, around 200,000 deaths were caused by accidents. Such road mortality numbers led to the idea of replacing “error-prone humans with technology” (Kröger 2016, 42). From the 1920s to the 1930s radio-controlled prototypes showed what was the only imagined technology to which was thought to be prone to address this issue. In the late 1930s, oil and auto industries took more complex approaches and began working on automated transport system with the main focus on redesigning highways - illustrations showed multiple lanes where vehicles would follow an “electromagnetic wire sunk into the road surface whose impulse regulated speed and steering” (ibid, 46). Each lane had separate purpose such as: safety lane, accelerating lane, cruising lane, express lane or bus lane. The new road design was meant to “end the 'slaughter' caused by human driving error and bad roads” (ibid). After the Second World War, many new technologies that could potentially be used in automated driving have appeared and disappeared. In 1953, an illustration of “crash-proof highways” shows cars driving without human intervention thanks to magnet detectors and radar technology. However, it is important to notice that vehicles still have traditional interiors - the idea was that systems still could be manually overridden by human drivers (ibid, 50). An advertisement from 1956 was the first one that showed a modified car interior where passengers were allowed to face each other and just spend time together – creating a picture of a happy family (see Illustration 2 below). While the dashboard of the car still had the traditional layout, none of the passengers had their seatbelts on. This idea is particularly important as it is still visible in advertisements today - apart from making traveling safer, it also suggests to “transform time spent driving into leisure time spent with family” (ibid, 52) which might be the sign of

previously discussed field of Mobilities, where many theories tend to highlight the importance of traveling and the value of time spend while being on the move.



*Illustration 2: Detailed version of the panorama - Magazine vol. 40, Nr. 5, 30. January 1956, p. 8.*

While the ideal family of the 1950s may look very different from the modern family today, the car industry needed to change its approach as well to respond to the perceived evolutions of the lifestyle, e.g., post-war American lifestyle. Today's car companies sell a wide range of products that are supposed to match and satisfy every category of customers. One may therefore ask how car designers perceive their ideal customer and common users of Automated Vehicles? While during the 1950s advertisements focus on the working class and middle class, the mobility experience of these customers is depicted quite differently from what one would expect nowadays. Driving a car, especially on a family road trip was expected to be an extraordinary event enhancing and confirming the consumerist nuclear family model, while today's advertisements tend to categorize the vehicle as a means to perform a safer and more comfortable daily routine. Even when families are pictured together, the quality time of the 1950s spend together has been replaced with a smartphone or a laptop e.g., reading emails and watching movies are presented as the rewards for not having to pay attention to the road. As an example, a recent prototype from the French company Renault, called “Symbioz”, using a Level 4 automated driving technology exhibits a vision of a

vehicle designed together with a video game publisher, Ubisoft using Virtual Reality (VR) technology. A headset lets passengers experience driving in VR where the real-time produced content creates a different illusion of the same trip (see Illustration 3 below). The VR headset is supposed to highlight the automated driving feature which it allows the driver to escape, let go and forget they're in the driver's seat (Papiernik 2017).



*Illustration 3: Interior of Renault Symbioz while in Automated Driving mode allowing hands-off activities e.g., Virtual Reality experience. (Copyright Renault. 2017)*

While the idea of removing ourselves from the boring everyday commute seems attractive, it may also bring depressing, dystopian vision of mobility, especially in comparison to the one from 1950s advertisements, with seemingly happy families. Papiernik further explains that Renault during their cooperation with Ubisoft “wanted an experience that would provide escapism” (ibid) which might be interpreted as the company suggesting that their product and the life of their customers is so uneventful that an external stimulant is required on a daily basis. As Kröger notices further down in the chapter - the industry is experiencing a cultural shift where “Sheer Driving Pleasure” as advertised by BMW, may turn into the “pleasure of being driven” (Kröger 2016, 64). In contrast to the other activities that have been automated, many of them were boring in the first place e.g., using escalators, elevators or washing machines. On the other hand, the activity of driving, apart from being “laborious, boring, tiring and dangerous” (ibid, 65) may also be a positive experience - and removing the last bit of entertainment in that is what have been bringing people to cars in the first



place - the element of control, sometimes connected to risk and danger. The transition to complete safety of “driverless” automobiles will require not only a reinvention of the car but also result in cultural leap (ibid).

As Kröger continues the history of Automated Vehicles, 1970s and 1980s have brought more electronic to vehicles and the development has shifted towards cars that would not have to depend on external infrastructure. As an example, the Eureka PROMETHEUS Project was a milestone for the development of Automated Vehicles, as it was the first one that recognized the importance of machine vision by using cameras and radars to navigate through traffic (ibid, 60).

From a historical point of view, technology has often been a background for creating strong beliefs and misconceptions about its possibilities that have not stood against time. As an example, in 1900's when aviation was growing rapidly, some believed that balloons would allow people to walk over lakes – illustrations from that time show a man on unicycle and carriages with horses attached to balloons simply taking a walk over a lake. Human fascination with technology has created many spectacular ideas and inventions that ultimately have failed. The concept of failure is necessary as well, as it often contributes to the final, successful stage of the product (Bijker and Pinch 1987).

## **New challenges to the ethics of technology**

The reason why it is necessary to discuss ethics in technology, becomes very clear as soon as one realizes how far society and technology has grown together. Following the technocentric point of view, one could argue that, during the course of the last 20 years, technology has had a strong influence on how people communicate, produce, consume, and travel. Many parts of the world are highly dependent on technology as it is converging with other domains of people's life in a substantial way. This connection to other fields makes it even more urgent to discuss the importance of society's relation to technology, as illustrated by current efforts to develop Automated Vehicles. As current interactive technology is occupied with becoming more “intelligent”, “smart” or “personalized” it may also be beneficial to discuss their relation of technology to individuals and society. When designing any advanced technology that is directly interacting with humans, it is impossible to avoid the discussion about new ethical challenges posed by new technological solutions. In the case of Automated Vehicles, which combines many technologies, it is necessary to consider each element that contributes to the whole system where humans may be surrounded by possibly intelligent agents. A quote from Noam Chomsky stating that “as soon as questions of will or decision or reason or choice of action arise, human science is at a loss” (Chomsky 1978) could

describe the possible scenario of a future in which technology has highly outpaced the ethics. In order to avoid the above described situation, and protect ourselves from such course of events, debate on ethics of intelligent technology is an absolute necessity.

The amount of ethical research focusing on Automated Vehicles has increased only in the last few years and is, as of writing, not extensive enough as the technology itself is still at a very early stage. However, many of the fields that have become a part of the AV development have already been studied from an ethical perspective e.g., the ethics of Artificial Intelligence, Human-Computer Interface, and robotics will be very helpful when discussing AVs. At the same time, it is important to point out that in the case of AVs, the phrase “the whole is greater than the sum of its parts” must be considered – each element of a vehicle, adds a certain value to the whole system that operates within a certain scenario, expressing a lifestyle or ideology. As a consequence, new ethical challenges may appear. Recent technological involving computing e.g., Artificial Intelligence, biotechnology, nanotechnology, robotics and neuroscience may highlight many issues that society is dealing with. There are many social, economic, political and ethical implications that need to be considered, which adds a significant level of complexity to the discussion, requiring substantial understanding of society's relation to the technology. In the following section I will try to get a closer look at several different visions that deal with the ethical questions in their scenarios e.g., to what degree the automotive industry is concerned with morality of their products.

When faced with a hybrid traffic system, where users of conventional and Automated Vehicles may coexist at the same time and space, this might require a new approach when discussing ethical issues - a clear situation by all traffic users should be generally accepted. Automation implies that the human decision is either partially or fully removed from the driving system - how should the discussion about safety, responsibility, and risk proceed - especially in case of accidents? Should the legal work focus on adjusting and building upon existing laws or creating entirely new set of rules for AVs? Smart Mobility advocates produce many opposing voices regarding the involvement of mentioned “human particle” - which also raises a question of freedom and control while using these vehicles. In that manner, different versions of programming the software behavior that is completely obvious for human drivers e.g., avoiding humans or driving the car into the lake – need to be coded into algorithms in a way that the automated system is able to understand as a set of basic rules. While the fundamental road rules have already been translated to software and conventional vehicles are mostly able to e.g., maintain speed limit or keep the vehicle between lines (when all ODD conditions listed on page 19 are met), they do not include any moral decisions. The main obstacle in doing that work is the fact that while road rules are clearly formulated and in most cases could be reduced to true or false statements, ethical systems are much more complicated and require

cooperation from many fields to create a system that will be able to behave morally.

### ***Basic ethical approaches***

In order to avoid misleading discussion from the very beginning, a brief presentation of the terminology and definitions is required. John Deigh, whose research focuses on moral, political and legal philosophy, offers useful definition of ethics which he describes as a “study of what are good and bad ends to pursue in life and what is right and wrong conduct of life” (Deigh 2010). Conduct of life includes dimensions concerning the purpose and meaning of life, e.g., behavior towards other people and living creatures. The field of ethics can be divided into theoretical and practical branches: the theoretical one, also called Meta ethics, is focusing on establishing reasons and values for our actions, trying to find out whether ethical decisions can be objective. The main point of theoretical ethics is to decide whether moral actions could be reduced to true or false values. On the other side, Practical or Applied ethics tries to determine our actions when facing moral decisions e.g., dilemmas. Practical ethics is going to be extremely useful for the discussion of Automated Vehicles as it provides a background for the debate on issues connected to real life situations, such as evolution of technology e.g., the morality of Artificial Intelligence. At this point it is also important to describe the meaning of morality as it is strictly connected to the idea of ethics, also referred to as a “system of moral principles”. According to Deigh, these are the “standards of right and wise conduct whose authority in practical thought is determined by reason rather than custom” (ibid).

The next distinction that one should make while characterizing the field of ethics, is the one between teleological and deontological systems, and Virtue ethics. Teleological system is based on goals that determine all actions – every decision that brings us closer to the goal is good by definition. In the case of Automated Vehicles a decision has to be made based on what kind of goal needs to be achieved – examples provided by mobility stakeholders include, e.g., decreased number of injuries and casualties, improved overall safety on the roads, and minimizing damage and harm. According to teleological ethical systems, every action would be justified in order to achieve that goal. The most popular theory that is based on teleological system is utilitarianism whose main goal is to provide the greatest amount of happiness to the greatest amount of people. The Greatest Happiness Principle formulated by John Stuart Mill makes happiness the highest value: “Actions are right in proportion as they tend to promote happiness, wrong as they tend to produce the reverse of happiness” (Mill 1863). According to utilitarianism, happiness is equal to pleasure and the absence of pain which counts equally to everyone. As the majority of Smart Mobility stakeholders represent the utilitarian approach, I will return to the ethical issues that may be encountered, after

the precise analysis of selected material in the Discussion section (see page 65) where the specific examples of AI implementation need to be contrasted with certain objections to utilitarianism e.g., hedonism, individual rights, and inability to predict the future. On the contrary, the deontological system, is based on duties and rules that determine our actions, while the overall goal or the consequences of those actions are not given such attention. Deontology could also be divided into Universalism and Relativism where main difference is the origin of given rules - while universalists may argue that rules come from nature or reason, relativists might say that rules depend on society or culture they work within. The third branch of ethical systems - Virtue ethics discards both rules and consequences by replacing them with an emphasis on creating good character which ideally, should lead to becoming a better person that stands separately from any duty.

### ***Discussing ethics of automotive industry***

While the car industry has been working on both passive and active safety for many years, accidents are still happening every day. Public debate focuses on human error as a main cause of those accidents, often forgetting about the possibility of a faulty product or faulty technology that may be causing them. Drivers do not account for all road accidents – many injuries and casualties were the result of car companies allowing defective components to their products. Especially one case is worth discussing: a questionable design of fuel system on Ford Pinto in the mid 1970's. At first it may look like a regular recall issue, however what makes this case particularly interesting, is that it has touched on many legal and ethical issues on many levels, that has never been discussed in public – similarly to accidents involving Automated Vehicles. The story began when Ford in the US market, decided to compete with small and cheap vehicles from Japan, and in order to achieve this goal, they needed to approach the production of their new car from a different perspective. Completely new design and shorter production time meant that everyone had to work under tighter schedule. This resulted in an issue with fuel tank that was very fragile, which when hit from behind, even at low speeds, would leak and often explode. Bad designs are a natural part of innovation, however Ford decided to deal with this issue from a strictly economical point of view, which surprisingly, at that time was completely legal – the company did a cost-benefit analysis which showed that fixing the tank before the car was declared ready for sale would cost \$113 million, while the damage payouts would not reach nearly half that much - \$49 million. Knowing the costs of redesigning the vehicle and potential risks, Ford decided to reject the design change and produce the car anyway. The details behind the cost-benefit calculations is what have been so controversial about this case – according to Ford, faulty design would lead to 180 deaths, 180 burn victims and 2100 burned vehicles. Then, the cost of each death was estimated to \$200.000, \$67.000 for each

burn injury and \$700 for each burned vehicle. Certainly, the most controversial number here is the value of human life – estimated by National Highway Traffic Safety Administration (NHTSA) in 1972 (Leggett 1999). Whole case has led to the debate around the negligence-efficiency theory that should measure three variables: “the magnitude of the loss if an accident occurs; the probability of the accident's occurring; and the burden of taking precautions that would avert it” (Leggett 1999). While this approach is accepted for strictly economical cases, it is far from moral to put a value on someone's life. Especially, if Ford as a producer, knew about the possible danger.

The “Pinto-case” raises many questions that seem to be unavoidable in the car industry, mainly how strong ethical considerations stand in product development? While Ford was not infringing the law, it made questionable decisions from an ethical point of view. Could that mean that legal and ethical principles have a significant gap, a grey zone, that could be used for the benefit of either side? The assumption made by Ford, that their actions were legal and equally ethical has caused a backlash and their project that was meant to save money, become even more costly for them. Ford has certainly learned that safety is a strong sale argument and most importantly, the value of the human-technology relationship from ethical point of view. The legal system at that time was not ready either, especially for cases of such magnitude. This case was mostly caused by the strong need for innovation – producing cheaper, faster and with higher profit. Additional conclusions that could be drawn from this particular case, suggest that, at any level of human-technology relation, many layers of control mechanisms are required. Controversial events regarding safety such as already mentioned Pinto fuel tanks, dangerous Firestone tires<sup>13</sup> or the most recent Dieselgate<sup>14</sup> may be an example that widely diffused automotive industry visions do not always meet real standards. Unlimited trust in good intentions of car industry might be overshadowed by several factors e.g., efficiency, competitiveness and innovation, which may have undesirable and unpredictable effects in the long-term, mainly to the society and environment. This issue will be revisited as specific scenarios of AV technology will be analyzed in the Discussion section (page 65).

When driving, humans have to rely on the processing power of their brains where many factors play a different role – everything from a basic instinct to survive to complicated calculations how a person should react to the environment inside and outside of the vehicle. Can pre-programmed algorithms make a better driver than a professional, skilled human driver? Progressing automation where the number of tasks that are being solved in the background by computers instead of manually by human is constantly rising, and further enhanced with AI, may reach a point when these tasks acquire an ethical character, e.g., AI taking autonomous decisions that in conventional

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13 Case of Firestone tires prone to separation is linked to 271 fatalities and over eight hundred injuries in the US.

14 Case where Volkswagen has been using a software that would allow them to cheat the emissions tests.

traffic where the human driver's responsibility. In such case – would a system based on Artificial Intelligence be capable of making a correct, and ethically just decision? While mechanical solutions can be tailored to a high degree of precision, the overall behaviour of large-scale AI-driven digital system is much more difficult to model and simulate for a long periods of time.

The fact that Artificial Intelligence is considered to be, and favored as a substantially the only element capable of processing ethical decisions – the discussion will mainly focus on this particular technology. Guidelines published by the Artificial Intelligence company DeepMind (Harding and Legassik 2017), which has created a separate unit focusing only on ethical and societal questions that are raised by the introduction of Artificial Intelligence may serve as a crucial example. In a statement DeepMind, company explains that in order to achieve an AI that “remains under meaningful human control and be used for socially beneficial purposes” researchers should “explore and understand the real-world impacts of AI.” (ibid). At the same time the other main goal is to “help technologists put ethics into practice and to help society anticipate and direct the impact of AI so that it works for the benefit of all”. (ibid). Setting such high standards in the field of AI is an important step in the right direction, even if it may sound idealized – it is a clear sign that the ethics of technology must be developed simultaneously with the technology itself. Additionally, the above cited statement includes some basic principles that apply to any technology, e.g., that the actions or results of the actions created by technology always have to be under the control of the human. Another condition is to make technology beneficial to all, which certainly is very close to utilitarian views, where creating as much happiness to possibly as many people is the main goal.

### ***Social perception of Automated Vehicles***

According to the study “The social dilemma of autonomous vehicles” (Bonnefon et al. 2016) which focused on people's perception on ethical structures of Automated Vehicles, people's reactions vary significantly depending on whether they were going to personally use these vehicles or not. The key findings of this study might be beneficial as for better understanding the social and cultural expectations on this new technology. As noticed by Bonnefon et al, society “must start a collective discussion about the ethics of AVs, that is, the moral algorithms that we are willing to accept as citizens and to be subjected to as car owners” (Bonnefon et al. 2016, 1). The research allows to get an insight into social perception of Automated Vehicle ethics, what are the expectations towards this technology and what kind of work needs to be done considering the field of ethics of technology. It is also important to point out that the presented study operates with quite extreme and unlike scenarios formulated as dilemmas typical for experimental ethics in order to bring out stronger reactions among subjects of the study and allow more pronounced results.

If the projections given by the car industry and stakeholders advocating for possible adoption of AVs are accurate, meaning that it is likely for SAE Level 5 Automated Vehicles to be a common sight on the roads in the next decade, there is no room for uncertainty and the “collective discussion” suggested by Bonnefon et al., (ibid, 1) about the AV technology needs to take place as soon as possible. In the study, 76% of people asked, agreed that it would be more moral for AV to sacrifice one passenger, rather than to kill ten pedestrians. Participants have also agreed that AV should be programmed in a way that would minimize the number of casualties. When asked “What should Automated Vehicles do?”, over 60% of participants agreed on a utilitarian approach – to “minimize casualties on road” but at the same time “sacrifice their passengers for the greater good” (ibid, 2). However, the study has shown that the same people “would prefer to use Automated Vehicles that protect passengers at all costs” expressing the opposite response to the previous question. Those answers indicate that while people agreed on implementing a utilitarian model in the first place, when confronted with personal scenarios e.g., involving family members in the vehicle, most of interviewees opted for the “self-protective model for themselves” (ibid, 2). The study describes this kind of behavior as “classic signature of a social dilemma” (ibid, 3) where people wish to “free-ride” for the benefits without involving themselves into the movement. The authors of this study compare these scenarios to situations of e.g., vaccination of children or recycling waste – where the main argument is the best global outcome in order to reduce harm. Being aware of the human nature, many of these things needed to be legally regulated e.g., compulsory vaccination of children before school, or encouraging to recycle waste by charging a trash tax. According to this study, people would not like to see government legally enforcing a utilitarian model into Automated Vehicles. The expressed likelihood of buying a vehicle that is regulated by the government and would sacrifice a passenger to ten pedestrians was also very low. Comparing the likelihood of purchasing an unregulated vehicle versus regulated one shows a substantial gap (59% to 21%) meaning people do not want the government to decide for them. As it was also pointed out by Bonnefon et al., there are many other issues beyond the study related to the AV technology – concepts such as “expected risk, expected value, and blame assignment” are challenges that need to be discussed between manufacturers and regulators.

While the study done by Bonnefon et al., could be treated as an early indicator on how people perceive Automated Vehicles and what are the expectations towards this technology among the society, it does not provide practical discussion on ethics in the automotive industry. A more critical-driven approach by Noah Goodall in his article “Machine Ethics and Automated Vehicles” (Goodall 2014) creates a more complex argument that could be useful in discussing ethics of technology in relation to Artificial Intelligence and Automated Vehicles. Goodall takes a critical

approach to “extreme unlikeliness” of situations involving automated car crashes such as those presented in “The social dilemma of autonomous vehicles” by Bonnefon et al. A traditional “trolley problem”, often used in ethics, where only one decision could be made and all consequences are known for each outcome is highly unrealistic according to Goodall (2014, 2). Scenarios created by the majority of automotive industry claiming that Automated Vehicles will be equipped with a technology that will never crash, are mostly based on assumptions and far-reaching implications. However, activity of driving, automated or not, will always contain some risk, and “ethical decisions are needed whenever there is risk” (ibid, 3). Additionally, “any activity that transfers risk from one person to another involves ethics” (ibid, 5) which is not the case only during an accident, but on a regular basis in everyday traffic situations. Driving for a moment on the wrong side of the road in order to give space to a cyclist could be considered a wrong decision from a strictly legal perspective, while being ethically right. Automated Vehicle will have to face multiple decisions that results cannot be predicted easily and “with these uncertainties, common ethical problems become 'complex' very quickly” (ibid, 4). Another criticism presented in his research is a statement that fails to see a difference between “absence of liability and ethical behavior” - the case of responsibility for an accident should not be misinterpreted as ethical system trying to avoid the accident (ibid, 5).

Once reviewed the wide range of possible issues concerning Automated Driving scenarios, I will present and discuss selected ethical rules that address some of the uncertainties raised by Bonnefon et al., and Goodall. A report “Ethics Commission, Automated and Connected driving” (BMVI, 2017) where experts from different fields have worked on a 20 point plan resulting in a document “Ethical rules for automated and connected vehicular traffic”. The primary purpose of AV technology is to “improve safety for all road users, (...) increase mobility opportunities and to make further benefits possible” (ibid, 10). Furthermore, protecting individual human life is more important than any “utilitarian considerations” and government regulations should “promote the free development and the protection of individuals” (ibid). Dilemmas presented by Bonnefon et al., should not take place and be eliminated at the level of initial design and programming, so that AVs should drive in a “defensive and anticipatory manner” (ibid, 11).

Further discussion about ethics, considering the level of human dependence on intelligent systems, issues of responsibility, controllability, transparency, data autonomy and individual rights could be found in the Discussion section (page 65), once specific scenarios of Artificial Intelligence implementation to automated driving are reviewed.

## ***Intelligent Agents***

The main obstacle in the process of creating an ethical structure is evaluating the unknown –



scenarios and simulations are still only to give an “idea” of how given situation might develop and as Goodall noticed: “[I]n reality outcomes are uncertain and there are several layers of choices” (Goodall 2014, 5). The technology of Artificial Intelligence is experiencing rapid progress, especially in the field of Machine Learning, which is believed to successfully build models based on data and perform human-like tasks. Technology that has been mostly used in Automated Vehicles is based on finite-state machines (FSM) which is a “common way to solve the high-level control problem in robotics and AI” (Olsson 2016). Further developed to hierarchical state machines (HFSM) which provide better modularity, the solution still has many disadvantages e.g., implementation in large complex systems “makes maintenance and modification quite labor intensive and prone to bugs” (ibid). Decision trees, referred as driving decision-making mechanism (DDM) in Automated Vehicles, is the main control system of AVs. Architecture of DDM is based on the sensor equipment which can “sense and collect traffic information, including vehicle states and road conditions in real time” (Zhang et al. 2017, 3). Then, after the data is processed, DDM “searches the relevant information and matches the accurate driving decision with the learning experiences, and then transmits the decision order to the control system” which “will control the actuators (...) to carry on with the corresponding operation” (ibid).

When related to ethical decisions, all potential obstacles would have to be pre-evaluated and then translated into the software by assigning to them a certain percentage – then it would be the DDM's task to process them in real time. However, the outcome would only be as precise as the amount and quality of data it could be fed, which in reality could show significantly reduced and generalized results. Suggested solution would be incorporating intelligent and moral agents into the DDM. This would require the highest level of artificial autonomous intelligent agent defined as a system “capable of actions based on information it perceives, its own experiences, and its own decisions about which action it performs” (Mills and Stufflebeam 2005). Additionally, the environment needs to be suitable for given agent, so that it can work within its domain. It is also important to point out that the agent is considered a part of environment, meaning that it “senses the impact of its own habitation” (ibid). Furthermore, these authors distinguish between reflex agents, goal-based agents and utility-based agents. A reflex agents react on given set of data, e.g., medical agents analyze symptoms in a dedicated database in order to suggest a possible diagnosis and treatment. The biggest problem in this type of agent is the restriction imposed to have saved records without the agent being capable of extending the record base by itself. However, such agents are used in automotive applications to implement road sign or lane recognition systems. The second group, goal-based agents, “consider different scenarios before acting on their environments, to see which

action will probably attain a goal” (ibid). At this level, agents become proactive and flexible so that they can adapt to the environment. An example of such agent would be the “Remote Agent” used by NASA in 1999 in order to monitor the mechanical health of the Deep Space One NASA spacecraft (ibid). According to its developers, because of the difficulties connected to developing, debugging, and modification during the mission, the Remote Agent system needed to “provide rapid response even to situations unforeseen by design engineers” (ibid). The described scenario applying to this category of agents seems very close to situations that occur in road traffic, e.g., high number of components that perform unexpectedly. However, the biggest flaw of such system is the lack of certainty of foreseen scenarios. While operating in an unpredictable world, it is impossible to recreate all situations and feed them to database. The last group of agents, the utility-based agents, adds another layer of interaction to the environment by rating each possible scenario. Factors that might be taken into consideration are: “the probability of success, the resources needed to execute the scenario, the importance of the goal to be achieved, the time it will take” (ibid). In order to achieve the highest possible level of flexibility and adaptability, the system is given not only goals and ability to evaluate situation, but more importantly the freedom of planning all possible paths to reach these goals. For many, this particular moment is the main doubt towards the Automated Vehicles – the freedom that might be equipped to the Artificial Intelligence, while simultaneously diminishing the human freedom from the process of what is generally perceived as “driving”. Closer analysis of scenarios proposed in various texts provided by automotive industry and Smart Mobility may reveal these degrees of freedom that are (often implicitly) suggested, while discussing the social and technological construction of the driver. The solution being suggested to the main issue of safety includes gradual retraction of direct, analog, and human inputs fed into the DDM, and replacing them with presets of choices which imply deconstruction of the human driver.

So far, I have reviewed and discussed the ethical, legal and historical aspects of automated vehicle technology. All these elements should be considered, as they give context and sufficient background knowledge to the central point of the discussion, being the possible effects on human behavior when introduced with the Automated Vehicles. These changes have the potential to directly influence the behavior of individuals with their physical and intellectual models as well as interactions inside the society such as ethical structures. These aspects will be discussed in the next section in relation to specific technological solutions.

## **Case study of Automated Vehicle Scenarios**

The topic for my empirical research is Smart Mobility and vehicle automation (Autonomous Mobility on Demand) implications to the construction and role of a human driver as an active user of transportation systems, in the context of projected benefits mainly presented by Smart Vision EQ Fortwo and Car2go services by Daimler AG, Self-driving cars by Waymo, as well as some specific parts of a SEDRIC by Volkswagen Group.

One may notice that while the automotive industry has entered the transition phase, their orientation towards some aspects of transportation has changed and become more complex where e.g., gradual adaptation of Smart Mobility and Smart City trends and aspirations could be observed. As it may seem that the automotive industry and Smart Mobility may share some common goals and expected benefits, a closer, critical review is required in order to reveal the perspective adopted by above-mentioned organizations towards the notion and construction of a human driver. I will be discussing views exposed in several white papers, reports and practical research reports, in order to find out whether their progress plan includes the same instruments and common points in a form of technologies, infrastructures or business models that might enable the realization of the automated mobility. At the same time I will search for ways of imagining and representing future changes in the roles of human driver and/or passenger linked with the adoption of Automated Vehicles.

One should not assume that the scenarios proposed by certain stakeholders will result in equally accurate and beneficial reality. A more thorough analysis of technological beliefs is required, as many solutions mentioned in scenarios of Smart City and automotive industry, indicate impact to efficiency, traffic flow, system safety, while also suggesting substantial consequences of technological innovation to the social, cultural and cognitive aspects. I will analyze these overlapping trends while looking at the certain features of automation that may result in gradual deconstruction of the role of human driver and coexisting effects of virtualization and dematerialization of a human actor of transport systems. A leading question for this exploration will be: Is it possible to trace any anthropocentric elements and social values of Smart Mobility that are being adopted by automotive industry?

### ***Introduction to the selected material***

I have used prospective research carried out by Benevolo et al. (2016) as a reference point and as a critical platform for discussing theories and visions combining Smart City and Smart Mobility. The paper “Smart Mobility in Smart City Action Taxonomy, ICT Intensity and Public Benefits” is

focusing on three major aspects of Smart Mobility. Firstly, it discusses which kind of actions are required so that we can speak of Smart City development; secondly, the authors explore how information and communications technologies support such actions, and finally, they discuss how and why these visions combining Smart City and Smart Mobility may be useful to society. E.g., they review various approaches to how people's life may change while using a smarter and automated modes of mobility. Building upon this contribution from Benevolo et al., I will look for any social and cultural value underlying these visions, and more particularly such values that might indicate changing perspective on a new, digital – that is virtualized and automated version of a driver.

In order to possibly achieve a deeper insight into such technological, cultural and social trends that may have a direct impact on the human driver, I have selected two companies that are considered to be the leaders of the development of automated driving technology and also as key examples of the trends and rhetoric that is expressed towards the technology of automation and its possible effect on human driver.

The first company, a German company, has long tradition in automobile history, and is considered to be one of the inventors of gasoline powered automobiles - Daimler AG. This company has released its own vision of how the future of transportation may look like in the book *Autonomous Driving*. The company's project Smart Vision EQ Fortwo, which can be linked with one of the use cases presented in the book, reflects the possibilities of technology available at this moment or at a very near future. When approaching the discussion in the book, it is important to keep in mind that the entire book does not discuss directly and in-depth any theory or ideology that could be associated with Smart City or Smart Mobility. The authors of the *Autonomous Driving* discuss many aspects of automated technologies and try to analyze them from many aspects but somehow choose not to bring Smart City into the debate.

The second company, US-based Google, is seemingly different from Daimler since it is considered to be specialized in computer technologies including AI and could be also considered a newcomer in the automotive industry. Google's proprietary automotive project started in 2009 as a “Google Self Driving Car Project” and evolved late 2016 into a separate company – Waymo.

A comparison of both companies, Daimler AG and Waymo, suggest that both companies have been developing closely related technology of Automated Vehicles despite their completely different history and general domain of operation. While comparing these two projects I will take a closer look at various circumstances and variables accompanying the development of the AV technology. A common criterion for comparing the approach chosen by these two companies is to assess their

technological, cognitive and ethical approach to the gradual retraction of human decisions in traffic situations through various delegation models. Such modes of can be interpreted as virtualization and dematerialization of the human driver. Daimler and Waymo, as other mobility and automotive stakeholders predict huge benefits and speak of the extreme potential of new automotive technologies. I will therefore focus on identifying and assessing, where possible, in these industrial narratives the alleged benefits of automotive technology, including AI, that may potentially influence social and cultural aspects of future driving activities e.g., human interaction with the AV interface, the need to adjust behaviour to new traffic situations.

In the following sections of the Case study chapter, I will explain the changing landscape of automotive industry with a special focus on Automated Vehicles (together with supplying services of carsharing and autonomous mobility on demand) in relation to Smart Mobility. In order to achieve a better understanding of the interconnecting themes of Smart Mobility and automotive industry, I will use the findings of Benevolo et al's. Research (2016) to find possible differences and common points to these two visions of transportation. Afterwards, I will discuss the two above mentioned industry projects – Smart Vision EQ from Daimler and Waymo's self-driving vehicle in the context of these visions – e.g., asking what implications to the quality of life, the relation to technology, the notion of the driver, or traveling itself could be found when adopting core concepts of Smart Mobility. I will also discuss specific examples illustrating evolution of automotive industry towards Smart Mobility, a concept which activates several Smart City initiatives reviewed by Benevolo et al. (ibid). By doing so, I will, hopefully, gain a better understanding of needs and expectations towards users of carsharing services such as Car2go. I will also analyze possible expected benefits of automated driving and autonomous mobility on demand that have been documented in various researches carried out by Car2go, Shared-Use mobility Center, and ARK Invest.

At this point it is important to clarify why I have chosen these two study cases. While there are other impressive and innovative projects from other car manufacturers, (some of them already mentioned) they do not offer any useful documentation that would provide a deeper insight into either the technology or into the vision underlying the project. From my own extensive preliminary research, mostly based on the large number of material that was often intended for the specialized press or for potential customers, I have chosen to analyze and work with the two projects from Daimler and Waymo for number of reasons. It is expectable, that the automotive industry keeps technological secrets to themselves, and any tactical or strategic information is often removed or

diluted in general rhetoric. However, the documents that I have selected reflect in greater detail specific near-future visions of society using AV technology. Such visions are related to a current perception and depiction of an idealized lifestyle or behavior. The core concerns of this thesis will be activated e.g., the various visions of a “new” automotive industry seen through the lens of Smart Mobility scenarios will be discussed from the perspective of current central themes of Digital Culture e.g., concepts of dematerialization, virtualization and automation. Additionally, the character of Smart Mobility and creative departments of automotive industry producing mentioned projects is strongly related to the need for constant innovation, which may bring rapid and substantial changes, resulting in research materials becoming quickly outdated.

### ***Basic principles of Smart City and Smart Mobility***

After the brief introduction to the selected material, I will take a closer look at ideas behind Smart City and Smart Mobility, what are the basic, underlying concepts and technological means to achieving goals of a better life in urban areas. Benevolo et al. have collected and analyzed large amounts of literature in order to investigate the “role of ICT in supporting Smart Mobility actions” (Benevolo et al. 2016, 13) meaning their approach is focused on specific technologies that contribute to changing the way people move in cities. Identifying these technologies, actions and various agents, the authors construct a complex map where each domain is classified depending on the public value or general impact it may have on the city.

The authors opt for three reference models which, in their view, are the pillars of the Smart City ideology, and which should be included in the further discussion:

- Digital city: “wired, ubiquitous, interconnected network of citizens and organizations” allowed by Information and communications technology (ICT)
- Green city: implies “sustainable development” by reducing pollution, managing waste and energy in a better way. Also includes green areas for public spaces
- Knowledge city: represents a city where data, information and knowledge becomes transparent and valuable resource (Benevolo et al. 2016, 15).

These three models are the most effective when working together - creating a Smart City which could be defined as “a city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of activities of self-decisive, independent and aware citizens” (Benevolo et al. 2016, 15 referring to Giffinger 2007). A closer look at these three dimensions suggests that Smart Mobility represents only one of the ingredients of a future Smart City, but is capable of influencing each dimension of the whole

structure. To achieve Smart Mobility goals, specific aspects of the Digital, Green and Knowledge City need to be integrated in the industrial vision. A basic ambition in Digital City scenarios is to create an arena in which people can interact and share knowledge and information in a digital format. This definition could be universally applicable not only to person-to-person interactions but also person-to-technology and technology-to-technology (system-to-system), especially when discussing mobility and Automated Vehicles where a system of interconnected devices could share data within a distributed system defined as Internet of Things (IoT). Such philosophy is also firmly rooted in the Big Data approach which is considered essential to achieving a Smart Mobility. Big Data-based scenarios should, in the context of Smart Mobility, obey a condition: collecting, sending, receiving, and analyzing data should create more useful information and knowledge exploitable in real time – e.g., as it is already the case with traffic systems collecting and exchanging the data on speed, weather conditions, and traffic congestion events. The combination of different technologies and solutions such as Machine Learning, Big Data, and IoT could potentially change the approach to the transportation system. The basic belief is that the more sensors and radars there are on the streets, the larger amount of precise and useful data is being fed to the system that could analyze, predict and suggest optimal solutions and patterns for transportation, that could be ultimately beneficial to people. It is also important to point out that mentioned models of Digital, Green and Knowledge City may share some common traits but also exhibit differences. For example, some versions of the Green City visions do not accept the industrial side of development and reject anything that may remove humans from the nature. The main point is that larger concepts such as the Smart City or Smart Mobility that build upon the three principles of the Green, Digital, and Knowledge City, in order to succeed and merge with any industry (e.g., automotive) should find the balance and draw these solutions and ideas that would work best while still keeping the basic principles of Smart City or Mobility. Following the debate presented by Benevolo et al. the goals of Smart Mobility could be ordered in six categories: “(1) *reducing (air) pollution*; (2) *reducing traffic congestion*; (3) *increasing people safety*; (4) *reducing noise pollution*; (5) *improving transfer speed*; (6) *reducing transfer costs*.” (ibid, 16).

In the next sections I will try to find out how does Daimler’s and Waymo’s strategy relate to mentioned visions and goals of Smart Mobility - if they recognize and accept them, or if not, how did they produce existing research results. A question whether it is possible to conclude which version of mentioned visions is closest to Daimler or Waymo, in relation to the notion of human driver, and decide which goal is the primary objective in their projects should be taken upon further discussion.

For the sake of this research, I will focus on private and commercial mobility exemplified by

Daimler's Smart Vision EQ Fortwo prototype, Car2go services, and Waymo's project. Solution that most frequently characterize this group of industrial actors, according to Benevolo et al. Involves the introduction of hybrid vehicles and the generalization of carsharing services. It is a true description; however not extensive enough. On top of already much popular hybrid technologies, there are other solutions aiming at smarter and more efficient mobility. Most of them are dictated by public policies and regulations such as EURO emissions, production of electric vehicles, systems that increase fuel efficiency or those aiming at improving traffic flow and safety such as Automated Vehicles. Benevolo et al. adds carsharing as one of the arguments for creating Smart Mobility solutions by private and commercial stakeholders. Until recently, private and commercial mobility has been perceived as two separate sectors which have been highly influenced by the perception of the nature of car ownership, a concept which is currently being actively reshaped and redefined by many companies as a reaction to possible decrease in the demand for new privately owned vehicles induced by services such as Car2go or Uber.

An additional aspect linked with the discussion of the evolution of car ownership by Benevolo et al., is that in order to create a true Smart Mobility in a given city, there is a need for fostering **cooperation between all mobility actors and stakeholders**. As there are many examples where private, commercial and public transport modes are developed not only apart from each, other but also completely separate from city infrastructure or policies that should support smart solutions. The case of the city of San Diego could serve as an example for bad politics and decisions working against citizens and users of carsharing services. Car2go company has started operating there in 2011 and was forced to leave the city only after five years. The reason was lack of charging stations, promised by federal government and rising popularity of ridesourcing services such as Uber and Lyft. Lack of charging stations combined with the number of electric vehicles, made many of them unavailable due to long charging time (Krok 2016).

### ***Daimler's scenario – Smart Vision EQ Fortwo***

In this section, I will look closer at the project Smart Vision EQ Fortwo which resulted in a prototype made by Daimler's division – Smart company. As changes in car industry related to electric vehicles and autonomous driving take place very rapidly, Mercedes-Benz has announced the creation of a new product branded “EQ” which stands for “Electric Intelligence”. EQ will focus on the development of electric mobility-driven ecosystems of innovative products, services, technologies. To clarify, the intention of this study is to analyze projected visions and benefits that could be found in the Smart Vision EQ Fortwo project that is designed to be an autonomous vehicle. Daimler has built many layers of brands and divisions that are focusing on the future of the

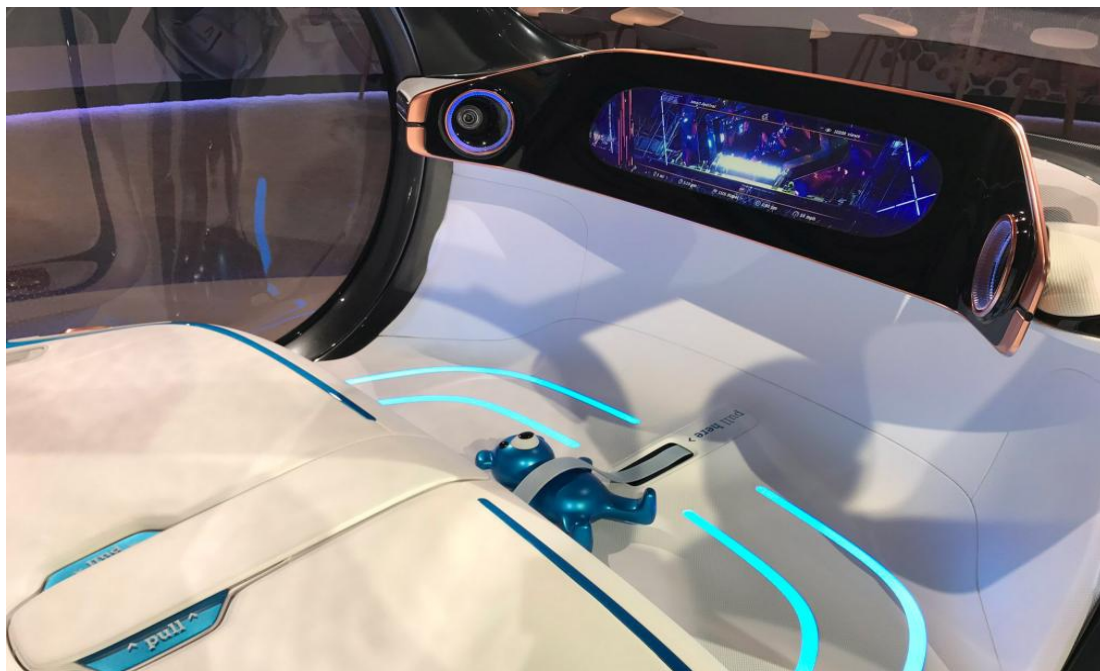


company that are now gathered under the “EQ” brand. Daimler has been expanding its field of operation and currently can propose quite an extensive portfolio as a car manufacturer. Smart Vision EQ Fortwo could be described as a representation of Daimler’s experiences integrating many mobility related domains. Smart Vision EQ Fortwo includes several products and services, e.g., Car2go - currently the largest carsharing operator in the world, Moovel - application providing a service that integrates all available modes of transport, Mytaxi - currently the largest taxi app in Europe, and Fliinc a carsharing platform for organizing short and dynamic journeys.

As already mentioned in the introduction to Case study section, Smart Vision EQ Fortwo is a concept that is derived from one of the use cases presented in the book sponsored by the Daimler and Benz Foundation. The book “*Autonomous Driving Technical, Legal and Social Aspects*” has gathered specialists from different disciplines such as engineers, geographers, urban and development planners but also psychologists, philosophers and sociologists which allowed them to create a holistic approach to autonomous vehicles and discuss many aspects of mobility that have been transferred to the Smart Vision EQ Fortwo. This section will work as an analysis of both sources released by Daimler, e.g., chosen chapters from the book “*Autonomous Driving*” and press materials for Smart Vision EQ Fortwo project, in order to find out how the car industry allegedly operates with knowledge created by “scientifically motivated questions and independent of commercial interests” (Maurer 2016, 7) to achieve a product that will be potentially desirable for their customers. The starting point for the book, is a representation of the evolving global picture of traffic and proposal to reshape the transport system emphasized by a fundamental conclusion that “fully automated driving offers the greatest potential for optimizing traffic flow” (Maurer 2016, 4). In addition to a purely technological approach rooted in engineering (ICT and automation), the book also presents its vision of the ethical, social, legal, psychological, historical and cultural contexts for the automated driving, whereas Daimler Foundation considers the social dimension to be of at least as great significance as the technological one (Minx and Dietrich 2016). Given such an overarching vision, the book outlines four major use cases which are thought to offer the highest potential to benefit from automated driving technologies: “(1) *Interstate Pilot Using Driver for Extended Availability*, (2) *Autonomous Valet Parking*, (3) *Full Automation Using Driver for Extended Availability*, (4) *Autonomous Vehicle on Demand*.” (Wachenfeld et al. 2016, 11)

Smart Vision EQ Fortwo is based on the fourth use case Autonomous vehicle-on-demand (ibid) and while other scenarios are worth studying as well, this specific scenario is the closest to the Smart Mobility ideology and provides sufficient documentation as its prototype was broadly discussed and demonstrated by Daimler. According to Wachenfeld et al., two major benefits of this scenario could be identified: (1) the “vehicle will be available at any requested location” and (2) “passengers use

the travel time completely independently for other activities that performing the driving task” (ibid, 18). The scenario description presents several conditions to achieve these foreseen benefits: the “driving robot” would receive the destination information from occupants or external entities such as users or service providers and the additional data collected from social networks would allow for better planning of routes, matching people and predicting the traffic behavior (ibid, 11). The vehicle itself would carry all driving tasks using its full automation capabilities. The interior of the vehicle would be designed without traditional “driver workplace” so that interfering with driving controls would be impossible for the passengers (see Illustration 4). While these basic task-oriented and design rules may seem straightforward, the set of exceptions the AV needs to deal with is makes this use case much more complex in real life than on paper. For example, public entities with higher exclusive rights such as police, ambulance or traffic management should be able to override the vehicle's system. As already mentioned, passengers could choose destinations or opt for “safe exit” solution in case of an emergency. However, even safe exit option could be also overruled by higher entities or authorities in unusual cases. Such solution raises not only system-specific issues, e.g., complexity management, but political and legal issues as well.



*Illustration 4: Smart Vision EQ interior. (Copyright Autoexpress. 2017)*

According to Annette Winkler, CEO of the Smart company, the Smart Vision EQ Fortwo is supposed to be “the most radical carsharing concept car of all: fully autonomous, with maximum communication capabilities, friendly, comprehensively personalizable, and of course, electric” (Winkler 2017). In order to achieve this vision, Daimler has worked out a CASE strategy

(Connected, Autonomous, Shared, Electric) which includes following steps:

- Connected: main goal for this principle is to communicate better with car's surroundings. The vehicle is meant to be Level 5 Automated, where passengers are no longer occupied with driving and are not expected to pay attention to the road situation, whereas communicating with pedestrians or potential passengers will happen through external displays around the vehicle. Since the vehicle is a two-seater, it is possible to use the "1+1 sharing function to make contact with other interesting users" (Winkler 2017) where first user will be notified about possible passengers based on the route and profile.
- Autonomous: this principle is the next step that is supposed to make the carsharing more convenient where "users do not have to look for the next available car" (Winkler 2017) and many steps are automated - the vehicle can pick up passengers from any location (based on a individual schedule) and when the trip is finished, it will continue to the next request on its own. As a result, all the vehicles are always on the road which maximizes the utilization of the car park. This also affects parking spaces and traffic in the long-term.
- Shared: construction of the vehicle encourages carsharing and is more suitable for use in such services.
- Electric: vehicle is fully electric, powered with rechargeable batteries - being an autonomous vehicle as well, it can navigate to charging station by itself when needed. (Winkler 2017)

The scenario where ICT plays a significant role is also expressed by Benevolo et al. 2016, where "systems for collecting, storing and processing data, information and knowledge" are mentioned to be an important component when creating autonomous driving systems (ibid, 24). Among the solutions characteristic for Smart Mobility, there are many overlapping with the ones mentioned in materials by Daimler and to be used by Smart Vision EQ e.g., integrated parking guidance systems, Urban Traffic Control (UTC), video surveillance systems for area and environment security, integrated systems for mobility management, traffic data collection systems, expert systems for correlation and filtering events and systems for the management of fleets of public transport adapted to UTC. While utilizing these solutions, the mobility scenario proposed by Daimler may potentially step out of an individual automated vehicle into a fleet of Automated Vehicles operating on a larger scale. This particular example is where the ICT systems such as Internet of Things, Big Data, managed by Artificial Intelligence stand very close to the Smart and Digital City visions presented by Benevolo et al. and described above. As a result, Automated Vehicles would become a part of an "information loop" as they would collect, send, and receive all possible data that could be used again for further benefits. This shows the evidence that automotive industry itself is going to

become even more data driven and eventually their main focus “will shift from the conventional vehicle technology to software technology, including AI, and data platforms that support the software technology” (ITS Initiative Roadmaps 2016, 10).

One of the sources that reveals the motives behind Smart Vision EQ Fortwo is the interview with Boris von Bormann, CEO of Mercedes-Benz Energy Americas, a company working on alternative uses for car batteries. Bormann predicts growth of interest in electric and plug-in hybrid vehicles in next years and his company focuses on creating a smooth transition towards a greener Smart Mobility. Bormann mentions Machine Learning that would take over the task of planning and knowing the patterns of electric vehicle (EV) customer – in that way “intelligent grid management” would have a positive impact on cities and power consumption. Based on the information about customers, vehicles would decide when and where to charge – for how long and at what price, to ensure the best possible user experience. He also notices a need for standards: “You can buy a charger, a smart home system, a solar system, an EV right now, but they don’t work 100 percent together” which creates a demand for a more seamless Internet of Things experience (Bormann 2018). To complete and illustrate the vision of future mobility by Daimler, Bormann has exposed his idea of “a mixture of shared rides on the weekends with rental vehicle or direct exchange where you can use your neighbor's car” (Bormann 2018). This confirms the scenario where privately owned vehicles will lose its significance and it will be expected for users and customers to remove any attachment to their private car. Instead, companies might replace it with any vehicle that could be personalized only to some extent by using previously gathered information about specific user e.g., seat position, commute routes, favorite music or schedule.

## **Expansion of Daimler's vision through Car2go services**

As exemplified in previous sections, leaders of automotive industry, in order to expand their operation and increase profits, add new companies to their investment portfolios. This section will get a more detailed look at the Car2go carsharing company, owned by Daimler. While Smart Vision EQ Fortwo project was created as a showcase of possibilities, it cannot directly compete with Waymo in terms of plausible implementation and therefore its value beyond visionary status should not be overestimated. However, Car2go has recently released a white paper in which they have expressed the possibility to initiate cooperation with Daimler by using such vehicles which have been presented by Smart Vision EQ Fortwo: “with Car2go, the operation of this vehicle in an intelligent fleet will also be possible” (Car2go 2017, 8). Car2go, may work as a continuation of the Smart project, where some basic principles will be possibly implemented, which calls for a in-depth

analysis of their approach towards the social and cognitive aspects of Automated Vehicle technology.

Additionally to introducing the notion of 'intelligent fleet', the white paper highlights the importance and the potential of autonomous vehicles not only for the concept of carsharing but also urban spaces within which they are intended to operate, stating that “self-driving, fully electric cars will make private transport in city centers cleaner, cheaper and safer” (ibid, 1). Arguments in favor of the new technology are similar to those presented by Waymo (discussed on page 53), e.g., Automated Vehicles have some clear advantages over traditional ones, regardless if they are a part of intelligent carsharing fleet or privately owned, and are treated as a daily means for transport for families. Efficiency is recurrently emphasized in both Waymo's and Car2go white papers, suggesting radical improvements to the utilization rate of cars highlighting the fact that privately owned vehicles sit unused on average for more than 23 hours per day and AV technology is expected to be a “quantum leap” for even higher “utilization rate” of the fleet vehicles resulting in smoother user experience (ibid, 1). Car2go in their white paper has formulated a strategy beneficial for their customers that will assure “optimal management of an autonomous carsharing fleet” (ibid, 1):

1. “Professional fleet management” – means managing both onboard hardware and software in the vehicles. When mobility services become “autonomous” and when the fleet of autonomous cars will need to share real-time data with intelligent fleet management systems, the additional amount of data to be processed is going to increase as well. In order to avoid vehicle downtime, resulting in lower utilization rate, and assure the best possible service to customers, Car2go is developing a software that will take into account these factors. This point raises the legal and ethical issues of delegating decisions to onboard software. The white paper do not discuss in detail to what degree the “external management systems” will be allowed to interfere with human interaction and how it may directly affect user experience of their customers.

2. “Demand prediction” – in order to fully take advantage of AV technology, there will be a need for precisely predicting the demand for mobility services – a software making use of concepts like Big Data and IoT, will consider local events, weather forecast or time of the day in order to ensure the best user experience. However, these concepts in order to offer proper and precise “management” require large amounts of traffic data and user data that needs to be analyzed and calculated. This creates an issue of predictability which is central for statistical science which is often an outcome of optimistic estimations and expectations towards the abilities of technology. Additionally, this may lead to the issue of privacy of Car2go users who will be required to share specific information about their use of the service in order to feed the management software.

3. Fleet intelligence – this point is directly connected to previous one – according to Car2go, predicting the demand needs to be considered from a system point of view. The problem of an efficient and optimal fleet especially in large cities cannot be solved individually for each car - “an autonomous carsharing fleet is more than just the sum of its cars” (ibid, 5). Already at this point, Car2go is using a software that is able to predict demand for vehicles in certain area – these calculations are made without human involvement. With such software, one vehicle is able to achieve up to 16 rentals per day and the only time when humans are needed is to actually move vehicles to the area that the computer has predicted. Once autonomous technology is available, Car2go predicts that cars will be able to “distribute themselves throughout the city based on the same logic” (ibid, 5).

4. “Intelligent charging” – Car2go has been using a software which predicts the need for charging vehicles based on different variables such as “demand behavior, driving behavior, or number of vehicles” (ibid, 5). After some time, Car2go has gathered enough information to create “the ideal scenario of an optimal charging infrastructure in a city” (ibid, 6) which has been shared and often used by other cities where company operates. By doing so, a better system efficiency can be achieved which is beneficial for cities as with electric vehicles, there is less noise and air pollution, which help fulfilling the Smart City objectives

5. “The best customer experience” – Car2go recognizes the social aspect of mobility on demand – e.g., how people are going to interact with vehicles, what their needs are and what they expect to constitute the best user experience. Car2go works closely with Daimler in order to get a better understanding of the best design for Automated Vehicles that will be specifically designed for mobility on demand. Making an automated vehicle is a very complex task by itself – and making it work in carsharing fleet adds another layer of challenges that need to be solved on individual vehicle design. Problems that have not been visible before such as opening a door, starting a trip, operating vehicles controls, simply communicating with the car - are going to require a new approach as users are not expected to have undergone the same prior learning as traditional private car owners. According to studies carried out by Car2go and Daimler Mobility Services, “customers want seamless connectivity between their smartphones and tech in the vehicle” (ibid, 7).

The white paper released by Car2go emphasizes the underlying deterministic view on technology, where strong belief and trust in the ability of technological artifacts to influence and alter human behavior both directly and indirectly is expressed.

## ***Scenario presented by Waymo***

As introduced in the former section, one of the first companies that have made an unexpected entrance into the automotive industry is Google. Google's work with automated driving technology started in 2005 when their vehicle “Stanley” won the DARPA Grand Challenge<sup>15</sup> Since then, Google has been very proactive in the field of vehicle automation – being the first to license their “self-driven” Toyota Prius in Nevada in 2012. Two years later, they have released a prototype build to be fully autonomous – where the interior had no driver instruments that would allow the passenger to take control over the vehicle. Since then, Google has been working with numerous car manufacturers (Toyota, Lexus, and Chrysler) and suppliers (Bosch, ZF, LG, Continental, Intel and Velodyne). During the course of several years, Google has managed to become a significant actor not only in the technological area but also as an actor calling for regulatory developments in the USA and elsewhere. In many countries, but most visibly in the USA, Google has been lobbying the authorities to legalize the testing of Automated Vehicles on the open roads. The creation of a strong lobby from Google's side, has accelerated the development of automated driving technology also outside of the US market. In 2016, “Google self-driving” car has become a separate company named Waymo, whose approach to AVs will be discussed in detail in the next section. Waze, owned by Google since 2013 is a company that should also be mentioned. Waze is a smartphone app that provides GPS navigation enhanced by user-based information. It was the first software to combine features of maps and information reported by community such as traffic, accidents, speed traps or fuel prices. In 2016 Waze started testing their carpool feature – focusing on San Francisco's Bay Area and in early 2018 expanding its operations to the whole state of California. By analyzing users' behavior on a daily basis, Waze is currently able to connect drivers and riders based on pick-up and drop-off locations, current traffic pattern and expected commute time, giving Waymo which cooperates with Waze, crucial information about drivings patterns and the behaviour of drivers during their regular trips.

In order to gain better insight into Waymo's vision the human driver, one may begin by analyzing Waymo's “Safety Report” a document that is meant to show the company's work and commitment to safety (Waymo 2017, 2). At the same time, this report is the document closest to a white paper that is made available to the public. The title of the document and the reasons that there are only a few other sources available on their website may be explained with the fact AV being a new technology needs to earn credibility among press, customers and skeptics, before more assertive

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<sup>15</sup> DARPA (Defense Advanced Research Projects Agency) Challenge is organized by the US Department of Defense. Being the most important event for those who work on AV technology it provided a basis for development of autonomous vehicles especially in the US.

publications are released leading to the careful statement that “fully self-driving vehicles will succeed in their promise and gain public acceptance only if they are safe” (ibid, 4). In order to do so, the report uses of rhetorical means that are supposed to attract and convince the reader to a specific technological scenario. As one may conclude, which I will prove later in this section, this scenario presupposes a lifestyle narrative proposed by Waymo. This narrative including aspects of e.g., safety management, open communication opportunities, and promises of extended mobility, suggests that the main goal is to replace traditional vehicles with “self-driving” vehicles, and simultaneously, conventional drivers by “riders” and users. It should be noted that the Waymo report provides far more technical details than documents provided by Daimler. In that sense it is much more difficult to extract the overall mobility vision presented by Waymo from the technological narrative. Nevertheless, in my analysis I will focus on indications within this narrative that might suggest the specific changes which may be required required to allow interaction with the automated driving technology.

The first argument advocating the potential of Automated Vehicles states that the automated driving technology will lead to “improved road safety and new mobility options to millions of people” (ibid, 3). This claim is supported by statistics data grouped in three categories: (1) *Safety*, (2) *Society and Mobility*, and (3) *Quality of Life*. In the Safety category, the report highlights that “94% of crashes involve human error” which leads to over “37, 461 road deaths only in the US” (ibid, 6) and 1.2 million deaths worldwide. Society has to deal with \$594 billion “in harm from loss of life and injury each year” and “277 billion in economic loss” (ibid, 6). According to the same document, traditional vehicles consume and waste people's time when stuck in traffic - “160 billion in gas burned and time lost each year” (ibid, 6) as there are groups of people whose quality of life suffers – because of their disabilities or age, their mobility is limited. At this point Waymo presents both a problem and and a solution exploiting their “self-driving technology” with a potential to address all mentioned problems by saving lives and improving mobility.

The next section of the document continues to explain the safety features that are addressed in the “System Safety Program” consisting of five areas listed below:

1. Behavioral safety: driving decisions and behavior of our vehicles (...)
2. Functional safety: ensuring vehicles operate safely even when there is a system fault (...)
3. Crash safety: ability of vehicles to protect passengers (...) (Waymo 2017, 11)

While the three mentioned categories are crucial to even allowing the vehicles on the public roads, and should be obvious for any car manufacturer, two additional safety related areas emphasize the importance of the cognitive interactions and user experience:



4. “Operational Safety: This refers to the interaction between our vehicles and passengers (...). Our approach to building a safe product is informed by our hazard analyses, existing safety standards, extensive testing, and best practices from a variety of industries. For example, through initiatives like our early rider program (...) we have developed and tested user interfaces so that passengers can clearly indicate their destination, direct the vehicle to pull over, and contact Waymo rider support.

5. Non-Collision Safety: We address physical safety for the range of people who might interact with the vehicle. For example, this includes electrical system or sensor hazards that could cause harm to occupants, vehicle technicians, test drivers, first responders, or bystanders.” (direct, 11)

As Waymo explains its approach to safety, the process requiring one to identify risks and evaluate what can be done to reduce them. Solutions may vary from software to hardware, controlling procedures, and design and architecture of systems. When the new solutions are ready, they are tested either on public roads, a closed course, or in a simulated driving environment depending on the application. Collecting operational knowledge is a crucial step for implementing and improving technology – when approved on all levels, cars are released and permitted for “fully self-driving operation on public roads” (ibid, 12).

## **Waymo's Early Rider Program**

Despite the fact that vehicle automation technologies are under development, many rules and standards specific for traditional vehicles are still applicable, e.g., when dealing with functional and crash safety features. However, most of the features that apply to design of the AV interface and thus, interaction between users and the system, are still in the testing phase, and no universally adopted rules can be applied. While there are numerous organizations that focus on testing safety and operational features and, in the case of public bodies, rule whether the product is ready to be released for public use or not, an independent body external to car companies which would test the safety of proposed solutions to be implemented in the interfaces of the AV is still missing.

Currently, car industry is allowed and, to some degree, trusted to self-regulate their own technological solutions, which might be an issue (e.g., Tesla's automated driving features discussed earlier) and has been historically proven to be potentially dangerous, as early adopters may pay the price of early technology.

Waymo's response to the safety challenge was the introduction of the Early Rider Program claimed to be the first public testing of Automated Vehicles. The program was created in order not only to learn the patterns and needs of users but also to educate them on how to use these vehicles.

According to Waymo, the program will teach AV developers “about how people want to interact

with our vehicles, and what it's like to ride as a passenger instead of a driver. Their experiences will help us create an in-car experience that is even more intuitive and easy-to-use" (Waymo 2017, 30). Waymo presents four principles for user experience that will guide the development of new technology around them:

1. Give passengers the information they need for a seamless trip;
2. Help passengers anticipate what's next;
3. Proactively communicate the vehicle's response to events on the road;
4. Help passengers engage safely with the vehicle (ibid).

In order to follow these four principles, Waymo uses different ways to create easy communication between passengers and the vehicle. For example, a display inside the vehicle, provides not only basic trip information just like in any traditional vehicle, but also a visualization of the environment: "that way, riders can understand what the vehicle is perceiving and responding to, and be confident in the vehicle's capabilities" (ibid, 31) (see Illustration 5 below). Trips can be started from the mobile app or the button inside the vehicle. In case of an emergency there is a "pull over button" which tells the vehicle to find the nearest safe stop and allow riders (as there are no more drivers) to exit. For safety reason this feature is not available from the mobile app. Waymo is also making sure that groups of people with different abilities may safely interact with vehicle – from the moment of ordering the ride to communicating inside a vehicle. By adding specific audio features and Braille labels in their vehicles, riders are able to know what is happening around the vehicle.



*Illustration 5: Interior of Waymo's AV, showing empty driver's seat, riders in the backseat, and in-car display updating riders about vehicles intentions. (Copyright Waymo. 2018)*

John Krafcik, the CEO of Waymo, during an interview at SXSW Conference (2018) has revealed the results of the Early Rider Program where hundreds of people had access to Waymo's vehicles for a year. In the beginning the vehicles were supervised by the testdriver, however during the last month in the final stages, engineers were confident enough to allow passengers in the vehicle without any “mission control”. One of the issues discussed by Krafcik, was getting precise pickup and drop off areas that were convenient for users e.g., people wished to be picked up at cart return place instead of in front of the entrance which would block the way for other road users, making them feel guilty. The element of driver community and behavior that is not necessarily regulated by the law was something that Waymo needed to recognize and implement into their system. One should also discuss the users' privacy that might be an issue in AV scenarios. As Krafcik explains, unexpected events that might occur during trips are valuable data to improve the overall system e.g., construction work or an accident which will be shared and uploaded with other Waymo users. Another scenario where Automated Vehicles will depend on the data that users provide them, is a situation when a Waymo user needs to be picked up from the airport. In that case, Waymo will know that the user is taking that flight, the number of luggage, other travelers and will send an adjusted vehicle. However all these situations are based on sharing the personal information, about the user – who, where and when was traveling. A situation where a carsharing company e.g., Waymo will know users schedule will perhaps need some social adjustment in the same way email services and social media have become “personal”.

The additional challenge of Automated Vehicles, according to Waymo, is to create a design that will allow easy communication across all new groups of users with different ages and abilities e.g., people that have limited or no experience with the activity of driving, people with visual disabilities that were not able to drive before, or people that should not be driving and take the risk of driving under the influence of drugs or alcohol. This has started the second program called “Let's talk Self-Driving”, where Waymo works together with other groups considered with safety and mobility such as National Safety Council, Foundation for Senior Living, Mothers Against Drunk Driving, Foundation for Blind Children, and East Valley Partnership where their work focuses on finding new ways to reach with the new technology to a broader public.

Compared with other vision statements (produced by e.g., Daimler), Waymo represents a somewhat wider and more detailed approach to the implementation of Automated Vehicles which could be supported by the fact that, their project represents of more advanced stage of development that has been tested outside simulations for a longer period of time through the public Early Rider Program. Additionally, Waymo is mainly focused on ridesharing services enhanced with Automated Vehicles, equipped with SAE Level 4 technology. Such automated driving system has no “human driver” on

board – only passengers or as Waymo labels them - “riders”. The discussion about the distinction between the driver and passenger is central for the role of humans not only in mentioned scenarios but in other situations where automated technology is involved. As mentioned earlier, there has been a significant concern about people overtrusting the technology. The situation where users expect it to perform in a way it was not designed to, may indicate the design itself is faulty. During the testing in 2012, Google was the first industrial actor to notice, that people expected too much from the lower level Automated Vehicles and failed to take action when asked. The transition from a passenger to a driver, also called by Google a “handoff problem” made designers of self-driving technologies rethink the approach: “The more tasks the vehicle is responsible for, the more complicated and vulnerable this moment of transition becomes” (Waymo 2017, 31). While Google was quite early to detect this problem and it did not get enough public attention, it has come back recently when some users of AVs experienced it by themselves – unfortunately with fatal results, where people have lost their lives (as discussed in page 24). The situation where people fail to understand the limits of technology and to take action in time is what made major vehicle producers redesign the approach as asking passengers to become drivers in seconds was both unfair and unsafe. The results of tests of lower automation level systems (SAE Level 1 - 3), show that once people are presented with the possibility to “forget” about driving, they tend to get distracted too easily and may fail to regain the control over the vehicle within the critical time span that is considered to be safe. Waymo's approach is to completely skip automation SAE Levels from 1 to 3 and focus on Levels 4 and 5. These two highest levels, do not require by definition human interaction, and presuppose built-in backup systems that will bring the vehicle to a safe stop, or at least to a situation of minimal risk. By removing expectations of a human taking over control when required, interaction between human and machine are also expected to be less complicated and more intuitive. However, in a recent interview, the CEO of Waymo has commented on the company's interpretation of SAE standards, stating that while their vehicles are capable of tasks within Level 4, the possibility of Level 5 automation as defined by the SAE is very low. A vehicle able to drive automatically anywhere, anytime and at any weather conditions is not possible as “even humans are not Level 5” according to Krafcik (2018). I will discuss in the following section issues related to the handoff problem with emphasis on ethical and cognitive issues. (see Discussion chapter page 65).

In Safetz Report, Waymo provides a rationale for the technology behind the driving tasks that are required to drive safely. Vehicles using their latest “self-driving technology” are based on a Chrysler Pacifica Hybrid Minivan. The report pays very little attention to vehicle efficiency, ecology or any other solutions that might suggest a better or cleaner environmental impact or comply with any

Smart City scenario. Waymo states that their technology does not require any additional external infrastructure to be fully functional thanks to onboard hardware. E.g., vehicles are equipped with four types of sensors: LiDAR – a 360 degree laser measurement system that scans the physical environment surrounding the vehicle, a digital “vision system” equipped with cameras that can analyze the surrounding world in high resolution and in color, a “radar system” that detects objects and movements, “supplemental sensors” such as audio and GPS sensors that detect emergency sirens or fill the gaps in interpreting the location of the vehicle. These systems feed the self-driving software which acts as the “brain” of the vehicle – as Waymo puts it. According to the Waymo Safety Report, the technology behind the system is capable of “understanding” the world in real time – it is able not only to detect the presence of an object, but also “understand how it's likely to behave, and how that should affect our vehicle's own behavior on the road” (Waymo 2017, 15). Which means that the automated driving system, is capable of learning and reacting to surroundings as well, suggesting the use of Machine Learning algorithms to process, interpret and make informed decisions based on collected data. As recently revealed by Krafcik, Waymo vehicles have driven 5 million miles combined, where every traffic scenario is being passed through and added to the “collective brain” making it “possibly the most experienced driver in the world” (Krafcik, 2018). However, it is worth noticing that the report does not include any discussion around the AI technology, which might be a conscious decision as a part of rhetorical strategy. By avoiding further explanation and comparing the software directly to the human brain or referring to the project as “building a safer driver for everyone” Waymo chooses to anthropomorphize their vehicle to avoid possible debate on e.g., the AI ethics of vehicle automation. Such avoidance of explaining which specific AI approach is adopted in their system is partially understandable as the Waymo Safety Report is mainly targeted at the press and potential customers. Nevertheless, by leaving out the discussion about core features of AI software that enables automated driving, Waymo chooses not to explain the functioning of a product which may have further consequences on their users. The problematic aspects of choosing not to cover AI topics are discussed in the next section (page 65). On the other hand, this strategy might be dictated by the fact that the current strong competition in the automotive industry does not encourage open access principles, as companies rather keep their industrial secrets.

What are the conclusions that could be drawn from the documents provided by Waymo? It is clear that their main goal is to make new ways of transportation safer and easier to use – not only for existing customers but also for new groups of people. As described earlier, their vision is rooted in the US market vision, where road safety and avoiding accidents is one of the strongest arguments that is supported by many actors and stakeholders. From the analysis of the rhetorical tactics used in

their report, while being rather technical, it does not offer explanations of technological solutions in detail. However, what might be considered as a positive theme for the report, is the fact that Waymo does notice the importance of the negotiation of the new user schemes to AV interfaces that would allow correct interaction between “riders” and technological artifacts.

### ***Benefits of Automated Mobility on Demand***

In this section I will look at research contributions dealing with different aspects of services advocating Automated Mobility on Demand which is considered to be a continuation of carsharing and ridesharing services enhanced with automated driving technology. The selected sources used in the following sections will serve as additional information providing a more precise and detailed perspective on the scenarios proposed by Daimler, Car2go, and Waymo. Compared with the finding of Benevolo et al. (2016), one may attempt to separate advertised promises from documented effect on society, if and when possible.

Introducing a fleet of Automated Vehicles in a service allowing carsharing is a key scenario developed by Car2go. Such scenario also aims at addressing limitations of traditional carsharing or ridesourcing, while integrating characteristics inherited from them. The Car2go scenario is expected to solve issues of e.g., safety by replacing human drivers with a supposedly flawless system that takes care of driving tasks, route planning, finding the best parking places, and by automatically and efficiently planning and finding the best times and places to charge the battery of electric vehicles. According to the research carried out by the Shared-Use Mobility Center (SUMC) there are many trends and use-cases for vehicle sharing. Depending on the size of the city and how well the public transport is developed it has the potential to make an impact on people’s choices of modes of transport: “the more modes people have access to, the more likely they are to sell or postpone purchasing a car” (SUMC 2016, 13). Benevolo et al. (2016), also supports this argument: “following the adoption of carsharing, one modal shift to other alternative modes of transport respect to the private car, such as walking or cycling” (ibid, 22). One of the clear trends in cities is that the number of traditional carshare<sup>16</sup> vehicles increases with city size but is also highly dependent on other modes of public transport (SUMC 2016, 16). On the other hand, one-way carsharing<sup>17</sup> which is a fairly new service, already indicates a better flexibility, being less dependent on other means of transport. What is even more important, one-way carsharing has shown

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16 Traditional carsharing requires customers to borrow and return vehicles at the same location. (SUMC 2016, 7)

17 One-way carsharing allows customers to pick up a vehicle at one location and leave it at another. (SUMC 2016, 7)

“significant presence” in car-dependent areas which shows huge potential in reducing household vehicle ownership.

It is important to make a clear distinction between documents such as white papers, produced by a given company and documented results implemented and evaluated by independent experts and by a large spectrum of users in the real world. In order to step out from the theoretical realm and test in real life situation specific solutions allowed by AV technology e.g., Automated Mobility on demand, independent research carried out by the Transportation Sustainability Research Center (TSRC) might provide some answers. In 2016, Innovative Mobility Research (IMR) which is a part of TSRC, has released the results of the survey on the “Impact of Car2go on vehicle ownership, modal shift, vehicle miles traveled, and greenhouse gas emission” (Martin and Shaheen 2016) in five cities in North America: Calgary, San Diego, Seattle, Vancouver, and Washington D.C. This research addresses one of the aspects of Smart Mobility, namely carsharing, and tests which expected benefits can be either confirmed or disapproved. As vehicles used by Car2go at that time (years 2014, 2015) were conventionally operated by human drivers, and not by using AV technology, the results of this research cannot be directly correlated with the benefits of Automated Mobility. However, there are several aspects that can be studied independently of the usage of AV technology, e.g., influence of carsharing concept to vehicle ownership and modal shift<sup>18</sup> should be analyzed closely as it is one of the recurring motives in Smart Mobility scenarios which may have direct impact on people in urban areas. The survey has gathered data directly from users of Car2go including data that could be collected from the vehicle's activity and from Car2go service. The data gathered has been processed to assess the impact of carsharing services on multiple layers which constitute an on demand service – user experience, actual traffic in given city, amount of vehicles on the streets and measured improvements in air quality.

The first section of the survey focused on the impact of Car2go on vehicle holdings. Results show that the carsharing service offered some of its users to sell their car or motivated them not to buy a car at all. By taking into account several factors applying to each city, such as vehicles sold, vehicles suppressed, the fleet size, users behavior it could be estimated that in total, due to Car2go service, the survey suggests that 28,155 vehicles have been removed from the roads of the five cities combined, which is a significant effect.

The second part of the survey takes into consideration the impact of Car2go on modal shift in mobility. Users were asked how their use of public transport has changed specifically to each mode

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18 Modal shift – the act of migration between modes of transport e.g., road, rail, air, water.

of transport – e.g., bus, urban rail, intercity rail as well as other means of transportation were considered e.g., walking, cycling, using taxi or ridesourcing services. One should notice that changes include the possibility of external modal shifts (between mobility modes) and internal shifts (inside one mode e.g., car and bike). Results show that the use of public transport has generally decreased among Car2go users with some minor exceptions. As for walking, in all cities except from Washington D.C, users have reported at least 20% increase in walking, which is a noticeable impact.

The next section of the survey analyzes evolution measured as Vehicle Miles Traveled (VMT). Depending on the scenario<sup>19</sup> chosen, the results show that between 21 to 37 million miles/year have been saved while using the 80% estimate, and from 6 to 12 million miles/year when using the more conservative 20% estimate. This translates to 34,000 - 57,000 saved miles/vehicle (80% estimate) and 12,000 - 19,000 saved miles/vehicle (20% estimate). Average VMT saved across all five cities per household was estimated to be 11%, which is also an important environmental benefit.

As stated in the conclusion of the research, one-way carsharing has a “notable impact on travel behavior, miles driven, GHG emissions, and the number of vehicles on the road within operating regions” (Martin and Shaheen 2016, 25). Outcome of this research gives clear indications that benefits of such services are visible across all the complex layers which constitute the urban space of transportation and when confronted with principles of Smart Mobility formulated by Benevolo et al. (2016), carsharing has the potential to achieve a strong impact to each of these layers. When enhanced with automated driving technology, additional gains in form of efficiency could be expected as well as challenges as for user experience and interaction with services providing AV fleets.

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<sup>19</sup> Scenario of an upper estimate meaning “annual mileage not driven on suppressed vehicles is 80% of the average annual miles driven on all personal vehicles held by respondents” (Martin and Shaheen 2016). The lower estimate is calculated to be 20% of these miles.



## Discussion

### ***Safety and ethics of Automated Vehicles enhanced with Artificial Intelligence***

Smart Mobility actions reviewed by Benevolo et al. and discussed above, as well as solutions suggested by Daimler and Waymo should not only be seen through the perspective of their primary goals, e.g., achieving general improvements in quality of life e.g., safety and efficiency. Once the scenarios have been successfully implemented in real life solutions e.g., in user interfaces and in observable real-time AV systems behavior, a critical discussion should deal with additional crucial themes such as the ethical, social, and cultural impact of the deconstruction of the conventional human driver and corresponding construction of the new users (riders) of Automated Vehicles. In a broader perspective the relationship between the emergence of a new automotive mobility and social organization requires further research.

A critical appraisal of the expected benefits of Automated Vehicles from the perspective of the ethics of technology, may be found in a study by Kalra and Groves (2017) who explore various solutions proposed by advocates of Automated Vehicles, e.g., issue of road safety, minimizing crashes and lowering road mortality rates. Most of all, this study tries to answer a crucial question: “How safe should highly Automated Vehicles (HAVs<sup>20</sup>) be before they are allowed on the roads for consumer use?” (ibid, 1). To provide answers, authors offer a brief overview of AV technologies and reflect on possibilities and concerns related to the challenges and uncertainties linked with AV technologies. While Automated Vehicles are promised to exceed human performance because of “better perception, decision making and execution of driving tasks” (ibid, 1) as machines in general have the ultimate advantage over humans (for some tasks) – they cannot be distracted, tired, or getting intoxicated, there are other factors in Automated Vehicles that may be questionable with regard to traffic safety, e.g., “inclement weather, complex driving environments, cyber attacks, hardware and software faults” mentioned in the research (ibid, 2). Such emerging new uncertainty factors in AV technologies have already been discussed briefly in previous sections of this thesis as they highlight social and legal expectations about the performance and AI-based human interaction as perhaps the most important challenge to the future development of a AV mobility.

As mentioned, conventional vehicles have now been on the market long enough and are subject to

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20 The research operates with a term Highly Automated Vehicles that while being consistent with the NHTSA standards, it is different from these presented by the SAE. HAV refers to Levels 3,4,5 Automated Vehicles that are capable of performing entire driving tasks

an increasingly reliable design process, e.g., testing of the overall safety of the vehicle itself and of the use situations. One of the main problems linked with achieving the same structure for AVs is that most of their performance is based on Machine Learning, a technology capable of improving its operation and extending its abilities, but still exhibiting a lot of grey zones, e.g., unexpected response and behavior. The problem with testing and improving AI related technologies used in AVs, is that they require much longer distance tests driven in real traffic, which is time consuming and already at testing stage, possibly ethically and legally challenging. Developing better testing opportunities such as accelerated testing on roads, more accurate simulations, and observation of behavioral system capabilities on closed test ground courses is prone to improve the processes of validating AVs (ibid, 3). In order to address the main question of proper timing e.g., “[When is it] safe to introduce Highly Automated Vehicles?” Kalra and Groves propose a model of Automated Vehicle Safety which “calculates and compares road fatalities” and considers two scenarios:

1. deploying HAVs when their safety performance is 10% better than average human driver (“*Improve10*”).
2. deploying HAVs in more distant future when their safety performance is 75% (“*Improve75*”) or 90% (“*Improve90*”) better than average human driver.

These two scenarios serve as a more realistic simulation of the implementability of AV technologies, and specify more precisely which concrete knowledge is required to answer the main question that should be considered by automotive industry: “[U]nder what conditions are more lives saved by each policy in the short term and the long term, and how much are those savings?” (ibid, 19). Additionally, the findings of the research should integrate social and ethical aspects of AV technology, and arguments provided by car makers should be reviewed critically. Issues of feasibility and reliability of automated technology using AI must be considered including additional human interaction factors that may influence the final outcome. It is important to remember that many conditions in the above-mentioned scenarios are “deeply uncertain” such as “[W]hen HAVs will be introduced to the marketplace, how quickly they will be adopted and diffused, how their safety performance will improve over time, and how the use and performance of non-HAVs will evolve” (ibid, 9). These conditions create a wide range of future possibilities that need to be taken into consideration.

According to the simulations carried out by Kalra and Groves, the results suggest that the *Improve10* scenario will be feasible in year 2020. Firstly, short term (15-year frame) results show that the “*Improve10* policy saves more lives than the other policies under nearly every combination

of conditions examined”<sup>21</sup> (ibid, 19). The main factor that produces the significant difference is linked with the rate of development, adoption, and diffusion as Kalra et al. remarks that the sooner HAVs will become common on roads, the more miles in the real world they are able to perform which leads to a higher rate of development. Cumulative life savings may reach 200,000 lives compared to the Improve75 and exceed this number when compared to the Improve90 scenario. Results of the second, long-term simulation (30-year frame) show that the “Improve10 policy saves more lives than the other policies under *every* combination of future adoption and performance conditions examined” (ibid, 26). Cumulative life savings may result in over 500,000 lives compared to the Improve75 policy and up to 700,000 lives when compared to the Improve90 policy. Savings in the second long term scenario are so significant because of the fact that the transition from 10% improvement in performance to 75% or 90% requires a higher number of miles driven in the real world which cannot be achieved in simulated surroundings.

However, to fully understand the results and the impact on mobility, it is important to consider the next question in the research, which addresses the pace of development after the deployment of HAVs and looks for “evidence suggesting that the conditions that lead to a small or no cost of waiting for HAVs that are much better than human drivers are more plausible than those that lead to higher cost” (ibid, 30). The main problem according to this study is that it is difficult to measure and evaluate the technology of current Automated Vehicles on the basis of performance compared to the average observed human driving behaviour. This may explain inconsistent results in real life situations, especially when such system must cooperate with or depend on inputs from human. This study refers also to sources from automobile and ICT industries claiming that “it will take many years of Machine Learning and many more miles than anyone has logged of both simulated and real world testing to achieve the perfection required for Level 5 autonomy” (ibid, 30 referring to Pratt, 2017), which could be supported by Goodall's article which also states that expectations of safety benefits of AVs may still be speculative: “an automated passenger vehicle would need to travel 1.1 million kilometers without crashing and 482 million kilometers without a fatal crash” to be considered safer than human driver (Goodall 2014, 6). It is worth noticing that the distance Waymo claims to have covered is over 8 million kilometers, however more specific data about incidents, interactions, crashes or how much of that distance was done in simulations is, as of writing, not known to the public.

As results of the simulations discussed by Kalra and Groves show, waiting for a “perfect” technology might be costly in terms of human lives. Steps that still need to be taken are to establish standards that would evaluate AVs and create a certain mark for performance that would allow them

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21 “95% compared with Improve75 policy and 97% compared with Improve90 policy” (Kalra et al. 2017)

to safely operate on the streets. A broad ethical debate is still necessary, as an early introduction of AVs has the potential of saving higher cumulative number of lives but, in spite of statistically positive benefits, still needs to incorporate additional ethical considerations. Introducing a technology performing slightly better than an average driver, introduces new risks to individuals and groups in direct contact with AV technologies as these may be sharing the same time and space in traffic situations. The question whether current social systems would accept exposing and sacrificing some of their members for the good of the future generations, could be considered. However finding the balance “between maximum personal freedom of choice in a general regime of development and the freedom of others and their safety” (BMVI 2017, 10) might be extremely difficult. Allowing conventional and fully Automated Vehicles into a real-world setting of hybrid traffic scenario would potentially result in creating a proving ground for a technology that is not considered to be fully safe – which, ultimately was one of the main arguments towards AV technology. As discussed in the ethics of technology section of the thesis, such decisions would be motivated by utilitarian approach which follows the principle to create the best possible results in the long term. Assuming that the primary goal of utilitarianism is to generate as much happiness, and save as many human lives as possible, following the Improve10 scenario would be highly consistent with this ethical vision and justified, but not from the position of non-utilitarian ethics. E.g., as discussed earlier, people do not want to put themselves into danger, but rather take the benefit from a certain event or technology. Additionally, one must consider important principles that are not emphasized in the utilitarian approach to real-life introduction of AVs, e.g., ethical positions which require to know *all* or *most* of the consequences of actions to be taken.

One conclusion that is clear at this point is the fact that solutions profitable for the automotive industry are not necessarily equally profitable for all its consumers. While creating innovation and introducing new technologies is required for any industry, it does not translate to the positive impact among the society. A scenario where only passengers of such vehicles benefit from advanced technology while other groups may suffer would be considered unethical, yet not impossible to imagine. The car industry, as other industries is a business relying on profits – those with the best financial resources will receive the best possible product and service. To simplify, the higher the price of a car, the safer the product will be, which also represents a situation on the car market present for years. To support that point, Robert, J. Sawyer, in an article “On Asimov's Three Laws of Robotics” has noticed a similar relationship between customers and producers across many fields:

The development of AI is a business, and businesses are notoriously uninterested in fundamental safeguards — especially philosophic ones. (A few quick examples: the tobacco industry, the automotive industry, the nuclear industry. Not one of these has said from the outset that fundamental safeguards are necessary, every one of them has resisted externally imposed safeguards, and none have accepted an absolute edict against ever causing harm to humans.) (Sawyer, 1991).

Fundamentally, one should raise issues which emphasize the ethical, cognitive, and social aspects of AV technology, e.g., to what degree would such scenarios with technological systems limit human freedom? Would scenarios proposed by Daimler and Waymo, which imply safety, efficiency, and comfort at the price of delegating control over our own actions and behavior constitute a reasonable arrangement? Less control and less freedom, replaced by the digital aspects of automation and virtualization of driver activities may have an enormous impact on how society treats individuals with their cognitive and physical abilities. Would processes of automation implying the removal of successive levels of human control and reducing the importance of a human role in general + be acceptable? Would the generalized introduction of AV technologies amount to society as we know it, where a theoretical privilege to move and decide freely is replaced either directly by the software embedded in a specific AV or indirectly by reducing individual to network element where safety and efficiency is the highest value? As the majority of companies that contribute to the creation of the new virtualized driver have taken the utilitarian stance, one must discuss the case of the individual rights that might be threatened. If the scenario proposed by Daimler, which suggests a total solution to mobility which includes handing over the power and ability to AI systems that will predict and decide what is the best for the users of traffic systems, rights of individuals may gradually lose its importance. In the report “Ethics Commission, Automated and Connected driving” experts stated that the “technological development obeys the principle of personal autonomy, which means that individuals enjoy freedom of action for which they themselves are responsible” (BMVI 2017, 10). In this case, one could notice a certain conflict between the ethical values proposed by independent organs such as Ethical Commission and industrial implementations of technology presented in their scenarios.

As an example, some elements of a larger scenario that is being advocated by Daimler, might indicate substantial changes to the way user's privacy is perceived. A situation when customers wish to fully participate in programs and services provided by a specific company, might result in a position where customers indirectly become victims of a constant need to improve efficiency, economy, and ecology of a system, which would require total transparency from its users. As explained earlier, car companies will become more data-oriented in a need of gathering and

predicting user patterns in order to suggest, or even attempt to alter user behavior. A scenario suggested by Bormann (2018), shows a future where one company might be able to be in a control of not only mobility solutions but also devices considered to be external to it e.g., car charger, smart home system, and power grid, all connected and available under the solution of a digital assistant or management system. Additionally, when related to a situation where users are asked to share all their use information to car insurance companies in an exchange for reduced rates, one may notice a progressing pattern among various stakeholders where privacy is being sacrificed for safety reasons. Similar processes and general direction of the discussion could be noticed regarding the future of the Internet. In reality, the majority of discussed processes could be defined as more aggressive commercialization where automotive industry, much like any other industry, tries to expand its field of operation when looking for further profits. According to the report “Monetizing car data” (2016) there are different potential categories of data generated by future mobility: e.g., exchanging of “live road conditions reports, predictive and remote service booking, trunk delivery/average load weight in the trunk or targeted advertisements” (Bertoncello et al. 2016, 16). Scenarios with companies providing total solutions might be advertised as more comfortable, intelligent, and efficient, however, for the possible exchange of users freedom and privacy. This might allow a situation where cyber security will require much more attention than before, and ensuring that all user data is safe from cyber theft or hacking will be crucial for gaining trust among customers.

Alex Roy, automotive journalist and a member of “2025AD Automated Driving Community” in his article “This is the Human Driving Manifesto” (2018) is raising a very valid point on keeping the AV technology safe while protecting privacy rights of its users. According to Roy, vehicles “must be capable of operating completely independent of any communications network” (Roy 2018) in order to be automatically anonymized by default. Manifesto presented by Roy presents a different approach to solving road safety issues of ethical nature such as freedom of choice: “technology that enables self-driving cars will allow humans to retain control *within* the safe confines of automation” (ibid). The point he makes is that people must be constantly reminded that companies who are controlling the mobility market are chasing the profit and it is not their duty to discuss or preserve social values. While often giving an illusion of doing that and creating a certain lifestyle or social mission behind their product, the industry is being controlled by its own internal values. Since Smart Mobility stakeholders mostly base their argumentation on safety and efficiency – where the “human error” is being highlighted across many documents, their image of a human driver is created to relieve people from the “tyranny and danger of human control” (ibid) or “enslavement of driving” (Krafcik 2018). By creating such interpretation of reality, scenarios imply that human by

driving on their own, equals to danger and is “in conflict with safety” (Roy 2018). However, while simulations may give an approximate image of the future, they may be quickly suppressed by the actual ability of Artificial Intelligence systems to produce expected results.

Roy continues discussing the main aspect of this problem, namely the ethical issue of freedom of choice. In Smart Mobility scenarios, the issue of Automated Vehicles is centered around the dilemma between safety and/or freedom. According to Roy, this choice should not be an issue in the first place, as it is artificially created by the industry to maintain the impression of demand and supply (ibid). There should not be a technology that creates a situation where people need to choose between being “Pro-Human or Pro-Technology” as stated in Roy's article. It should be possible to be both at the same time, and technology should enable both features: “Pro-Choice in how people get from A to B, Pro-Life in the deployment of safety technologies that both save lives and preserve freedom, without which there is no quality of life” (ibid). Roy states that the argument of potential benefits is defended on a wrong basis as the “banner of 'safety' may fly on the flagpole of autonomy, but it is raised by the hands of profit” (ibid). Smart Mobility stakeholders supported by political groups attempt to define and create how the driver reality may look like in the future. When reading the SAE J3016 standard, (discussed on page 15) it is clear that the aspect of human freedom is completely ignored – according to the SAE document, humans have reached their limits and “have nothing to add to the safety equation” (ibid). However, the safety itself is difficult to define and it is impossible to establish how inherently safe a specific Automated Vehicle is. While the industry has come up with standards and tests that would determine passive and active safety of conventional vehicles (such as airbags or anti-lock brakes), similar standards are not ready for AVs. As Kalra and Groves have commented, “there isn't an accepted method for gauging whether a car is nearly perfect or safer than a human driver” (Kalra and Groves 2017). In scenarios presented by automotive industry Roy defines vehicle automation as Series Automation – one that “temporarily substitutes for humans without any demonstrable safety benefit and *almost certainly reduces safety over time*” (Roy 2018). Claims made by Waymo in their safety report as they were building “safer” and “world's most experienced driver” should be supported by legally approved tests and standards, which do not exist yet. At this point those claims are nothing else but advertising promises that are not rooted in reality.

Roy supports the argument of deploying “partial automation” which “augments our abilities while protecting our freedoms” (ibid). According to the author, instead of waiting for the perfect Automated Vehicle which requires a number of many elements to perfectly line up, the better solution would be to let the vehicles improve human driving. Instead of removing the human driver, Roy argues for vehicles that would not let people crash – a solution that would require a slightly

different approach from automotive industry. Rules presented in the “The Human Driving Manifesto” by Roy are supposed to protect humans but are not against the technology itself: “we are Pro-Technology, but only as a means, not an end” (ibid) which is a valid point when discussing the philosophy of technology, as originally formulated by Heidegger in his work “The Question Concerning Technology” (1977). In order to relate Heidegger's view on technology to the above discussion about Automated Vehicles, one must understand the clear distinction between means, ends, the act of instrumentation, and causality. Assuming that a given technology is a means to a human end, a technology can be defined from an instrumental and anthropological point of view. When faced with a possibility of a technology of Automated Vehicles, whose operational efficiency is strongly depending on Artificial Intelligence, one must consider whether the roles that were clearly established until now, will possibly change with a negative outcome for the society. Visions of technology presented in the above analyzed scenarios from Daimler and Waymo may privilege a technocentric approach, and even presuppose that AI technologies, through Human-Computer Interaction may influence human behavior in a precisely planned unidirectional manner. Such technocentric scenario would imply that humans become 'the instruments' while technological progress becomes an end in its own. Society being controlled and instrumented towards a certain behavior would result in humans treated as means (in Heideggerian terms, 'standing reserves') in order to achieve a certain goal. Once again, such scenario may be interpreted as essentially utilitarian as it implies and possibly accepts some level of exploitation of individuals to be justified as necessary way to produce more benefits for more people. In order to prevent a utilitarian dystopia, the following rule has been formulated by the Ethics Commission on Automated Driving which states: “The protection of individuals takes precedence over all other utilitarian considerations” implying that licensing of AVs must be justified with a positive outcome of the balance of risks (BMVI 2017, 10). While such rules and regulations are absolutely necessary to safe implementation they are not expected to be respected by all car manufacturers as they are not standardized across Smart Mobility landscape.

Waymo claims that their “self-driving technology” is meant to be “inclusive”, that is, allowing people with different abilities to move around. However, such inclusiveness depends on how the technology is being used – if scenarios presented by the industry become a reality, some groups might gain increased and beneficial mobility while some groups might lose the actual right to exercise their freedom, e.g., by making human driving an undesirable activity for safety or financial reasons, e.g., by introducing “AV-zones only”. Roy is clearly representing car enthusiasts, a group of people who enjoy driving on their own, but not being driven or transported. While the invention



of automated cars might not directly affect car enthusiasts, it may potentially push the boundaries of how far technology would be allowed to interfere with human behavior. The Ethical Commission, concerned with this issues, suggests that one should not expect or force individuals to a point of “degrading the subject to a mere network element” as it is “ethically questionable” even if “it can unlock existing potential for damage limitation” (BMVI 2017, 11). One can only assume that commission's work will create a basis for further development of Automated Vehicles, and approved equally as other standards e.g., these proposed by SAE.

### ***Cognitive implications of Smart Mobility scenarios***

Companies in their utopian presentations claim that anything but positive outcome of AV technology is possible where humans easily adapt and understand these technologies. In reality, people often misunderstand and misuse technologies to their own benefit and against original creators' plans. Smart Mobility stakeholders often mention profits that are a direct result of anticipating the potential of Artificial Intelligence. Exemplified by recurring patterns of technological determinism at distance (delegated determinism) scenarios produced by Daimler and Waymo use rhetorical methods to convince that proposed AV technologies incorporate a specific technical configuration carrying the potential to solve some societal issues (e.g., accidents caused by human error) by planting the intention among the society to change their behavior. In that case, one should analyze the cognitive processes that might be influenced by such systems. As briefly pointed out in the theoretical section (page 12), further perspectives of Interaction Design and theories of technology will be considered.

First of all, it is important to recognize risks connected to traveling – over the course of many years, the human brain has managed to learn to see and evaluate the risk, first while on foot, then by riding horses and more recently using motor vehicles such as cars, planes and motorcycles. The speed of traveling is constantly rising and due to that it is pushing the limits of human brain perception and reaction times – which at some point has been supplemented by assisting and automation technology. However, automation technologies need to predict and react to an environment that is often unpredictable, e.g., in scenarios where Automated Vehicles operate together with conventional drivers on open roads, AV needs to exceed capabilities of human brain and evaluate many risks simultaneously.

In such case where Artificial Intelligence ambitions to process ethical and cognitive decisions, human interaction with such system is confronted with additional layers of complexity, where aspects of cooperation, understanding and providing correct inputs can be found problematic. Reflective

cognitive processes such as problem solving, planning, reasoning and decision making that will be required by potential users of AVs will be renegotiated as a transition from the solutions provided by conventional vehicles to the ones suggested by Smart Mobility scenarios, will require developing completely new mediating schemes. When interacting with a conventional vehicle, a driver was required to perform a wide range of activities with the vehicle before and during the trip. Many of these activities were the result of conscious processes e.g., planning the route, while some of them barely required user's awareness e.g., closing a door. The majority of the activities in a conventional vehicle require an interaction with physical artifacts, which contributes to the development of mental models, used by people to “reason about a system and, in particular, to try to fathom out what to do when something unexpected happens with the system or when encountering unfamiliar systems” (Preece et al. 2015, 86). Mental models of how to drive conventional vehicles have been under development for a long period of time and could be considered nearly common knowledge, whereas knowing how the vehicle works is limited only to mechanics and car enthusiasts. By contrast, when interacting with an Automated Vehicle, people lack the same level of interaction as number of previously existing activities have either disappeared, has been automatized, or reduced to a display or voice control interface. However, in order to create a complete and functional mental model which would allow appropriately safe and efficient interaction between users and vehicles, manufacturers should consider creating a system that allows users to be at least accustomed to and educated about the processes taking place behind the automated driving. A majority of discussed car producers have chosen the “less is more” approach in order to avoid information overload. However, this restrictiveness may lead to confusion since the decision to remove as much information flow as possible, may prevent the 'instrumental genesis' and mental scheme creation from a proper communication with a system. The cabin of Smart Vision EQ Fortwo vehicles are equipped with a display that shows crucial information about the trip e.g., route, destination, speed, but may also function as a screen for social media or entertainment. As stated by Smart: “the vehicle functions are controlled via personal mobile device or voice input, an arrangement that is intuitive, convenient and hygienic” (Smart, 2017). However, this solution does not provide any information about how the vehicle actually works, what is going to happen, and which calculations are being carried at the moment. This may lead to a situation where mental models of users may be incomplete, with low-risk awareness and based on “inappropriate analogies and superstition” (Preece et al. 2015, 87). Preece et al. suggests a more transparent approach to designing the interactive technologies which would allow users to be more efficient and react better if a system started malfunctioning (ibid, 87). One of the conditions for creating a transparent system would be to provide a “useful feedback in response to user input” (ibid, 87) which is mostly practiced across

the discussed mobility scenarios considering passengers and even pedestrians. A Smart Vision EQ Fortwo will inform users whether it is available or busy, or it is safe to cross the road in front of the vehicle. However, additional feedback which could be considered as driver-oriented is not provided, an approach which could be justified with the fact that a human driver, in a strict sense, is no longer present in the vehicle – only a 'rider' or a 'user' is present. Nevertheless, some companies e.g., Waymo, have chosen to create an extended user experience by adding screens in their vehicles that apart from providing instructions, will also show a visualization of its surroundings, including nearby road users, lanes, and crosswalks (see Illustration 5). Additionally such displays will also show information which is meant to explain the vehicles 'intentions', e.g., stopping for pedestrians or searching for a safe place to let passengers out. By providing such extra information, Waymo hopes to minimize the risk of misunderstandings and makes it easier to evolve a better mental models for users, as well as to encourage them to rely on the technology acknowledging that “even though people aren’t driving, a sense of control is critical to help people trust the technology” (Rothenberg 2017). Finding the optimal balance between full system transparency and full system dissimulation in order to provide sufficient amount of information would need to be defined differently across various Smart Mobility scenarios and situations.

Another cognition model that should be considered is the approach of distributed cognition which “studies the nature of cognitive phenomena across individuals, artifacts, and internal and external representations” (Preece et al. 2015, 91). This approach, in contrary to a mental model which focuses on individual's thoughts and processes, opens for a wider range of activities across the system which is the case of Automated Vehicles in real life situations. The main ambition of the distributed cognition approach is to study “how information is represented and re-represented as it moves across individuals and through an array of artifacts” (ibid, 91) which could be exemplified by any driving scenario. When driving a conventional vehicle driver must provide inputs that are mostly physical which also return a physical feedback, in that way by distributing the processes through different artifacts, a driver controls a vehicle and gets an idea (representation) of car parameters and road conditions. Additionally, the processes of externalized cognition could be observed when interacting with a vehicle as a driver – any artifact that reduces the amount of work load e.g., automatic wipers, fuel range indicator or blind spot alert system, relieves the driver from cognitive activities and processes that the person would otherwise have to perform individually.

In the automated driving scenarios proposed by Smart and Waymo, users are required to use their own smartphone or communicate through a voice control in order to e.g., fetch a vehicle, initiate a

trip, or enter a destination. By providing minimal inputs that could be defined as a combination of a driver and passenger, whole sets of processes are being externalized to corresponding artifacts, which do not return the equally sufficient information about the representations, back to the passengers. Such scenario might lead to a cognitive dissonance of AV users, especially for those who have pre-existing knowledge and experience with conventional vehicles. Whole cognitive framework produced by the activity of driving might become incorrect and outdated, and changing it depends on many factors. While discussing the learning processes on the individual level, one should discuss the Activity Theory (AT) framework, briefly introduced in the theoretical section of the thesis. The AT model consists of three levels of behavior which require different level of conscious attention – *operation* (little conscious attention), *action* (some conscious planning), and *activity* (requiring meaningful conscious context). “Activities can be identified on the basis of the motives that elicit them, actions on the basis of conscious goals that guide them, and operations by the conditions necessary to attain the goals” (ibid, 311). All levels have an “intimate and fluid” relationship between each other and once one element is changed the whole model is likely to be reconstructed. When reflected to the automated driving scenario, most of the components will be potentially modified, where relation between the operation, action, and activity will be completely transformed. Main concern when introducing a new technology is the time span and actual ability of users to make adjustments and obtain new, complete models which would allow them correct and safe use of any artifact.

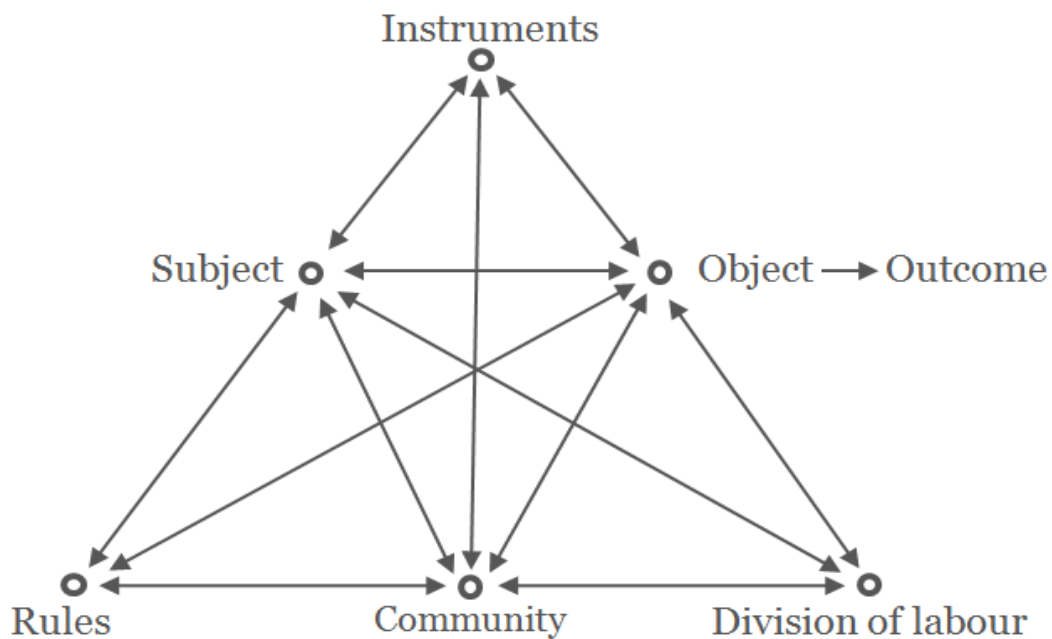
Ultimately, when adopting the cognitive perspective on interfaces and automation, it appears that the automated driving scenario exhibits many common characteristics with aviation and cockpit automation – a field with much longer experience and history of testing and simulation. Flying a plane creates a complicated mental and conceptual models where additional elements are added to the operation and interaction with the machine. Mentioned advantages of cockpit automation are similar to the ones proposed by Smart Mobility stakeholders, e.g., increased comfort and efficiency, relieving pilots from repetitive or non-rewarding tasks, and reducing workload (Skybrary 2018). On the other hand, while the active involvement decreases, pilots must engage in the monitoring state and become a supervisor, an activity that humans struggle to uphold for longer periods of time. The solution suggested by current AV technologies with vehicles with no driver instruments operating with SAE Level 5 could be considered engineering shortcut. A design that would neither require nor allow human attention and intervention, if not handled correctly might have negative results. The reason why aircrafts still need a complete crew in the cockpit is that technologies of automation are designed to work under predictable circumstances and that the task of a human pilot is to react

creatively to solve the problem that nobody has foreseen - in real time. In order to do so, the pilots need to have the access to all the instruments at all time, so that when in case of a system failure they can quickly respond to the problem, reclaim the control over the plane and focus on the primary goal which is to fly the plane. Some recent plane crashes had been attributed to a cognitive conflict between the pilot's mental model and the information displayed by onboard instruments.

As discussed earlier, and described by Google as “handoff problem” users of AVs become easily distracted and their reaction times when transitioning from a passenger to a driver state may be unacceptable from the point of view of safety. Removing all driver instruments from AV would deny any kind of user control over the vehicle and only allows exception handling using the metaphor of an “emergency button” or by take contact, if time and circumstances allow, with consultants. Such “emergency button” approach cannot be considered to be a sufficient replacement for a conventional driver instrument layout, unless car manufacturers can ensure that a vehicle is capable of entering into a safe condition without human assistance (BMVI 2017, 10). However, a simple example by Goodall might illustrate some issues connected to full automation: a situation when an Automated Vehicle approaches a tree branch lying in the middle of the road – what should be car's “reaction” to such scenario? According to the law, the vehicle is not allowed to cross the double lane in the middle of the road and while a conventional driver would evade the obstacle when it was safe, the Automated Vehicle would need some sort of additional confirmation that an unexpected situation can be solved by “breaking” the law. A scenario that would include a SAE Level 5 vehicle with no traditional “driver-interface” could be rather problematic unless it would already have a built-in database of such obstacles together with a set of rules and exceptions what to do in such situation. This kind of backup system would have to expect the unexpected – a condition unattainable for automated systems, however not impossible for automated systems enhanced with Artificial Intelligence using Machine Learning. Additionally, one must remember that the amount of education and training which is required from aircraft pilots is much more extensive than the one expected from those who apply for a driving license. Solutions described in the Skybrary report (2018) suggest mainly that further training to improve the understanding of automation systems may help. However, while education and developing driving skills may have positive results, recreating the same training structures into automated driving scenario is unlikely to happen as it would be too costly and time consuming.

While previous section covered the underlying cognitive processes on the individual level, I will continue with the part of the framework of Activity Theory which offers an extended theoretical

scope including the “issues of motivation, meanings, culture, and social interactions” (Kaptelinin 2012), an approach widely adopted in the Human-Computer Interaction field. Activity Theory (AT) – inspired HCI theory could be considered as post-cognitivist, as it emphasizes the fact that the way individuals use technology creates a more complex and dynamic context e.g., “networks of interrelated activities – forming an activity system” (Preece et al. 2015, 312). An extended model of Activity Theory proposed by Engeström (1999) may be helpful when analyzing the tensions and possible transformations inside the automated driving scenario (see Illustration 6). Following Rabardel's model of mediated activity, tools and instruments that have been present in car interiors for years, have been a part of an instrumental scheme for understanding and controlling the tasks of e.g., driving. This scheme-based field of activity has been shaping not only the driver's immediate surroundings e.g., the cabin and the dashboard inside the car, but also how drivers generally have behaved and reacted to the world outside of the vehicle. The variety of car companies have produced different vehicles aiming at different groups, where users generally expected better use values of the product with every new generation. For many drivers and passengers, well-designed vehicles are synonymous with precise and accurate steering and responsive braking, that is a human-machine system that feeds the driver with correct information so that he or she can make correct decisions. Good cooperation and interaction between vehicle and the driver allows better control of the vehicle – safer and more pleasant experience to both driver and passenger but also any road user nearby.



*Illustration 6: Engeström's Activity Theory model.*

A simple model of AT originally proposed by Russian psychologists did not stress as much the collective values of performing an activity as Engeström's model does. Additionally, the original AT model was not sufficiently applicable to mapping how people use interactive technologies e.g., computers which is "typically not an object of activity but rather a mediating artifact" (Kaptelinin 2012). In that sense, people "are not interacting *with* computers: they interact with the world *through* computers" (ibid). When reflected to the notion and the role of the driver, Smart Mobility stakeholders have the potential to transform that complex relation between different elements of driving activity by adding automated technology through Artificial Intelligence implementation. Considering each element e.g., rules of driving activity (legal and social constraints), community (interaction with the new technology, issues of acceptance and possibility of divided user groups to conventional and AV users), mediating artifact/instrument (substantially renegotiated in Smart Mobility scenarios), all these processes of transformation will contribute to the new outcome, reshaping the system of activities related to the vehicle, not only driving itself but traveling, being a passenger, sharing a car, commuting, picking up a date, or going on a family road trip.

These activities constitute what is considered to be a construction of a subject who holds a role of a driver. In scenarios proposed by Smart Mobility stakeholders such as Waymo or Uber, in order to achieve certain efficiency and safety goals, processes of dematerialization could be seen at two different levels: product dematerialization/virtualization and activity dematerialization (detaching activity from physical action). As revealed in Daimler's report, ownership of the vehicle will lose its importance and the product itself will be potentially replaced by a service – a process already visible in carsharing or ridehailing models. The process of dematerialization on the activity level has been gradually evolving as the requirements of human involvement to control a vehicle have been constantly reduced. When reaching a certain point and when enabled by AI technologies, the 'driving activity' might be not only completely dematerialized but heavily virtualized as well. If Machine Learning algorithms reach acceptable performance levels, as foreseen by Smart Mobility scenarios, Automated Vehicles are expected to constitute better, safer substitute for human drivers. A virtual simulation generated by AI is expected to produce a driving behavior which aims at replacing a conventional, human driver. As the majority of scenarios rely heavily on the potential of AI technologies as the primary solution to all vehicle automation challenges, one should discuss a wide range of possibilities and outcomes generated by human interaction with a AI-driven AV systems. A framework provided by the Human Information Interaction (HII) (Russel et al. 2016) might be useful as it studies how, and why users find, consume and use information in order to solve problems, which is the case when interacting with the AI. As discussed earlier, AI techniques could be defined as proxies for humans and in automated driving scenarios should focus on the

elements that would improve the performance of human interaction with such system e.g., information representation or knowledge management, especially when systems are requested to execute gradually more complex tasks in the process of simulating humans. Especially Machine Learning (e.g., currently Deep Learning algorithms) is being promoted as a powerful method of AI implementation of human learning, reasoning and adapting to information in order to perform human-like tasks (Russel et al. 2016, 36). Seen from the HII perspective, humans enter in a recursive HII loop where “AI interacts with information and humans interact with AI, which is itself information” (ibid, 36). If the AI implementation proceeds as designed it is supposed to provide a seamless interaction between humans and the rest of the world while executing humans intentions. However, as AI is instrumented to delegate information between humans and the real world, while the amount of information-based interaction is increasing, such solution can potentially result in higher number of errors and misunderstandings between human and technology. As noticed earlier, goals of automation are efficiency and reliability which also often require controlled environment and “explicit structuring of such environment” (ibid, 36). In any driving scenario, where parts of the environment are restricted by traffic rules, the number of unpredictable events that Artificial Intelligence will have to compute will be transferred to increased amount of new information it will be required to process and channel to users. If completely autonomous systems were possible, this process would have been simplified as human interaction could be completely excluded from the information loop. In a case of ideally controlled environments uninfluenced by humans, systems would be able to perform uninterrupted by humans, thus performing autonomously. Assumptions that the Smart Mobility is going to design a total solution which entirely removes human from the system, may not be achievable as “humans are never completely removed from AI-enhanced automated processes” (ibid, 37).

Goodall (2014) decided to focus on a core scenario that is the most known and widely advocated by the car industry itself, namely that Automated Vehicles will never crash by definition. Even with perfectly controlled vehicles and environment there are still many situations that would allow accidents or collisions. Such approach is already reflected in the previously mentioned statement from Tesla (2018) (see discussion on page 26). Goodall presents three scenarios where Automated Vehicles could be operating: “(1) *imperfect systems*, (2) *perfect systems with mixed human-driven traffic* and (3) *perfect systems without human-driven traffic*” (ibid, 2). *Imperfect systems* could mean everything from software to hardware failures leading to miscalculations and accidents. When dealing with *perfect systems* and human-driven traffic, Automated Vehicles would have to deal with many unpredictable situations that somehow had to be modeled, calculated and evaluated in real time. While many conventional vehicles are capable of doing these things at the current state of



technology, it is impossible to completely eliminate the risk of collision when dealing with unpredictable situations. In order to predict and react to any threat on the road, automated vehicle would have to “overreact” to many road situations, which would eventually create a larger threat to the rest of the traffic e.g., pedestrians or vehicles operated by humans who lack the same reaction times and abilities. Sudden braking and swerving would impose more dangerous situations to outside environment than benefits. The last scenario is the least likely to happen in the near future, where Automated Vehicles become autonomous – allegedly *perfect system* without human-driven traffic intervention is prone to deal with situations that still confront human to many dangers created by other road participants, e.g., pedestrians, cyclists or even wildlife. While technological advancement is capable of calculating and predicting the speed of surrounding vehicles, reading road signs and anticipating the behavior of other vehicles, a truly autonomous system that includes all vehicles governing themselves would be a much better option. In that case vehicles could communicate with each other creating a vehicle-to-vehicle safety net in urban areas. However, such scenario depends on enormous financial and infrastructure investment from many stakeholders who may wish to create smart infrastructure and build a Smart City that would allow autonomous systems. This means that humans and AV technologies may depend on each other creating a network of interactions that may potentially result in unpredictable outcome. Such scenario presupposes the issue of responsibility – for as long as humans are influencing the performance of the system, the ultimate responsibility relies on the human side. Additionally, such responsibility could be characterized at two levels – firstly, users' intentions and awareness about functionality and purpose of the technology should be clear, and secondly, the obligation to design technology which ensures clear and safe interaction with humans. Creating and improving interfaces that would allow appropriate interactions between automated systems and its users should become a primary goal for any company that considers development of Smart Mobility products. However, sources analyzed in this thesis suggest that current industrial approaches to designing and implementing AV-based mobility scenarios strongly relies on over-estimated predictions and partially unrealistic expectations about the power of e.g., AI technologies, while failing to foster user-centered experience e.g., focusing on delivering instructions and seamless interaction.

When considered from the perspective of the theoretical SCOT framework, (discussed on page 15), majority of analyzed mobility scenarios suggest a rather reduced model of technological development which fails to consider several social and cognitive aspects of artifact evolution. Historically, in order to satisfy different social groups, car companies have been expanding their offer by producing different artifact configurations resulting in a variety of car models. Each social group creates a relation with different artifacts in form of perceived problems and possible solutions

to them (Bijker, Pinch, 1987, 36). However, Smart Mobility scenarios suggest that this time, one overarching mobility scenario should address the needs and aspirations of various social groups. Since drivers as a social group are not mentioned in these scenarios, problems and expectations of such group are not considered. By providing a virtualized version of a driver, the human as a driver is clearly, not a central point of design for Smart Mobility stakeholders. The following design choices that were taken as a consequence of that approach, result in a technology that does not pay attention to any of driver's needs, expectations, or emotions, by combining them with other social groups.

In this regard, does any of Smart Mobility scenarios convey the historical values of the 'human driver', from the perspective presented by Bourdieu (see above page 22)? Such values, defined as a set of various dispositions that create a system of “emotional, cognitive and bodily dimensions” characteristic of the historical human driver may no longer have relevance in the emerging context of automated driving scenarios. Once the driver environment becomes less material and once the activity of driving becomes simulated and operated by AI-based systems, one may ask, how such changes will affect users of traffic systems a larger scale? The impact of changing landscape of automotive industry could be analyzed from the perspective of Bourdieu's theory of practice, e.g., the concept of “hysteresis effect”, briefly introduced in the theoretical section. One must remember that the concept of *habitus* is supposed to operate below the level of consciousness and that “change in the habitus in a period of transition is not a reflexive process” (Kerr and Robinson 2009, 830). Considering the emotional and bodily dimensions that are part of the old habitus, these dimensions cannot be directly transferred into new scenarios involving a combination of AV and Smart Mobility. The potential impact of the new technological configurations suggested by e.g., Waymo, Daimler, or VW, will spread to any user of a traffic system who may not necessarily experience a conscious relation to the habitus involved by conventional vehicle scenarios. In that case, while the majority of these habitus-related elements are replaced with new sets of configurations applying to the use of Automated Vehicles, acquired dispositions may no longer be applicable. All social groups e.g., drivers, pedestrians, cyclists may need to reevaluate and possibly forget their previous practices due to the new, “changed context and function” (ibid, 840). Individuals who may be affected and experience mismatching habitus imposed by the new order of mobility are those car enthusiasts and professional drivers who earn their living by driving. People who strongly identify as drivers may have to deal with technological changes on both conscious and unconscious levels in order to evolve new practices and dispositions that would match with the new scenario. Additionally, the tension between “subjective nature of individual responses” and the “objective nature of workplace change” may explain some of the difficulties created by the new AV

technological solutions (McDonough and Polzer 2012, 362). Assuming that the technology of Automated Vehicles becomes fully commercialized and replaces conventional taxis, garbage trucks, and delivery vans, people connected to the workplace that concentrates on the activity of driving will be, according to the hysteresis “unable to recognize the value of new positions” (ibid, 362). As the technology of automation focuses on reducing the human involvement in the system, according to AV scenarios, one should notice a decreasing demand for human workforce in certain areas of transportation. Similarly to the field of commercial aviation, where the pilot crew has been, in many cases reduced from three to two pilots (a trend that suggests a further reduction to only one pilot) one may expect changes to the workplace of e.g., truck drivers. Solutions such as truck platooning allow for connected highway driving where the first truck leads other trucks behind it, forming a convoy. The system will automatically detect highway junctions, obstacles, or interference from other vehicles and will adjust accordingly. While such technology is available today, it is not impossible to imagine that in the future only one driver would be required in the leading truck. In a situation where several trucks are heading to the same destination, drivers in following trucks would be no longer required. In a recent statement, Waymo has revealed their plans on developing “autonomous semi-trucks”, which would be aimed at fixing the shortage of truck drivers in the US<sup>22</sup>. Technology of Automated Vehicles, if developed successfully, has the potential to disrupt many jobs that are gathered under the profession of a driver. This may lead to further organizational changes of a workplace where a number of people required to do the same amount of work may be reduced, and people will respond more to intelligent automated systems instead of interacting with each other. Professions of e.g., dustman, taxi driver or delivery man, require both social skills and physical sacrifices which might disappear and lead to “loss of personal recognition and social belonging” and relate to “loss of pride in their work” (ibid, 367). Neither Daimler or Waymo address these issues directly in reviewed publication. However, the idea of habitus is strongly connected to the set of interests, opinions and behaviors considered as lifestyle.

Habitus is both individual and collective, which means it can generate and unify collective practices, [lifestyle] can be understood as a product of the habitus historically constructed by the experiences that are 'unconsciously' modeled and incorporated from the social relations that make up living conditions and the position of the agents” (Wacquant, 2002)

In that case, since selected materials are mostly produced for marketing purposes, they tend to operate with urban, active, social lifestyles of their customers. Daimler, in a clearly marketing

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<sup>22</sup> According to John Krafcik, CEO of Waymo, the logistic sector is short of 50 thousand truck drivers, a trend which may grow to 175 thousand in 2023-2024.

manner decides to show and convince certain social groups e.g., politicians, journalists, city planners, and potential customers about their technological abilities. By doing so, Daimler creates its own “industrial” version of Smart Mobility that would operate inside the Smart City. This version, showing a scenario which includes a specific lifestyle displaying that Smart Vision EQ Fortwo is a platform for the technology of Automated Vehicles. Daimler is fully aware that cars, similarly to e.g., clothes and mobile phones are a part of what defines people's lifestyle. By introducing these elements of cultural value, it creates its own lifestyle inside of automated driving scenario. In materials produced by Daimler, the context is shaped around people who live and work in urban areas, who wish to be effective and efficient both at work and during their free time – made possible by e.g., algorithms that predict work hours and send a vehicle to collect them at right moment. Values that play a significant role in Smart Vision EQ Fortwo are technological innovation and solutions that would enhance comfort and efficiency of traveling while being aesthetically attractive.

When expanded with additional sources from Daimler group, it becomes clear that the approach taken by a company focuses on creating a new lifestyle where many aspects of everyday life will be determined by technology. Surrounded by additional infrastructure of e.g., charging stations at work, solar panels at home, digital (and personal) assistants powered by Artificial Intelligence making the best possible suggestions and adjustments to the system, and finally the driving system itself which will be a virtual substitute for a human driver – all these elements constitute a mobility scenario by Daimler. In that case, such complex approach that takes into account so many factors of human life becomes more invasive, even disruptive.

The lifestyle created in the scenario by Waymo could be characterized as more family-friendly, where the type of the vehicle that can seat up to 7 passengers is not a coincidence. In analyzed materials Waymo focuses on other aspects than Daimler and tries to create an impression that their product will be safe and convenient, by making traveling easier by extending the target groups to “underserved communities” that were not considered by car companies before e.g., elderly, children, people with disabilities. In materials from their Early Rider Program, which allowed children or retired people to get access and give feedback about AV technology, one can see that passengers gained confidence and were able to relax during trips. Waymo claims that personal car ownership is not their primary goal at the moment and their AV will make bigger impact, creating larger safety net when shared with others. According to Krafcik, automobiles are historically associated with personal freedom and the skepticism towards the AVs is related to the “consumption biased need” (Krafcik, 2018). Through the AV technology, Waymo offers time and “productivity

benefit” which really depends on how people really decide to use the technology for their benefit. Additionally, Waymo has taken the route of adaptation to existing infrastructure – there is no sign of additional plans to their project that would suggest expansion outside of the AV technology. Waymo focuses on solutions that could be applied to any traffic system, and be rather limited by own operational domain.

## **Results and Conclusion**

### ***Summary of Findings***

The theme of my thesis was to focus on the idea of vehicle automation and technologies enabling the implementation of it e.g., Artificial Intelligence. In order to specify this theme and relate it to the Digital Culture, the work aimed at exploring and analyzing the scenarios produced by both Smart Mobility and automotive industry. In that way, I could focus on the possible impact on the users and interactions in the new mobility scenarios that emphasize automated technologies enhanced with AI. Findings suggest that the realization of various mobility scenarios may lead to further effects on the society, often more extensive and unexpected than those scenarios may imply.

The development and the future of transportation sector highly depends on legal and ethical debate which is mostly fueled by the arguments of e.g., improved safety and efficiency by personalized management of time and space, extending mobility groups or reduction of fuel emissions. The wide range of the expected benefits expressed in Smart Mobility scenarios will possibly translate to even more widespread and complex consequences to the users of systems that are based on the technology of automated driving.

The technology of automation, enhanced by Machine Learning and implemented in the core system of Automated Vehicles, is essentially a processes of dematerialization, virtualization and corresponding digitization that will release a series of challenges affecting the sociological, ethical, technological, physical, and cognitive domains of human lives that are far beyond the control of automotive industry. Projects analyzed in the Case study section of the thesis, e.g., Smart Visions EQ Fortwo by Daimler, Waymo, Sedic by Volkswagen suggest that, by employing vehicle automation, tasks of the human driver will be gradually replaced, until fully removed and virtualized by the system of automated driving. Such scenario will lead to the situation where any user of current traffic system will have to adapt their behavior to the new artifacts and technological configurations. However, the most significant adjustment will rely on the experience of social

groups of historical drivers who will need to reevaluate and renegotiate their actions and mobility-related mental models. Such adaptation may involve stretch from the lowest, unconscious level of habitus which defines people's actions and forms their identity to the higher level of conscious social construction of how people interact with each other and technology e.g., reconfiguration of urban lifestyle made possible by new opportunities of automobilized time-space.

In that case, discussed frameworks of human interaction with systems, machines and computers are helpful as they provide theoretical application frame of reference for analyzing and assessing what constitutes mobility-related human activity and may help one understand better interplay between human and mobility AI-enhanced interfaces. From a socio-constructivist perspective of technological development and artifact creation, it is not possible to predict and explain beforehand to what extent the effects the expected effects of vehicle automation will happen. If these specific AV technologies are to be broadly implemented in the versions discussed in this thesis, the social response and pattern of adoption remains uncertain, as the introduction of *any* technology may lead to different and unforeseen solutions and configurations. Such individual and collective user response may depend on the actual benefits and challenges that will be met by users of the future AV. At this moment, negative reactions to AVs are mostly dictated by the perceived challenges to society's ethical fundamental and individual/social perception of lifestyle. People's reluctance towards new technology could be linked with their own representation of comfort, freedom, and control, indicating that solutions suggested by Smart Mobility may not always satisfy their expectations. Social perception of any technology plays a significant role as people that interact with new technology activate pre-existing assumptions and expectations. Some of those will need to be reconstructed e.g., physical and cognitive behavior of human driver, while some may be created on false basis e.g., issues of ethical responsibility exemplified by the trolley problem that should not occur. vehicle automation has the potential to confront the users of automotive industry with completely new social and ethical challenges, expected from any technological change taking place, involving e.g., massive digitization, real-time sensing, automated decision-making, reconfiguration of personal privacy, generalization of surveillance and data protection. Additionally, increasing ethical and political objections to situations where people may be forced to interact with some form of intelligent agents may arise.

Since vehicle automation is expected to allow the development of largely profitable business models e.g., autonomous mobility on demand, the pressure created by citizens and mobility stakeholders on the authorities as for e.g., evolving fair and equal rules for human and virtual drivers, establishing international standards, and in some cases allowing necessary special infrastructure is expected to increase. Standards published by SAE, e.g., J3016 cannot and should

not be treated as the ultimate definitions, since they still may impose biased systems of belief, e.g., disregard the importance of human ethical autonomy in the future automated driving scenario. The field of vehicle automation is evolving dynamically which calls for not only updating, but indeed breaking new ground in legal development. Ethical standards should be clear and constant e.g., ethical rules collected by the Ethics Commission (2018) offer a potential to solve some uncertainties but most importantly ensure that both actions and results of actions of Automated Vehicle systems are under human control.

However, technology is a breeding ground for strong beliefs e.g., about the capabilities of Artificial Intelligence. Such situation where actual evidence for lasting benefits is being replaced with confidence in the future promises of AI creates social and ethical issues that are difficult to meet with consistent and clear answer. As stated, this applies particularly to the assumed feasibility and ability of Artificial Intelligence to provide definitive answers to the challenges posed by various scenarios for Automated Vehicles. As car makers and Smart Mobility stakeholders are convinced of the unlimited power of their technology to contribute to a wide range of technological, social, environmental, and cultural solutions, one may remain cautious and critical to some ideas diffused in such scenarios. The processes of migrating from one technology that either monitors or works as driver aid, towards a full automation technology may indeed produce a general dissonance of perception, as society's expectations to the capabilities of given technology and the way such technology should interact with the outside world in real life might be conflicting.

## ***Conclusions and future of the field***

I hope that my analysis of collected materials will contribute to a growing discussion about human interaction with technology. Especially what I would like to achieve is to highlight the importance of deliberate and thought through design of artifacts particularly in the automotive industry. Development of correct and appropriate user experience that focuses on individual and social values is going to be a significant ability. Technology that accurately manages to convey the identity and lifestyle will be central to creating a meaningful design, thus making it a powerful tool that is beyond the marketing sector.

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