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Assessing the future accessibility of mobility

A QUALITATIVE RESEARCH ON THE EXTENT OF USER REPRESENTATION OF OLDER AND PHYSICALLY DISABLED PEOPLE IN THE NETHERLANDS BY AV TECHNOLOGY COMPANIES

AUTHOR: VICTOR VAN STERKENBURG, 5504791
V.L.D.VANSTERKENBURG@STUDENTS.UU.NL

DATE: 19-08-2020
INTERNSHIP ORGANIZATION: KIM NETHERLANDS INSTITUTE FOR TRANSPORT POLICY ANALYSIS
SUPERVISOR: T.TILLEMA, TAEDE.TILLEMA@MINIENW.NL
THESIS SUPERVISOR: DR. J. FARLA, J.C.M.FARLA@UU.NL
SECOND READER: A. PEINE, A.PEINE@UU.NL

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Abstract

As the worldwide population is aging, the number of people experiencing travel impairments is expected to increase. At the same time, the introduction of automated vehicles (AV) is widely expected to have a wide range of advantages and disadvantages, yielding many implications for society. Vulnerable users experiencing travel impairments, which includes older and physically disabled people, are more significantly affected by social exclusion, because of a lack of access to economic opportunities. At the same time, the needs of these vulnerable users are still often not addressed by major AV technology companies. This research draws on existing literature in user involvement in technology design to research societal implications of AVs for older and physically disabled users. This framework was used to address the central research question: *How are older and/or physically disabled people in the Netherlands involved and represented in automated vehicle technology developments?* An explorative and qualitative research was conducted, in which in-depth interviews were conducted with interest organizations representing older and physically disabled users in the Netherlands. These organizations delivered important factors to consider regarding the involvement and representation of these users in AV technology design. Various user involvement factors were also mapped and analysed from car manufacturers and people mover (PM) companies. These results were then used to map how representations of older and physically disabled users have influenced AV technology design. Although older and physically disabled users in the Netherlands are barely involved in automated vehicle technology projects, these groups preferred a focus on earlier involvement in the design, mock-up and prototype testing and the use of physical contact over virtual contact. In addition, developers should focus on facilitating an interplay between user groups, targeting separate user groups first, after which user groups could collectively be approached. Car manufacturers base their user involvement preferences on striving to approach the standard human in design as close as possible. To achieve this, car manufactures use customer clinics as their main user involvement tool with a representative customer sample of young, middle-aged and older users. Older users were also mentioned as part of several research projects with universities. At the same time, users to be involved also depend on user profiles, created through data analytics, marketing perspectives and automation factors. Based on these factors, older and physically disabled users are not considered a high priority for AV technology development, which results in scarce involvement of older users and no mentioned involvement of physically disabled users in AV technology projects. Physically disabled users were expected to be increasingly involved in AV technology projects as the industry was shifting towards urban mobility and PM shuttles. PM companies themselves focus on all users that are using public transport services, although users are not directly involved in the design. Instead, transport operators act as an intermediary actor, transferring user input from user groups to people mover companies. Mentioned adaptations, such as improved braking and on-board safety systems indicate that both older and physically disabled users are involved by transport operators and represented to some extent. User representations of older users have also influenced some AV technology developments, if customer clinics were used. The most notable examples include adjustable low-level AV settings for speed and distance to a lead vehicle and streamlined AV system behavior with measurement technology. This shows that older users are represented to a small extent in both private and public AV technology developments and that physically disabled users are represented to some extent in public AV technology developments.

Keywords: automated vehicle, people mover, user involvement, user representation, user involvement methods, user involvement preferences,

Preface

This paper represents the results from a Master's thesis conducted for the master's program Sustainable Business and Innovation, followed at Utrecht University. This thesis was conducted as part of an internship under the Netherlands Institute for Transport Policy Analysis (KiM). The institute provided adequate contacts and knowledge used to gather respondents and data, which were essential for completing the result.

Acknowledgements

I dedicate this thesis to my grandmother, who, I believe, would have experienced tremendous benefit from the potential of AV technology and was one of the reasons for me to choose this subject.

I would like to thank my thesis supervisor Dr. Jacco Farla at Utrecht University. He challenged me to be critical of my work and let me rethink when it needed to be. He also provided guidance regarding the best course of action. At the same time, he stood in when I needed help in finding the right track. I would also like to thank my second reader, Dr. Ir. Alexander Peine for providing very useful feedback on my research proposal and for assessing my thesis in advance.

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Furthermore, I would like to thank all my colleagues at KiM that provided me with useful insights and a lot of interesting stories of mobility research throughout the years. I would definitely like to keep joining for the pubquiz events.

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List of abbreviations

ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance Systems
CARA	CuARdian Angel
AI	Automotive Industry
AV	Automated Vehicle
HMI	Human Machine Interface
IO	Interest Organization
ITS	Intelligent Transport Systems
KI	Knowledge Institution
KiM	Kennisinstituut voor Mobiliteitsbeleid
NG	National Government
PT	Public Transport
RG	Regional Government
PM	People Mover
SAE	Society of Automotive Engineers
TS	Traffic Service Company
UCD	User-Centered Design
USID	User-Sensitive Inclusive Design

1. Introduction

In order to ensure a future of inclusive and accessible mobility, it is needed to provide this accessibility for every social group to create a truly inclusive transport system (Martens, 2018). However, vulnerable social groups, that experience some form of travel impairment, often experience challenges in adopting and using mobility solutions, therefore hampering their access to transportation (Mladenovic & McPherson, 2016; Pettigrew, Cronin, & Norman, 2018; Suen & Mitchell, 2000). As the worldwide population is aging, the amount of people experiencing travel-related impairments is expected to increase (Martens, 2018) just as the demand for accessible transportation (Suen & Mitchell, 2000). It is therefore deemed crucial that products and services are designed to suit older and disabled people (Gyi, Sims, Porter, Marshall, & Case, 2004). Intelligent transportation systems (ITS) could show considerable potential in offering mobility solutions for vulnerable people with disabilities (Suen & Mitchell, 2000).

A potentially influential ITS in contributing to accessible mobility, comes in the form of automated vehicles (AVs) , which are broadly defined as ‘’vehicles used to move passengers or freight with some level of automation that aims to assist or replace human control’’ (Stocker & Shaheen, 2017, p. 1). Within AV systems, a clear distinction between six levels of automation has been defined by the Society of Automotive Engineers (SAE) indicating clear differences between different levels of automation as shown in Figure 1 (NHTSA, 2019). Although the implementation of fully autonomous cars is subject to speculation, some research estimates that it could be implemented in the next 10 years (Anderson, Nidhi, Stanley, Sorensen, & Samaras, 2014; Milakis, Snelder, Van Arem, Van Wee, & De Almeida Correia, 2017).

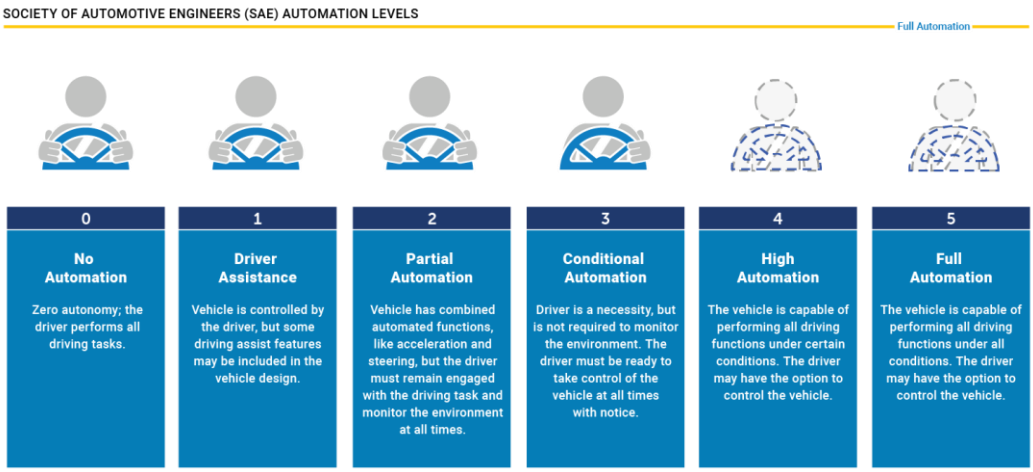

Figure 1: Six level of vehicle automation (NHTSA, 2019)

Recent developments in AV systems show the potential to increase the safety and accessibility for all future transportation (Abraham et al., 2016). A large body of research widely expects the implementation of autonomous vehicles to increase overall vehicle miles travelled (VMT) especially for older and disabled people, but also shows a clear lack of empirical evidence (Fagnant & Kockelman, 2015; Harper, Hendrickson, Mangones, & Samaras, 2016; Millard-Ball, 2018; Reimer, 2014; Tillema et al., 2015). Older and disabled people are also expected to benefit from better access to personal education and employment opportunities, increasing their overall productivity (Litman, 2019). At the same time, AV

systems have been criticized, because of potential product liability issues (Gurneyt, 2013) and the necessity of very complex computer systems (Litman, 2019). The implementation of AVs as well as autonomous ‘’micro-transit’’ services could also create more pickup and drop-off delays, which could lead to increased traffic congestion and more emissions (Gruel & Stanford, 2016; Litman, 2019). Increased travel by underserved populations, such as people with travel impairments, could also contribute to increased energy use (Milakis, Van Arem, & Van Wee, 2017).

As older and disabled people tend to experience various forms of social exclusion, these groups are disproportionally affected by transport-related exclusion (Kenyon, Lyons, & Rafferty, 2002; Milakis et al., 2017). This form of exclusion is not per se caused by a lack of social opportunities, but instead by a lack of access to opportunities, networks and services. (Kenyon et al., 2002; Preston & Rajé, 2007). Policy recommendations to tackle this problem include the reduction of traffic costs and the use of new technologies to increase social contacts (Preston & Rajé, 2007). Advancements in in-vehicle technologies, that rely on some form of automation, have shown to provide several benefits to older drivers, including improvements in travel comfort and safety (Eby et al., 2016; Yang & Coughlin, 2014). Other advancements have been proposed, such as vehicle interfaces, that support different modes for input and output of data (Sebillo, Vitiello, & De Marsico, 2009), as well as new education systems (Reimer, 2014; Yang & Coughlin, 2014). AVs might also present various privacy trade-offs for older and disabled people; future AV regimes could for instance decide when and where they could travel, limiting their individual mobility (Glancy, 2012). This could also pose a more drastic ‘’Hobson’s choice – either to take this autonomous vehicle mode of personal transport that tracks your every movement, or to have no individual vehicle mobility at all’’ (Glancy, 2012, p. 1186), potentially increasing the extent of transport-related exclusion.

Having a wide range of potential benefits and disadvantages, AVs are expected to yield wide-ranging policy and planning implications (Millard-Ball, 2018; Mladenovic & McPherson, 2016). At the same time, the needs of older and disabled people are often neglected in the development of new mobility policies and programs related to AV solutions (Abraham et al., 2016; Pettigrew et al., 2018; Shergold, Lyons, & Hubers, 2015). While some companies, active in developing AVs (Hawkins, 2018; Statista, 2019), have mentioned future efforts to make autonomous driving accessible for older and disabled people (Toyota Motor Corporation, 2019, pp. 12, 14, 45, 48; Toyota Nederland, 2019; Volkswagen AG, 2018, p. 48), most major car manufacturers fail to mention the needs of these vulnerable social groups in the design of AVs (BMW Group, 2018a, 2018b; Ford, 2018; Ford Motor Company, 2018; General Motors Company, 2017, 2018; Tesla Motors, 2018). To provide more social inclusion would require an increase in proactiveness from private and public sectors to ensure the availability of fitting AV options (Pettigrew et al., 2018).

A promising theory in linking users to the technology design process is the concept of ‘user representation’ (Akrich, 1995). It refers to the process of imagining the prospective users of a certain technology, after which these images can influence the design process and can potentially be built into a technology as so-called scripts. When these representations show signs of age-discrimination, they could become an inherent part of society, once they are built in (Neven, 2010). Therefore, mapping how users are imagined in design processes can help in understanding the roots of certain scripts (Neven, 2010; Peine, Rollwagen, & Neven, 2014).

While current research has mainly focused on the technical part of AV systems, little research has been conducted on societal implications of AVs for older users (Faber & van Lierop, 2020). Furthermore, no

research has been conducted specifically on user representation and involvement in AV technology development related to vulnerable social groups, such as older and physically disabled people. An exploratory research aimed at identifying the extent of user representation amongst AV technology companies related to users experiencing travel impairments could therefore yield interesting results.

Research conducted by KPMG (2018, 2019) showed the Netherlands coming in at the first place of their Autonomous Vehicle Readiness Index for two consecutive years. Besides being the best performing country in the Infrastructure category, it also ranked consistently high in the top five of the categories 'Policy & Legislation' and 'Consumer Acceptance'. Estimates, based on an extensive scenario analysis also indicate that full automation could be implemented in the Netherlands as early as 2025 (Milakis, Snelder, et al., 2017). This shows the potential of the Netherlands as the country of choice for this research. The aim of this research is therefore to investigate the extent of user representation of older and physically disabled people in the Netherlands and AV technology companies. The central research question is:

How are older and/or physically disabled people in the Netherlands involved and represented in automated vehicle technology developments?

In order to answer this research question accordingly, the insights gained will be synthesized with respect to the following sub-questions:

1. *Which user involvement motives and methods are described in literature as important when involving older and/or physically disabled users in technology design?*
2. *Which factors do interest organizations consider important regarding the involvement and representation of older and/or physically disabled users in AV technologies?*
3. *What ideas and preferences of AV technology developers determine how and to what extent they involve older and/or physically disabled users in the design process?*
4. *How are user representations of older and/or physically disabled people influencing current and future AV technology developments?*

By answering these questions, it can allow insights into the visions that AV technology developers have of their users and to what extent older and physically disabled users are involved and represented in AV technology developments. This will add to the relatively scarce, but growing body of literature on societal implications of vehicle automation, indicating the scientific relevance of the subject. In addition, it can potentially provide new knowledge on the measures needed to ensure mobility for vulnerable social groups.

The outline of this thesis is as follows. After this introduction, chapter 2 will further elaborate on theories, such as the role of users in innovation processes, the concept of user representation and social exclusion theory. This chapter will also provide some mobility numbers of an aging Dutch population alongside several AV design considerations. Thereafter, in chapter 3 the research design and methods for data collection and analysis will be explained. The results will be presented followed by a comparative analysis of the results in chapters 4 and 5. Finally, the results will be discussed in chapter 6 followed by a conclusion of the results in chapter 7.

2. Theory

2.1 User involvement in innovation processes

2.1.1 User representation

As interest in societal acceptance of technologies grows and users of a technology are increasingly recognized as potential sources for innovation, the engagement of users in innovation processes has been receiving increased attention (Rohracher, 2005). A core argument that Rohracher (2005) mentions in this context is the notion of just how users are perceived; users are neither seen as passive consumers of products nor seen as highly influential in the technology design process. At the same time, active methods of interaction between users and technology developers are deemed crucial, especially when new technologies are emerging (Nahuis, Moors, & Smits, 2012). While users may serve a very active role in user-driven innovation, users are considered limited in their involvement due to various reasons (Rohracher, 2005). Users might fail to participate in the co-design of technologies because of constraining routines within organizations, institutions or socio-technical regimes, that allow for little participation in the co-design of technologies.

In addition, the involvement of users is dependent on how user aspects are represented and implemented in technologies (Akrich, 1995; Rohracher, 2005). This entails that potential user groups of a technology are imagined after which these images can then appear in the work of actors involved in the development of a technology. These can then influence decision-making in the design process and potentially be built in as technology scripts (Akrich, 1995; Neven, 2010). As users are considered to have more specific knowledge, effective involvement can help designers in accurately targeting user needs and requirements (Essén & Östlund, 2011; Fischer, Peine, & Östlund, 2019).

2.1.2 Users as a source of innovation

Essén & Östlund (2011) have discussed several theories regarding which users to involve as potential sources of innovation and how to involve them. Rogers' theory of the diffusion of innovations is mentioned as it focusses on the adoption process of innovations by users and organizations, where innovators and early adopters are expected to be among the first to adopt innovations (Rogers, 1995). A similar theory, but with a heavier focus on user innovation (Essén & Östlund, 2011), is von Hippel's lead user concept with two distinct characteristics; lead users are considered to possess general product needs much earlier than other users and are more likely to benefit by coming up with a solution to these needs (von Hippel, 1988). Therefore, in rapid-changing markets with sophisticated technology, lead users are being called essential for market research. (von Hippel, 1988). Argued to be the most influential method for approaching consumer-driven design (Essén & Östlund, 2011) and successfully used in various applications (Eisenberg, 2011; Lüthje & Herstatt, 2004), the lead user method, as developed by von Hippel and colleagues (Herstatt & von Hippel, 1992), suggests screening for lead users, based on von Hippel's (von Hippel, 1988) two characteristics, and once identified, involving them in special problem-solving sessions to create various concepts.

As von Hippel's lead users overlap with Rogers' adopter categories of early adopters and innovators, a limitation of both theories is identified as the sole focus on innovative users, that would have better

developed needs than others and are more eager to adopt novelty and change (Essén & Östlund, 2011). As lead users would only present a small number of users, they would not be an accurate representation of the larger part of the market (Herstatt & von Hippel, 1992; Magnusson, 2003) and would therefore require inclusion of a larger variety of users in the innovation process (Herstatt & von Hippel, 1992). At the same time, it is suggested that reaching laggards through innovative users would be inefficient due to a misalignment of needs related to various technologies (Essén & Östlund, 2011). Especially older users would most likely fail to fit in an innovate category and fail to be used early on in design processes as they are traditionally considered very unsupportive to novelty and change, therefore overlapping with Rogers' category of laggards (Essén & Östlund, 2011). When user representations show signs of age-discrimination, these ideas may be built into the technology and eventually, as a materialized form, become a part of society (Neven, 2010). Therefore, in order to understand the age scripts in technology, it is importance to examine how ageing users are imagined in design processes (Neven, 2010; Peine et al., 2014).

2.1.3 Involving older users

By questioning the vision that older users are seen as laggards, Essén & Östlund (2011) used research circles to explore the potential value of involving retired users as starting point for service innovation. This method requires collaboration between researchers and users and emphasizes the systematic development of knowledge with a clear research interest (Östlund, 2008) and differs from von Hippel's method of providing users with toolkits in that the researcher is responsible for most of the structure, whereas users are required to reflect and continuously participate (Essén & Östlund, 2011). Using research circles, Essén & Östlund (2011) provided one of the first empirical examples of how older users can be involved in the early stages of service design and show potential as a source of innovation if granted with the right tools. Other research has added that the introduction of some technologies can allow for extensive learning from older users, where this group became early adopters and also a clear source for innovation (Peine, van Cooten, & Neven, 2017).

A more recent literature study on older users in design practices has stressed that older user involvement does matter in design practices, but doesn't necessarily lead to beneficial outcomes (Fischer et al., 2019). Case studies that involved older users had three types of reoccurring outcomes: a sense of learning for the designers (1.), design adjustment (2.) or a sense of increased participation for older users (3.) (see Figure 3). The type of outcome from older user involvement differed based on whether designers chose to involve older people in order to improve the quality of products (material motivators), to identify a better understanding of the surrounding environment (soft motivators) or to grant older people more participation (normative motivators) (Fischer et al., 2019). This adds an extra dimension to the previously mentioned comments from Essén & Östlund (2011), who indicated that user innovation projects depend on which users to involve and how to involve them.

Figure 2: The process of user involvement of older people, based on Fischer et al. (2019).

2.1.4 Involving disabled users

In striving for universal usability, researchers and designers have to consider all potential user groups, including people with disabilities (Newell & Gregor, 2000). In traditional ‘’user centred design’’ (UCD), this could be problematic in finding representative users, because of the wide variety of characteristics and functionalities that this user group possesses (Newell & Gregor, 2000, 2002; Newell, Gregor, Morgan, Pullin, & Macaulay, 2011). Therefore, Newell & Gregor (2000, 2002) have proposed an extension of the UCD method known as User Sensitive Inclusive Design (USID). In line with the UCD method, it focuses on users as the heart of the design, but aims to achieve more inclusivity by using experimental techniques and methods to communicate results (Newell & Gregor, 2000). Examples, such as interactive live theatre have proven to be a very effective tool for efficient communication between designers and technology need requirements (Newell, Carmichael, Morgan, & Dickinson, 2006; Newell et al., 2011). Other methods to facilitate inclusive design for disabled people include the use of computer-based design tools, that allow designers to have access to virtual users early on in the design process (Gyi et al., 2004). Using so-called anthropometric data sets and user preferences, this allows for the visualization of previously excluded individuals stimulating more empathy and understanding of issues relevant for older and disabled people. These studies show that with the right involvement method, designers can achieve inclusive designs, for all types of users.

Literature insights can now be used to tentatively answer the first research sub-question. Designer choices regarding which users to involve, how to involve them and why are influential for general user involvement in innovation processes. Designers have the potential to learn from older and disabled users early in the design process if granted with the right tools. Important motives to involve older users are to improve the quality of products, to identify a better understanding of the surrounding environment or to grant older people more participation. An important motive to involve physically disabled users in technology design is to strive for USID. In addition, research circles, interactive theatre and computer-based design tools are mentioned as helpful tools for involving both older and disabled users in technology design.

2.2 Travel-related social exclusion

The concept of social exclusion has been broadly researched, as it focuses on the consequences of transport deprivation (Titheridge, Christie, Mackett, Hernández, & Ye, 2014).. Kenyon et al. (2002) have identified nine key dimensions, including poverty and a dedicated mobility dimension, that are all seen as aspects of social exclusion. Within the mobility dimension, a lack of access to adequate transport can reduce the accessibility to economic opportunities and social networks (Preston & Rajé, 2007), especially for people with constrained physical mobility which can also reinforce other social exclusion dimensions (Kenyon et al., 2002). A lack of access to adequate transport is seen as a barrier for employment opportunities, educational and training opportunities. A clear example of this is the low private ownership of cars in certain neighbourhoods, which can create difficulties in forming and maintaining formal and informal social networks, potentially isolating people from family and friends (Kenyon et al., 2002). Seniors, that quit driving, have also shown to make 15% less trips to the doctor and 65% fewer trips visiting family and friends, which increases social exclusion and causes even more risk for a degradation of health (Ohnemus & Perl, 2016).

2.3 Mobility numbers of an aging Dutch population

Although future health conditions of older people are expected to improve over the coming decades, this also applies the share of people experiencing co-occurring travel impairments. While 66% of people over 65 years old in the Netherlands were experiencing some form of difficulty traveling, this group contributed to a 13% share of the total population in 2007 (Martens, 2018). More recent numbers from the Dutch statistics bureau ‘Centraal Bureau voor de Statistiek’ (CBS) prevail that the population share of people over 65 years old had increased towards 18.5% in 2017 (CBS, 2017) and could rise to nearly 26% in 2040 (CBS, 2019b, 2019c). Furthermore, data show that 42.5% (65-75 years old) and 55,8% (over 75 years old) suffered from health problems that lead to limitations in their capabilities (CBS, 2019a). At the same time, these age groups on average still account for an annual number of kilometres travelled by car of 5612 (65-75 years old) and 3280 (over 75 years old) (CBS, 2018).

2.4 AV Design Considerations

In order to decrease transport-related exclusion, research has stressed the importance of mapping the potential societal benefits of automated transportation (Crayton & Meier, 2017; Pettigrew et al., 2018). While new transport policies are shaped, the inclusion of different stakeholder groups in order to include the needs of older people is deemed vital. Crayton & Meier (2017) have also stressed the importance of the use of the AV technology to bring mobility to all populations that are mobility-impaired. At this moment, the process of aging and the related physiological changes is deemed to demotivate older people from driving, due to the necessity of sensory, motor and cognitive functions for safe driving, (Crayton & Meier, 2017; J. Meyer, 2004; Yang & Coughlin, 2014). The introduction of AVs and appropriate supporting policies is therefore seen as especially useful in increasing the mobility of aging populations (Abraham et al., 2016; Crayton & Meier, 2017; Eby et al., 2016; Harper et al., 2016; Pettigrew et al., 2018; Shergold et al., 2015). This is also consistent with SDG target 11.2, aiming to ‘’provide access to safe, affordable, accessible and sustainable transport systems for all … with special attention to the needs

of those in vulnerable situations, women, children, persons with disabilities and older persons" by 2030 (United Nations, 2015).

But although most of the academic literature and technology developments related to AVs has focused on the technical aspects of design and operations (Pettigrew et al., 2018; Yang & Coughlin, 2014), neglected factors remain revolving around the driver or the driver-vehicle interaction (Yang & Coughlin, 2014). In order to benefit from the potential value from introduced in-vehicle technologies, the focus during design should be on the user (J. Meyer, 2004). In the case of AVs, the notion of designing around the driver and driver-vehicle interaction can provide interesting design considerations (Yang & Coughlin, 2014), as this can be heavily influenced by the needs of the users and it requires to adapt the product to the user characteristics (J. Meyer, 2004). Because of inherent safety issues related to these technologies, usability considerations are of major importance in generating consumer acceptance and satisfaction In addition, design choices that are relevant for older drivers are considered to bring improvements to the device for all users (J. Meyer, 2004). Key aspects that need to be considered in the interaction of an older driving population with AV technologies include acceptance, learnability and net effectiveness (Yang & Coughlin, 2014).

Acceptance

Despite older people taking longer to learn how to use new in-vehicle technologies, they have shown to be motivated to adopt a certain technology if they are advised on the potential benefits. Furthermore, the design of a method that explains these benefits is deemed important to let older people gain more experience with new technologies, which can increase their willingness to use them.

Learnability

At the same time, Yang & Coughlin (2014) argue that the older people can't be expected to adopt and learn from the technology without some form of adequate training. In order to train older people, it is recommended to combine technology training together with driving and education programs. The European Commission has mentioned similar arguments regarding the revision of driver training systems to improve vehicle-user interaction for all users (G. Meyer, Blervaque, & Haikkola, 2019).

Net effectiveness

While younger drivers tend to have more trust in warning systems, older drivers have shown to get distracted from warning system triggers. Because of their experience, such a trigger can cause them to ''second-guess'', letting them look for reasons why the alarm is triggering. Here lies the risk of an automated feature staying unused if the driver distrusts the automation.
One recommended solution entails that in-vehicle systems can show their validity during the warning with several warning levels, creating increased sensitivity in the interaction between driver and vehicle (Yang & Coughlin, 2014).

2.5 Towards an AV user involvement framework

The previously described theories on user representation and user involvement of older and disabled users can be used to draft a framework to analyse the user involvement and representation of older and disabled users in AV technology development, as shown in Figure 3 below.

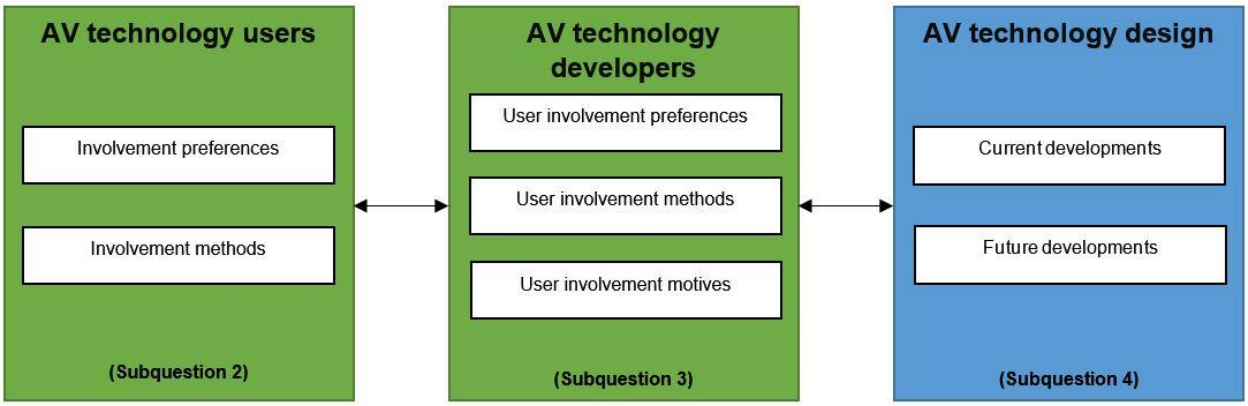

Figure 3: AV user involvement framework

AV technology developers are thought to possess specific user involvement preferences regarding which users to involve and why (Essén & Östlund, 2011; Gyi et al., 2004; Rogers, 1995; von Hippel, 1988). AV technology developers are also expected to use certain user involvement methods regarding methods of interaction and involvement and why the choice is made for this type of method (Essén & Östlund, 2011; Herstatt & von Hippel, 1992; Newell et al., 2011; Östlund, 2008). If AV technology developers involve older users in the design, it is argued that they will possess specific motivating factors or user involvement motives in line with Fischer et al. (2019) (see Figure 2). In line with these factors, it is assumed that potential AV technology users have knowledge of the methods they are involved in and preferred involvement methods. Furthermore, it is assumed that AV technology users possess certain expectations of AV technology as well as preferences and recommendations for AV technology adaptations. User preferences for involvement methods and adaptations can then potentially influence current and future AV technology developments, provided that AV technology developers consider these preferences to a certain extent.

By interviewing interest organizations, it allows for the identification of the methods which are used to involve Dutch older and physically disabled users in projects related to AV technology developments. Other aspects that can be identified under involvement methods include the extent of involvement, extent of interaction and project involvement effects. It is assumed that interest organizations possess representative knowledge of older and/or physically disabled users, which could help also help in identifying preferred involvement methods and the feeling of representativeness amongst older users and physically disabled users. This leads to an answer for sub-question 2.

By interviewing AV technology developers, it allows for the identification of user involvement preferences as well as the methods of involving users. Specific motives for involving older users can also be sought after. In addition, effects can be identified regarding the influence of user involvement of older and/or physically disabled users in current and future AV technology design. This leads to an answer to sub-questions 3 and 4

Current AV developments can then be compared with expectations that interest organizations have of technology and the expected attitude of older and physically disabled users. Expected user preferences regarding adaptations can subsequently be compared with both current and future AV technology developments. This allows for a thorough analysis of all results, which can be used to give an insightful answer to the central research question.

3. Methodology

In this methodology chapter, the research design is presented followed by the research sample, as well as the method of data collection. Hereafter, the means of data analysis will be elaborated upon.

3.1 Research Design

This research has been conducted as part of an internship at the KiM Netherlands Institute for Transport Policy Analysis, which is part of the Ministry of Infrastructure and Water Management. KiM has assisted in providing contacts, knowledge and information. This thesis has used an explorative, qualitative approach to map, assess and reflect on the user involvement and representation of older and physically disabled users in AV technology design. In order to provide an adequate answer to the research question, literature recommended the use of qualitative research methods, such as focus groups or semi-structured interviews. Although the use of focus-groups has been used before to explore users' preferences regarding AV technologies (Faber & van Lierop, 2020), this thesis has used in-depth interviews to collect qualitative data on the user representation and involvement of vulnerable users (older and physically disabled users) in AV technology development. In addition, if data issues were to occur, in-depth interviews are a recommended research method, because of ethical and privacy-related reasons (Adams & Cox, 2008).

3.2 Research Sample

As it was deemed vital to include the opinions of public health stakeholders (Crayton & Meier, 2017; Pettigrew et al., 2018), the first part of the sample consisted of relevant public stakeholders in the form of interest organizations that represent the needs and interests of both older and physically disabled people in the Netherlands on regional and national levels. These included the Dutch national organization representing disabled people Ieder(in) and several organizations representing retired people; KBO-PCOB, the Federation of General Elderly Associations (FASv), the Dutch Association for Organizations from Retirees (NVOG) and the General Dutch Union for Seniors (ANBO). Interest organizations are considered to be aware of the needs of their members, because this contributes to a sustained membership and thus the survival of the organization (Lowery, 2007). It was therefore assumed that these organizations possessed knowledge that was important to consider when involving or representing older and physically disabled users in AV technology projects.

The second part of the sample consisted of Volkswagen and Toyota, which were considered among the most active AV technology companies (Hawkins, 2018; Statista, 2019) and have stressed efforts to make AVs as accessible as possible (Toyota Motor Corporation, 2019, pp. 12, 14, 45, 48; Toyota Nederland, 2019; Volkswagen AG, 2018, p. 48). BMW, Ford, Tesla and General Motors were also contacted for additional interviews as they have also shown to be among the most active companies in AV technologies. Of these four companies, only BMW and Ford responded. In addition, in some cases, 'people mover' (PM) companies already collected experience with users, based on actual use or simulation data (Sam Lott, Gettman, & Tai, 2009), and may have already used this experience in the adaptation of the technology. Therefore, part of the sample consists of PM companies, which have also been contacted and interviewed in this sample part.

AV technology developers were thought to base their technology designs on anticipation of their users' characteristics with various preferences for user involvement and user involvement methods, because these can contribute to increased usability and subsequent consumer acceptance and satisfaction (Meyer, 2004). Insights into these methods helped in determining how older and physically disabled users were envisioned and to what extent they were involved in AV technology development. Once information was collected from AV technology developers on user involvement preferences, methods and motivating factors, it was investigated how the involvement of vulnerable users has influenced current AV technology developments and how this user involvement might influence future AV technology developments.

3.3 Data collection

Relevant stakeholders were asked questions in semi-structured interviews. Two experts were also contacted to express their knowledge of the presented subjects to increase the quality of the results (Bogner, Littig, & Menz, 2009). While the first two interviews were conducted physically, all other interviews were conducted via the online medium Microsoft Teams, due to the ongoing COVID-19 situation. Interviews lasted from half an hour to approximately 1.5 hours and were recorded provided that the interviewee gave permission for this. If permission was denied, a report was made of the interview. The extent to which a research can be reproduced over time with a fixed methodology relate to the reliability of a research. In addition, this asks for consistent findings over time and an accurate representation of the total population within a study (Golafshani, 2003). The validity of a research refers to the extent to which research methods measure what is intended to measure (Long & Johnson, 2000). This research aimed to interview relevant interviewees within AV technology companies, which can be considered relatively hard to reach without the appropriate network. As snowball sampling is considered adequate to locate, access and involve hard to reach or hidden populations (Cohen & Arieli, 2011; Dragan & Isaic-Maniu, 2013), the use of this sampling method was deemed fitting for this research. Furthermore, snowball sampling was deemed fitting, because it is effective in researching *organic social networks* between different types of populations (Noy, 2008), referring back to the previously mentioned interest organizations and AV technology companies. Using the snowball sampling method, relevant interviewees were identified and contacted, adding potentially relevant information to this subject.

From the starting sample, the aim was to reach a total of 20 interviews in the final sample. It was deemed fitting within the recommended sample size for qualitative interviews in single-case studies (Marshall, Cardon, Poddar, & Fontenot, 2013). In addition, it was assumed that the snowball sampling method would increase the relevant sample size the most for interest organizations, because of the estimated wide variety and number of organizations. In total 18 interviews were conducted, which included a variety of local governmental organizations, which was recommended by several interviewees, because of their knowledge on AV technology projects in the Netherlands and the industry. Insights from experts and governmental organizations were analyzed by comparing them with current and future AV technology developments. This allowed for a critical reflection of the AV technology industry by both experts and governmental organizations, leading to new insights and a more complete answer to the research question. As this research partially focused on interest organizations representing older and physically disabled users in the Netherlands, all corresponding respondents were conducted in Dutch. This was done to ensure that every interviewee approached could provide their knowledge and insights in the most convenient way. The following table gives an overview of interviewed organizations, including the position that each respondent had within the corresponding organization.

Table 1: Overview of interviewees, corresponding organizations and interviewees' positions.

	Organization	Type of organization	Respondents' position within organization
1	Katholieke Bond van Ouderen – Protestants Christelijke Ouderen Bond (KBO-PCOB)	IO (Interest Organization)	Policy Advisor & Active and Assisted Living (AAL) Project Manager
2	Federatie Algemene Seniorenverenigingen (FASv)	IO	Project Manager
3	Dwarslaesie Organisatie Nederland	IO	Representative volunteer
4	Metrocov	IO	Representative members
5	Ieder(in)	IO	Policy Employee Mobility & Accessibility
6	Safe Driving Insights (SD-Insights)	TS (Traffic Service)	User Experience Designer
7	Institute for Transport Studies, University of Leeds	KI (Knowledge Institution)	Chair in Human Factors of Transport Systems
8	University of Twente	KI	Assistant Professor Industrial Design Engineering
9	Vereniging Nederlandse Gemeenten (VNG)	NG (National Government)	Project Manager *Iedereen Doet Mee!*
10	Gemeentelijk Netwerk voor Mobiliteit & Infrastructuur (GNMI)	NG	Policy Advisor
11	Rijksdienst Wegverkeer (RDW)	NG	Senior Advisor Intelligent Mobility
12	Provincie Groningen	RG (Regional Government)	Program Leader Smart & Sustainable Mobility and Public Transport
13	BMW	AI (Automotive Industry)	Product Manager Automated Driving
14	Ford	AI	Senior Researcher Human Factors
15	Volkswagen	AI	Project Manager Automated Driving
16	Toyota	AI	Human Factors Research Engineer
17	2getthere	PM (People Mover)	Sales Manager
18	Navya	PM	Area Manager

3.4 Data analysis

Interviews were transcribed and subsequently coded using NVivo 12.0 as this allows for the generation of new insights (Strauss & Corbin, 1998). First, open coding was conducted, in which labels were given to the data that can be identified and classified according to specific themes as displayed in Figure 3. When new actions or interactions appeared, these were used to define new concepts to provide higher quality inductive data. Second, axial coding was conducted by exploring clear and complete conceptual relationships between the initial labels. Third, the interviews were subject to selective coding, where data was further refined until no new properties, dimensions, or relationships emerge during the analysis and data saturation was reached.

4. Results

The following chapter will elaborate on the results. Insights gained were derived from seven recurring concepts, which stem from literature and the "*AV user representation"* framework (see Figure 3). Supportive quotes have been added where it was deemed fitting for additional insights. The first section will elaborate on interviews with representatives from interest organizations, lobbying for the needs and wishes of older and physically disabled users in the Netherlands. The second section elaborates on insights from AV technology companies, which included representatives from four traditional car manufacturers and two PM companies, whereas the last section grants insights into current and future AV technology developments based on user involvement, compared with technology expectations and preferences of users. Every paragraph makes a distinction for the focus on older and physically disabled users if applicable. The final section presents an in-depth analysis, that compares the results from each actor group.

4.1 AV technology users

4.1.1 Older users

Involvement methods

Three out of four corresponding interest organizations said there was little to no interaction between AV technology developers and older users, while discussing factors related to involvement methods, such as the extent of user/developer interaction. Projects, that involved AV technology, were only started little by little and focused only on public AV projects, involving people movers (PM). There was a large sense of unawareness amongst interest organizations that these projects exist. Various reasons were given for the lack of interaction with developers, including the fact that senior organizations are considered unprepared for these projects.

"In summary, I think that the interaction between project developers on the supplier side and on the customer side has not been established, because we are not ready yet." [IO]

This also relates to the lobbying agenda of interest organizations. Although most senior organizations lobby for "older" mobility needs of their senior members, such as public transport (PT) needs, there is little to no exchange of information with their members on new mobility systems such as AV technology. One interviewee representing a national governmental organization, confirmed that few AV technology projects in the Netherlands specifically focused on users, as most pilot projects are focused on improving the technology with new traffic situations.

"What we have actually seen so far is that vehicles are first used to test the technology; how can they deal with certain traffic rules? Can they handle the position on the road and things like that? There are very few tests where there have been passengers involved." [NG]

While discussing the feeling of representativeness of senior users in AV technology, one interviewee mentioned it to be little to not present at all. Cars in general were mostly designed for younger people, when it came to factors such as ingress and egress and this would be no different for future AV technology in private AVs. In addition, older men with general science or business experience, were mentioned as they could feel unrepresented, because of unfulfilled potential in using their creativity and experience if they were to be involved in projects.

"Especially older men, coming from a business or a scientific background, still have a lot to offer at the age of 75. They are being less approached for these types of projects or not at all. And there is still sufficient brainpower, experience and a high degree of creativity in these men. As a service provider, company or as a government organization, you could very well use these people in a project to try out the market value of a new product or to test it." [IO]

One AV technology project, which did specifically focus on senior drivers was the EU-funded research project CuArdian Angel (CARA). The project aimed at providing seniors with extended mobility through new Advanced Driver Assistance Systems (ADAS) concepts, which was discussed, during two interviews with a participating interest organization and traffic service company. During the first CARA project, wishes and needs of seniors were mapped and used to develop three ideas for ADAS concept systems (Cuardian Angel, 2019). Since the follow-up project CARA II has started, the aim is to continuously consult seniors to develop these ideas into standalone products, such as a self-reliability test and driving behavior coach. All concepts were still under development, as the project is still expected to run until May of 2021 (Cuardian Angel, 2019). The third idea, which was brought up several times by one interviewee, revolved around a supportive navigation system that avoids traffic situations considered difficult by seniors during the first CARA project.

"And the other concept is a navigation system that offers seniors the most comfortable route from A to B. As you get older, many physiological functions in your body simply deteriorate, which means that you will also find certain traffic situations more difficult and you will get less experience. So, we want to offer a navigation system, which can avoid certain traffic points that are considered to be difficult." [TS]

Both Dutch organizations, that are involved in the project, mentioned various involvement methods to consult seniors, including workshops and focus groups. In the Netherlands, the corresponding senior organization reached the seniors through social media as well as their own magazine and invited them for an open panel application in which surveys were used to gather participants for the project. In addition, pilot tests are used to improve the product based on final iterations.

Involvement preferences

When asked about preferred methods of involvement, interest organizations representing older users mentioned the use of panels and local face-to-face contacts with AV technology developers via senior organizations as the most important. Although, it was considered to take more effort, it was stressed that this was the most preferred as older users considered personal contact assistance extremely important.

"Another way that works quite well is to locally approach those seniors, that are still mobile and like to visit each other, through these types of senior associations. But that takes much more time and more effort and then representative people would have to physically come and have a chat, et cetera et cetera. I would advise against that, but I know that older people would like that" [IO]

Furthermore, interest organization stressed the importance of good facilitation of the involvement. It was recommended to use either interest organizations or external network organizations as contact facilitators due to the size of their networks. One interviewee also suggested the idea of establishing a clear senior representation at car manufacturers on a national level to create a senior-based label certification for AV technology in private AVs.

"If you had something like a senior representation with car manufacturers in, for example, a national club of car manufacturers, you would have the same construction as the 'Association for Housewives'. At one point, they started participating in the design of [...] products, such as refrigerators. That was then being tested at the "Association for Housewives". And then you could receive a label for the approval of the Dutch 'Association of Housewives'. [...] And when it comes to cars, that does not exist." [IO]

4.1.2 Physically disabled users

Involvement methods

While discussing the extent of interaction between physically disabled users and AV developers, all four interviewees representing disabled users collectively shared that there is little to no interaction with AV technology developers, similar to the extent of interaction seen with older users. No collaborative projects have been mentioned between interest organizations and developers, focused on involving users in the development of new technologies. One exception was a case where interviewed members were involved in a PM test, which had to be initiated by the interviewees themselves. Although not involved in any part of the design process, a physically disabled user and visually disabled user were involved in a test ride, after which a short evaluation was undertaken in which the users' thoughts and commentary were noted.

"We are not involved in the development of the vehicle itself. We were there when the line in Capelle aan de IJssel was being built. Then we could comment on it in the sense of; that's good, that's not good. But it is not true, but perhaps for other members of a specific target group who have advised, that we are involved at the level of planned developments." [IO]

As to reasons why there has been no interaction between AV technology developers, two out of four interviewees showed negative expectations regarding the thoughts that developers have of people with physical disabilities. Interviewees argued that there was scarce interaction between municipalities and developers. Municipalities were however also mentioned as a potential facilitator for future AV technology projects, focused on involving users. The little presence of interaction with developers and project involvement were linked with insignificant representation of disabled users in AV technology. Disabled users would not feel represented within AV technology and most industries in general, because developers would have a low priority for disabled users. Developers would not consciously think about involving disabled users in the design of new AV technologies and would try to come up with user needs themselves instead of discussing the specific wishes or needs of disabled users.

"So, I think they are either just not aware of the fact that this is a very specific group that has very specific wants and needs, or they think they can figure this need out for themselves." [IO]

Involvement preferences

Regarding preferred methods of involvement, three out of four interviewees representing physically disabled users first mentioned that these users would need to be allowed to participate earlier in the design phase of new technologies. If disabled users were involved early in the development process, it was argued that the wishes and needs of non-disabled, ordinary users would come along and be jointly implemented. This has the potential to establish a continuous feedback loop even after a technology is finished.

" And if the product is there, you have a continuous feedback loop with your users, and you could also set it up more specifically for people with a disability or the elderly." [IO]

Methods of involving disabled users could have different shapes, depending on the technology and the stage of development. Developers could hire disabled users, who have experience with AV technology as test users or invite disabled users on a regular basis to perform the same task. Developers can also facilitate interaction between different types of users, researchers and representing organizations in the form of panels, where the first interaction between different stakeholders was recommended to be in physical form. Based on personal thoughts, two interviewees recommended the use of focus groups, which should first focus on separate user groups (e.g. solely older, physical disabled users) after which collective evaluation with all user groups was also a possibility. The choice for physical sessions with separate user groups was argued to stimulate interaction between similar users. In addition, the development of life-size design models or mock-ups and prototypes was recommended as this could be tested among several different user groups.

"Well, when the drawing phase is done, then I do think you should exchange thoughts about that. In addition, it is important that the designer builds a prototype based on that drawing, whether it can drive or not. And you subsequently invite those different target groups independently of each other to test the prototype in a fenced off area, so that they really sit down with a group of people. You will be amazed by the different reactions. You get a lot more interaction by really letting people feel and experience the technology instead of using a video conference […] Separately and if necessary, also with a collective session. Even with the 1.5m rule or to what extent it could still play a role, but you learn from it as a designer." [IO]

4.2 AV technology developers

4.2.1 Traditional car manufacturers

User involvement preferences

Various AV technology companies active in the automotive industry stated that user involvement preferences depend on a multitude of factors. Three out of four representatives of traditional car manufacturers stated that a baseline user is used to design new vehicles around, referred by one representative as the 'standard human'. This standard human would have a fixed set of characteristics regarding age, length and weight and would fit roughly 70 to 90% of a population. To approach this standard human as close as possible, one expert stated that user groups to be involved in vehicle development, were defined with a significant size and diversity of younger, middle-aged and older people representative of all potential users in order to ensure the acceptability of products. In addition, although car manufacturers argued that they do not exclude any users, some users that would not fit with the standard human, were not directly included in the design and were subject to adaptations that were to be made later.

"The point is that if you design the vehicle, you design it for 90% of the population that are close to the standard human as I told you. And then for the remaining 10%, you need to just do adaptations" [AI]

Before involving users in the development of new technologies, user groups are envisioned and targeted by creating profiles, which are largely based on marketing predictions. Examples of marketing predictions mentioned by two car manufacturers and one expert included expected customer values and social attributes, such as income, hobbies and occupation. These attributes then influence the user targeting for certain vehicle types and luxury levels. Targeted users are then involved if a development project revolved around the corresponding vehicle type or luxury level. Marketing predictions were said to determine the differentiation in targeted user groups. Although car manufacturers would have similar target groups, marketing perspectives amongst these companies would influence the characteristics per company.

" But the differentiation in user groups with OEMs is often more based on marketing perspectives, like from what social background are people, what aims and values they have, and that has an influence on what kind of car types they are believed to appreciate." [KI]

An influential aspect for the profile creation of user groups revolved around customer data analytics. One car manufacturer representative mentioned that the analysis of customer data was essential to be representative of the size of the customer base. Data collected was analyzed to map how users used various functionalities and to extrapolate driving behaviour. This had the potential to be used in future AV technology systems.

if you want to be representative on our customer base, which is one hundred million customers at least. Then we talk about data, not interaction. […] So, we have a data centre on the customer data use. So, we

understand very detailed how people use our functionalities. So, we try to extrapolate their today's behaviour to future automation systems by analysing the data. [AI]

While further discussing AV technology, it was argued that, besides traditional marketing predictions, user groups would be targeted based on the level of automation and the automation functionality, referring to the road scenario in which an AV would have to function. Examples mentioned by one car manufacturing representative included the highway automation functionality and the city automation functionality. Wealthy family households were included as the target group for highway automation, whereas if the focus lied on city automation, the target group would consist of the whole society. It was argued by the same interviewee that the highway automation functionality would act as a promotor of brand values, which was considered one of the main reasons for targeting and involving a specific user group in the design and development of new technologies.

"So, we are looking into the profiles of who is driving long trips, who is driving long daily commutes. And these are typically, let's say, family households. Mid aged. And with a quite wealthy background. This is, let's say the key target group of automation and vehicles for a highway." […]
And so, we see the automation on highways, as a kind of promotor of the […] brand values. So, we are sticking to our target group that's obvious and normal and simple as it is. [AI]

In the end, targeted user groups to be involved in vehicle developments, seemed to be most dependent on the marketing focus of car manufacturers. One car manufacturer illustrated this by mentioning an industry-wide focus on vehicles that were sold the most and which user groups were willing to pay for higher luxury levels with newer technologies, such as AV technology. Because AV technologies were considered expensive, the technologies would be first introduced to more premium luxury vehicles, after which they would be deployed in other vehicles. The design for automation functions was also deemed very similar to the design for other vehicle functions, such as ingress/egress and interior design. Similar to the user profile creation based on expected vehicle preferences, different AV solutions with varying automation levels and functionalities were deemed fitting for different user groups. These factors would influence the users that are envisioned, targeted and involved by car manufacturers, if new developments revolved around AV technology. At the same time, two manufacturers added that they were aiming to create appropriate AV solutions for all types of users.

"So usually and traditionally with OEMs, we start at a premium brand, putting new technology in, and then we go down the line, and try to introduce technology in other vehicles […]
So, these automated driving functions are not far away from the approach we have today for designing our function. […] the result is that you have different types of vehicles, and this will also be done also for automated driving. So, you don't create automated driving for people that are 25 years of age, and neither for people that are 65 years of age. So, it should be covering, preferably all of them." [AI]

While further discussing user involvement preferences, one interviewee mentioned that there seemed to be a shift in design thinking that would become in favour of involving users early in the development process of new vehicles. At the same time, car manufacturers would struggle with involving users early on, because of a relatively small focus on ergonomics or "human factors", compared to a technology-focused perspective. One expert argued that despite improvements over the last decade, human factors engineering was still in need of improvements. As the number of employees working on human factors would lie significantly lower compared to regular engineers, this would cause discrepancies between what users do and what engineers envision. It was argued that this was one of the causes of accidents with AVs

"But roughly, I would say in terms of the OEMs you have 300 to 400 engineers to one human factors person in a company. […] And mostly they think it's about ensuring the technology works, rather than whether the technology will be used and understood by the user. […]

So, I think again, it comes to that engineers don't think that what they've engineered will break. And unfortunately, we've seen, because of the accidents, that people do things that the engineers were not envisioning, which is incredible." [KI]

Older users

In line with previously mentioned results, most projects that involved users, partially involved older users to approach the standard human as possible in the design, provided that customer clinics were used as involvement method. At the same time, marketing predictions, automation level and functionality and customer data analytics influence the targeting and involvement of user groups for AV technology projects. If one of these factors would fit with the elderly target group, they were argued to be involved in the project. However, older users were not specifically mentioned as a target group when discussing AV technology projects. In addition, very few AV technology projects focussed focus specifically on older users. It was argued by one expert that car manufacturers would find it challenging to involve older users and test new systems on them for privacy and safety reasons. In line with this, two car manufacturing representatives talked about looking at older users using special adaptable ergonomics suits, that would limit the users' movement speeds. This suit was used by ergonomics engineers to perform trials on vehicles, aimed at fitting future vehicles to the characteristics of older users. It was confirmed by both one expert and governmental organizations that there was a tendency amongst traditional car manufacturers to test new AV technology using own employees, whether it involved a field test or internal development.

"And you might know this kind of helmet, which is possible or suit, which you can wear and then you feel like being an elder, an elderly person. So, you are restricted in your movements, you're restricted in your sight and hearing, and especially as the head movement is restricted because of the neck issues of elderly people. And with this suit, we do many trials on how to interact with our vehicles so, that's part of our ergonomics department to really fit the future vehicles to these requirements" [AI]

Physically disabled users

In line with previous results, it was mentioned by several interviewees that cars and AV technologies were to be designed with the standard human in mind. As most people worldwide would fall in this category, adaptations for specific user groups, including physically disabled user would come later. This also had to do with the fact that higher levels of AV technology, that are absent as of today, would still need to be further developed and the technology needed to mature before human factors aspects of older and disabled users regarding automate driving were taken into account. These factors were also brought forward by other interviewees active in governmental organizations, knowledge institutions.

"Because you clearly notice that they are still working on getting the technology working." [NG]

"And what you typically see with a relatively new technology, that there is a first focus on the technology itself to get it reliable. And then at a kind of second or third stage, there comes an interest in providing more comfort, and more optimization towards the user needs." [KI]

In the current situation, special adaptation vehicles were made for disabled users, using partnerships with special separate companies in dealership networks. It was mentioned by only one car manufacturing representative that disabled users would also be involved in developments on special adaptations vehicles. In addition, no specific preferences were mentioned to involve physically disabled users in projects

revolving around AV technology. Although physically disabled users were mentioned to be thought of, it was argued that these groups would start to benefit from this technology in vehicles especially made for cities. As several car manufacturing representatives and experts argued that the industry was focused to venture into urban mobility, it was argued that these users would become important in the design of future automated vehicles

"I think the traditional European manufacturers are catching up on what the Waymo's and the new players are thinking of using automation for. So, you know, your pod-like vehicles, they definitely want to focus on the people who cannot drive." [KI]

"We have some smaller corporations with […] service and supply companies, who care much about disabled people. So, we are looking into the market of, when we come to future designs of vehicles for cities, how to for example, better support the introduction of wheelchair space for our vehicles [AI]

User involvement methods

In line with previous paragraphs, AV technology developers would include a variety of different people to approach the standard human as close as possible. The main method of involving users were considered to be the customer clinics or customer studies, used by all respondents for involving users, where two car manufacturing representatives argued it to be an unofficial industry standard. Customer clinics were mentioned as an encompassing term for performing studies on users based on internal developments. During these clinics, developers would have people interact with prototype vehicles and specially built simulators to collect data.

"So, the interaction takes place via customer clinics or customer studies. Those customer studies are more or less an industry standard. We have people interact with prototype vehicles, we have people interact with simulators." [AI]

It was argued by one car manufacturer that vehicle owners were usually invited for these clinics to test prototypes, after which they would be subject to an anonymous testing procedure. At the same time, target groups with corresponding preferences for vehicles and automation aspects were also of influence for the composition of customer clinics in line with previous results. Other involvement methods, that were brought up by car manufacturers and experts included focus groups, simulation studies and customer surveys. Focus groups were aimed at sparking discussions with users, to see what people envision of AV technology and how users thought of prototypes. Focus groups were also used in several different formats. One interviewee mentioned the use of an exploratory electronics groups, which would first identify if something was possible, after which this group would further explore the idea and research it. Other focus group sessions revolved around wish composing as well as co-creation in collaboration with start-ups. Simulation studies were used if car manufacturers solely wanted users to interact with simulators for collecting data on new systems. If users were not able to be directly involved, several car manufacturers also used customer surveys to gather expectations. This allowed them to gather customer data on a worldwide scale using web-based surveys. If conducted in a certain order, it was argued by one car manufacture that these involvement methods could be efficiently integrated to complement each other. Initial collected information from focus groups and surveys could be used to develop a prototype for a driving simulator or test vehicles, which could later be used in customer clinics and field tests. This also allowed car manufacturers to collect data and perform adaptations based on these data.

“And of course, all those different approaches basically integrate with each other. So, they give us a possibility to start with a focus group or to start with a web survey and based on this you can come up with a prototype for a driving simulator, or integrate them into a test vehicle and then people can really interact with these kinds of technologies. And this gives us the data really to adapt the human machine interface, or the human factors in general to the needs of our customers.” [AI]

In addition, some experimental methods were mentioned revolving around virtual reality-based systems and the use of design "charays". Design charays were described as intense brainstorm sessions where participants would try to conceptualize what they were thinking with drawing, throwing items around and discussing each other's thoughts. Although a design charay had the potential to involve users, the involved car manufacturing representative mentioned that this method was used solely in collaboration with Stanford University to create design guidelines for AV interfaces. Virtual reality-based systems were still in development and planned to look at the interaction between AVs and road users. It was argued that this would be very suitable for involving users while not exposing them to any risk. Although car manufacturers would still rely on a combination of digital and physical means to involve users, one expert argued that the use of virtual tools such as virtual reality was argued to be used more extensively before

the year 2000. In line with corresponding literature, this statement can be confirmed (Lehner & DeFanti, 1997; Purschke, Schulze, & Zimmermann, 1998).

" Also, what you saw when virtual reality became a bit more common and popular. But that's now like more than 20 years ago, you saw at that moment also some attempts to do co- design where ordinary users and customers could actually make their intentions and ideas feasible within a virtual environment. I think that has reduced a little bit, this approach." [KI]

Older users

When asked about specifically involving and interacting with older users, one interviewee mentioned that customer clinics always contained several older users. Older users were also involved in almost every other way a "normal" user would be involved in. Customer clinics would be initiated by inviting a couple of hundred people, that would be good representation of the overall population.

"So, with regards to taking elderly drivers into account, usually we conduct our customer clinics. So, this is very much focused on having a sample, which is quite representative for the overall population. So, we try to get enough young people, middle aged people, and also elderly people as good as possible to really have a good representation of the overall population available when we do that." [AI]

Although little development projects that were mentioned, solely targeted elderly users, one specific project called Alfasy was brought forward specifically aimed at developing an age-appropriate HMI, which involved a more significant number of older drivers, compared to other products. This project further distinguished itself from other user involvement projects by using screening methods to identify older users that could be prone to becoming motion sick in AV simulator machines. As the project relied for a large part on simulation testing, this was done to exclude users, who were sensitive for becoming 'simulator sick'. In addition, a separate medical examination was conducted to identify different impairments, which also distinguished the project from other user involvement projects.

"I think there was also a medical examination taking place to check if people had any kind of visual impairments or hearing impairments and that was done together with this screening for simulator sickness. And this is something, we usually would not do in a, so to say, normal study. That's something which was probably special about the study." [AI]

Interviewees indicated that research projects would also have a specific focus on older users. One co-creation study was mentioned, which looked at how older users would transport themselves to a doctor in rural areas, whereas two other research projects focussed on minimization of driver cessation and potential health monitoring systems. One interviewee argued that in-vehicle health systems would be especially relevant for older adults, as these systems could mitigate crashes in the event of cardiac issues.

"We also have a section of research on health monitoring systems. And this seems particularly relevant for older adults. And so, there's a lot of visions for that as it relates to sort of cardiac events, and the sorts of things that you might experience on the road and thinking of ways that safety systems can prevent crashes from those types of things" [AI]

Physically disabled users

When asked about specific involvement methods for people with disabilities, only one interviewee expected, with some uncertainty due to the size of the company, that the corresponding special customer clinics were used to design specially adapted vehicles. In line with this, these vehicles can be provided by dealership networks affiliated to the car manufacturer, which was expected to be present amongst the entire industry.

"We build and sell and do adaptation vehicles for disabled people. And how can you do that without involving them in a specific customer clinic. It's impossible. So, you need to have them. I mean there is nothing worse than a normal engineer without any understanding of limitations of disabled people, that tries to build up a car for them. Otherwise this will not work. So, I'm sure that those people are also involved." [AI]

In line with Gyi et al. (2004), it was mentioned by one car manufacturing representative that computer models, based on anthropometry data are used in the design of new technologies. However, it was unsure if this was also specifically used in the design of special adaptation vehicles for physically disabled users.

User involvement motives

In line with Fischer et al. (2019), representatives from car manufacturers were asked whether they chose to involve older people in order to improve the quality of products (material motivators), to identify a better understanding of the surrounding environment (soft motivators) or to grant older people more participation (normative motivators). One interviewee did mention that the representing OEM considered older users important to look at to consider in the design as the worldwide population is aging, leading the market to shift towards elderly people. This sketched a clear business case why there was an increasing focus on older users, which can be considered a material motivator. In line with previous results, research projects with different universities, that were brought forward by interviewees, would often focus on older users. One interviewee mentioned several projects, one of which aimed at sustaining seniors with driving abilities, allowing for more participation. This was therefore considered a normative motivator. In addition, the same interviewee stressed that the corresponding company had a clear sense of respect for older users.

"We've always had a set of research projects with different universities on older drivers to sort of minimize the need for driver cessation. So, we had some research early on about... because as you age your sort of useful field of view, you might be aware of this research, decreases. And so, we had some research to look at how to reduce those negative effects on driving." [AI]

It was argued by one expert that material motivators for inviting older users would be the most present especially within German manufacturers, because the quality aspect remained extremely important from a competitive point of view. At the same time, there was a shift towards normative motivators within the industry, because of societal and ecological interests that would put significant external pressure on traditional car manufacturers to focus more on all types of users.

"I would say but I can be wrong, of course, but I think […] focusing on the quality, that's still something very important. […] But maybe that's also shifting with a notice that there is a lot of pressure also on the OEMs. They also rely on public money in many occasions, so they have a growing responsibility for the whole population also, for example, with regards to ecological aspects and pollution, etc." [KI]

One interviewee mentioned an additional motivating factor for involving older users in the development of new technologies. Older users in general would be more willing to pay for different car aspects, including AV technology, which was an additional reason for inviting them. One expert confirmed that this was one of the reasons, why the industry has had a large focus on this target group to begin with.

"this willingness to pay is missing on your list because, because this is for those who can pay that and afford that. Then of course you invite them to discuss, which kind of materials they like, Is it wood or leather or something like that or like aluminium. So then, you start designing your vehicle and this is one of the reasons you may involve elderly people of ages of 50 and above, because they can afford that vehicle." [AI]

4.2.2 People mover AV technology companies

User involvement preferences

The two interviewed PM companies both expressed that intended target users are comprised of every potential user that uses PT services. Both interviewees also mentioned that it was the company's goal to make the vehicle suited for every type of PT user. At the same time, these companies stated that they are obligated by law and regulations to follow this in their overall vehicle development.

"Well, the answer might be a bit generic, but we see pretty much all users of transport systems as a target for autonomous vehicles. The idea being to use the autonomous vehicles to change the way we approach cars and vehicles in general. So, the regular users of cars are our target in terms of changing their habits so that they do not use personal cars but prefer shared and autonomous vehicles with a more public transport, or at least shared mobility perspective." [PM]

One interviewee did acknowledge that their vehicles could be especially useful for older users and blind users as there are no driving components in their vehicles and both interviewees showed that there has been a clear focus on providing a proper service for wheelchair transportation. Additionally, although these companies have mentioned efforts to make their vehicles as accessible as possible, one interviewee mentioned that the company had no preferences for more direct user involvement.

"Well to be honest. No, because the people knowing it the best, are the companies operating the transport services. You know, they have their drivers in buses, in metro and trams, having contact with the users every day. So, they're already very good at gathering the advice and the opinion of people. So, there's not really a will on our side to do this job." [PM]

User involvement methods

Regarding the extent of user interaction, both interviewees mentioned that there is no direct interaction between them and end users. The interviewees had regular discussions with transport operators, which act as an intermediary actor between them and the end user, similar to PT structures. Transport operators were considered to discuss different design aspects and options with user groups after which relatively final advices are discussed with the PM companies. One interviewee mentioned that there were no specific meetings with transport operators about different user groups.

"We do not specifically have meetings about impaired people with the transport operators. The transport operators would come to us once in a year when we do like a general meeting at the beginning of the year and they would outline the modifications they would like to see, including the ones from user groups." [PM]

User involvement motives

Because both interviewees mentioned that PM companies have no direct involvement of older users in the design of their AV technologies, there were no direct user involvement motives identified.

4.3 Technology Design

After discussing user involvement preferences, methods and motives with AV technology companies, it was explored how the involvement of older and physically disabled users has influenced current AV technology developments and could influence future AV technology developments. Furthermore, representatives from interest organizations were asked what users' expectations and expected attitudes towards AV technology would be as well as their preferences for AV technology adaptations and overall recommendations. The following chapter will first discuss abovementioned aspects for both user groups followed by car manufacturers and PM companies.

4.3.1 Older users

Technology expectations

When touching aspects related to technology expectations, interviewees were asked about the expected attitude of seniors towards AV technologies. Most interviewees initially expected that seniors would be hesitant towards the technology. Although the idea of AV technology in private vehicles is expected to show potential in providing increased mobility for senior citizens, most of the interviewees agreed that the idea of fully autonomous Level 5 AV technology would be perceived as uncomforting. One interviewee argued that most seniors would be conservative and stick to what they grew up with, because this gave a psychological feeling of familiarity. Their conservativeness was also partially caused by the laggards' label that would be put on older users throughout parts of society. As seniors considered themselves safe drivers, it was also mentioned by three interest organizations that seniors value keeping their independence. Level 5 autonomy was therefore not idealized, whereas the idea of supporting systems within Level 3 automation were deemed a golden midway on highways and other traffic situations that were perceived by some as ''dangerous'' and are therefore usually avoided. Supporting systems were acknowledged by some as ideal or potentially beneficial as older users would consider trust and safety as extremely important but would likely not want to fully depend on fully autonomous private AV systems.

> *"What I can say regarding the results is an overarching theme that kept recurring; they like to stay in control. I did see a large group which didn't want to become solely dependent on these systems". [TS]*

However, it was argued by several car manufacturers, experts and one governmental organization that their attitude would become increasingly positive, after experiencing any form of AV technology. Experiencing the technology was considered essential instead of being told about it. Furthermore, two interviewees involved in the CARA project mentioned that seniors were increasingly becoming interested in learning more about advanced technologies.

At the same time, three interviewees representing an interest organization for seniors expected that seniors were likely to avoid overly complicated technologies. This was given as one of the main reasons that seniors quit driving although the idea of technologies as a helping hand was also acknowledged. In line with this, one expert confirmed that, although open to technology, elderly would find it challenging to deal with this technology. In addition, seniors were argued to be unaware of current driver assistance systems. Seniors were more likely to discover the on-board systems by accident or by hearsay from their closest contacts.

"[…]. Going through the booklet, that may have to do with our conservativeness, it takes a while before you either accidentally discover such a system or that it is pointed out to you by friends, acquaintances and colleagues that your car also has something like that. " [IO]

This was confirmed by both experts, referring to studies that concluded that ordinary users already had a relatively large unawareness of in-vehicle systems and that elderly users would not have more knowledge on these systems. One expert even pointed out that only 10 to 15% of ordinary users were aware of an ACC system and knew how to use it. This number would lie even lower for senior drivers potentially resulting in dangerous situations when they would try to use such a system on the road.

"And you see from studies, that a lot of ordinary users already don't really know what kind of systems are in their car, and how to operate them and what the kind of system limits are. So, I have no reason to expect that it's easier for this particular target group." [KI]

Technology preferences

When discussing preferences for AV technology aspects, two interviewees from within the CARA project mentioned feedback on driving behavior to be perceived as preferential for seniors in line with results from the first CARA project. Feedback on driving behavior was considered very important and although the largest part of participating seniors was fine with feedback during driving, a significant group pointed out that feedback after driving was also very much preferred. In line with adequate feedback, adequate education or training courses also needed to be provided to guide seniors in becoming familiar with private AV technologies. This was also argued by one expert comparing it with pilots being trained to operate certain systems with autonomous capabilities. Training could either be delivered with the vehicle itself by manufacturers or co-developed by senior organizations. In addition, it was recommended that this could come in the form of in-car training, offering more autonomous capabilities with more user experience.

"So that's a development that we see and how can we then offer those trainings? There are some first thoughts about a kind of in-car trainers, that the car could also adapt to how advanced you are with your car and how experienced you are. So maybe in the beginning, when the car is new to you, it offers other functionalities or less functionalities until you have gained a level or certain level of experience or something. So, these kind of ideas about adaptivity, that's something what a lot of interest is in right now." [KI]

Alongside training, three out of four interviewees representing seniors mentioned the importance of keeping a personal method of contact with car manufacturers providing private AVs in case of emergencies, which was in line with the first results from the project CARA II. Initial results indicated that from the three concept systems tested, the CARA navigation system and driving coach system were perceived quite positive, but that seniors wanted to be able to have a device, such as a button to indicate stressful situations in the final version of the product (Eichhorn, 2018). Additionally, it was recommended by another representative from an interest organization that seniors would benefit the most from a helpdesk, that could provide personal contact assistance in case of a problem or malfunction.

"With the possibility of having a potential permanent incidental contact, but preferably being permanently in touch with a kind of helpdesk, which can intervene immediately if something starts to beep and the senior panics." [IO]

Having a form of personal contact assistance was also confirmed by one interviewee representing a

regional governmental organization when discussing public AV technology. During a PM project, involving users, it came forward that older users especially valued the presence of a safety steward in an autonomous PM shuttle during test drives. It was argued that this technology granted the governmental organization a choice whether they wanted to use a safety steward, depending on the target group.

"And what we have also seen is that this target group benefits greatly from such a host. Our goal is not necessarily to have anyone in the vehicle as a host on all those routes, if this could work anywhere. It is quite possible that if you drive from a retirement home to a care center, you consciously choose to have a host on such a route." [RG]

When asked about whether seniors would be open to use public AV technology, one interviewee mentioned several conditions, including a degree of affordability, accessibility, convenience and added value that would have to be met by governments or developers. These would have to be recorded in laws as detailed arrangements to facilitate this form of AV technology. If these conditions were met, older users were likely to use public AV transportation services with potential door-to-door functionalities. Two interviewees representing national governmental organizations also expected that PM shuttles or any other form of public AV transportation services would be more interesting for this group than private AVs. AV transportation services would fit better in public domains with a timetable and could contribute to achieving more accessible mobility in rural areas where existing PT services were considered to disappear.

"And you see specifically for this target group that actually only those people movers are interesting. That is why Groningen is also working on this. Groningen says yes; we have a lot of villages that are somewhat remote with people with walking difficulties. They do have a transport need when you have to keep normal public transport in the air with a driver and a timetable, that is no longer possible. But suppose we can have an autonomous shuttle drive on-demand so those people can at least just do their shopping. That is actually one of the few places where people think in this way" [NG]

Although a small number of older users were argued to be able to afford private AV technology, one interviewee stressed that personalized financial offers would be suitable for older users. In line with expressed expectations regarding the attitude of older users, this could partially decrease the experienced hesitance towards purchasing a private vehicle with higher levels of AV technology (Level 3 and above) in the future. Besides financial technology needed to feel secure as if a human driver was controlling the vehicle. This was also stressed by one expert, indicating that older users would not want to use the technology if the technology acted too abrupt when controlling the vehicle.

" And it needs to be designed in a way that is nice to have. So that if it's replacing me as a driver, it drives as I would like it to drive. And if it doesn't, then they don't like it and they turn it off." [KI]

4.3.2 Physically disabled users

Technology expectations

In line with previous results, interviewees were asked about expectations of physically disabled users towards AV technologies. Interviewees expected that it was hard to predict the expectations of physically disabled users as this group was argued to be as heterogenous as people with no disabilities. One interviewee argued that differences between AVs and PT services would most likely fade away over time. It was mentioned that most people in the future, including people with physical disabilities, would not own their own private AV, but would rather use public AV services. In line with interviewees representing older users, two interviewees representing disabled users came forward with an important attitude aspect that this could grant more independence for both older and physically disabled users.

"It is the future. It is the ideal solution, the key to independence. I am 100% convinced that elderly people and people with disabilities will use it if the technology is possible" [IO]

When asked about a scenario where future regimes for private AVs could pose privacy problems for vulnerable users (Glancy, 2012), one interest organization representative argued that private AVs could indeed pose problems for people with physical disabilities, as they might be obligated to give their information for specific adaptations. Although giving up information, was expected to lead to more functionalities, it was argued that every user should be able to make a choice for privacy or more functionalities. At the same time, the widespread introduction of Level 5 private AVs was expected to pose social issues, such as increased loneliness as people with physical disabilities would no longer need chauffeurs or people to escort them around. In addition, this could pose problems if an accident were still to happen.

"In itself it is of course also loneliness, the social function that transport also fulfills, which then partly falls away. Because, for example, you no longer have a driver or no longer have fellow travelers. And the guidance aspect; if something goes wrong, there is not someone there with you right away." [IO]

At the same time a theme potential cost issues of private AVs were brought forward by all interviewees representing related to private AVs for physically disabled users. All interviewees representing physically disabled users were on the same line on the fact that people with disabilities on average make low incomes and despite receiving significant mobility increases, could therefore be excluded if future implementations of AV technology turn out expensive. Related to this, when asked about whether personalized financial arrangements would be suitable, all interviewees mentioned that special arrangements will have to be made in a way for the technology to be financially feasible for physically disabled users.

"You often see, with people with disabilities, not always, but often, that they are unable to work and have not been able to enjoy normal education, which means they have less chance of a job, which in turn means they have less income and higher healthcare costs. So, then you are left with that income which is often lower. And if there are promising technologies such as self-driving cars, then I think that this group, although they would benefit greatly from this, would not be able to use it because it would be too expensive. So, I think that's still an issue." [NG]

Other considerable factors stretched around the theme of the expected usability of both private and public AVs. Fully autonomous AVs could show potential in making physically disabled users less dependent on other people and PT facilities, which was considered relatively inaccessible. Private AVs on the other hand were argued to cause difficulties as users with a disability would most likely experience trouble in taking over control of a private AV when the boundary limit of the system is crossed.

"So, this changing role of the driver, that you become a kind of supervisor that should be able to understand the system in combination with the ability to take over when it comes to its boundary limits that's already quite challenging for an ordinary user, I would say. And then I think disabled people may experience that as even more bothersome, as even more difficult." [KI]

Technology preferences

When discussing preferences for AV technology and potential adaptations, interviewees mentioned similar points when compared to interest organizations representing older users. Physically disabled users would most likely prefer public AV services over private AVs. Personal guidance would also remain important in the case of malfunctioning in line with expressed technology expectations. AV technology companies should therefore focus on creating simple systems, that would be comprehensible for all users.

"And I think the understandability is very important; that you just keep it as simple as possible. Of course, this applies to everyone and also to people with disabilities, to keep it as simple as possible." [IO]

At the same time, interviewees brought some notable differences forward in expected preferences of physically disabled users. Physically disabled user would rely significantly more on adequate arrangements to make public and private AVs financially feasible, in line with expressed expectations around potential cost issues. Suggestions were given in the form of licensed tax cuts, subsidies on a national level and adaptations in municipal laws for financial support. Different expectations were also stressed regarding preferences for training or education. Although one interviewee did not believe that special education or training was needed for physically disabled users, two interviewees mentioned that some form of digital training for private AV technology would most likely be beneficial to handle complementary apps and support systems, thus ensuring a degree of digital accessibility.

"Yes, I think for some parts of the concept, perhaps if you are using an app, you might need training on how to use that app to reserve a car, for example. If you have a wheelchair and you need to secure it in such a vehicle, you would probably have to do that alone, while a driver is currently doing that. I think for certain parts you should definitely offer an adequate manual or extra support." [IO]

Other recommendations focused on in-vehicle aspects, expressed by individual interviews.
Similar to current PT services, public and private AVs should also include adequate ingress and egress for disabled users and adequate safety systems for wheelchairs. In line with expressed technology expectations regarding the potential difficulty of taking over control, one interest organization representative recommended that developers should include systems with adjustable force control and adequate positioning if a physically disabled user had to retake control in lower automation levels (i.e. up to and including Level 3) when asked about preferred adaptations.

"I think in particular any adjustable control systems that is needed to operate the vehicle. And also the positioning of, for example, control keys, as keys or joysticks will likely be used with higher autonomy". [IO]

4.3.3 Car manufacturers

Current AV technology developments

While every interviewee could not go into specific details on user experiences from involvement in AV technology projects, it was assured by two interviewees that users had mostly positive reactions and were in some cases surprised of the technology. It was argued by one car manufacturer and confirmed by one expert that overall positive reactions were a result of short testing and positive first impressions. Longer testing period with extensive driving was argued that it could generate more relevant criticism from users. Moreover, one interviewee mentioned that their data analytics center provided insights into how people used current low-level AV systems.

"I talked about this data analytics center. And with this data analytics we now, much better understand how people use these systems" [AI]

The same car manufacturer representative also mentioned some implementations, where it was not clear if they were based on active user involvement but were considered important to mention. These revolved around feedback systems in the steering wheel, which were thought to be helpful for disabled users. When asked about implemented adaptations, that were based on user input, most mentioned various aspects, which were sometimes not able to be pinned to one specific user group, due to the composition of customer clinics. All implemented adaptations revolved around lower levels of automation, i.e. Level 1 and 2, present in vehicles today. Two interviewees mentioned the system feedback behavior as an important aspect.

"What we have understood now is the feedback to the driver. I don't know if this is specifically something for young or old people, but for users in general this refers to when the system is active or not so at what times the system cannot work and give the control back to the driver. This also refers to how you should announce that to the driver, so that he or she knows that the system is not active anymore" [AI]

Linked to this, one interviewee mentioned increased speed range support from 0-210 km/h for Adaptive Cruise Control (ACC) and adjustable AV settings in their Level 1 and 2 vehicles regarding preferred speed and distance to other vehicles. This was done to make it suitable for various driver ages. Another interviewee mentioned user testing to have led to company-specific guidelines on how to minimize driver distraction in the design of new vehicles as well as car symbols that are easier to comprehend as part of efforts due to their ISO involvement. A final category of adaptations that came forward, based on general user input were related to the visual and acoustic HMIs. One interviewee mentioned that customer feedback led to clear decisions regarding the location of various driver assistance aspects, such as parking and ACC and the timing and appropriateness of the acoustic HMI.

"And what we adapt based on these customer studies is regarding the visual HMI. Is it easy to understand? Where is it located? Is it located in the cluster display? Or is it maybe necessary to locate it in the center stick? So, maybe this is an example which goes a bit more into the details. Because if you look at most vehicles, driver assistance HMI for parking is usually in the center stack. The driver assistance HMI for other stuff like adaptive cruise control, it's in the cluster display. That is also something which comes out of these customers clinics." [AI]
[…]

"Other examples include the timing and the appropriateness of acoustic stimuli. Do users want them at all? Are they too bothersome or not? Are they necessary? How conspicuous do they have to be? And this is closely linked to the warning or information strategy at all. When do you give a warning to the user? When does the user, the driver have to take over? How early does that have to be and how do you do that? Do you do that with visual or acoustic HMI with vibrations." [AI]

When asked about standards for AVs influencing the usability for all types of users, two car manufacturers mentioned no awareness of clear AV standards, but it was argued by one interviewee that this was due to the unreadiness of the technology. On the other hand, one interviewee mentioned the presence of an SAE standard for accessibility that was adapted for automated vehicles. Furthermore, another interviewee specifically mentioned to work with an ISO standard focused on human-centered design.

"from my work point if we talk about norms and standards, there are those ISO norms. 92- 41- 110 for dialogue principles and the ISO 92 41 210 for human-centered design for interactive systems." [AI]

When asked about legislation for AVs influencing the usability, three out of four interviewees mentioned no awareness of specific AV usability legislation but were aware of legislation regarding the approval and admission of AV test vehicles on the road. It was confirmed by one interviewee representing a national governmental organization that these laws were the only guiding regulation for AVs.

Older users

As mentioned before, although few projects and involvement methods have been specifically focused at older users, most specific experiences with older users revolved around positive reactions. In line with a previously mentioned field test with Level 3 automation, one interviewee mentioned that older users experienced fear reductions after experiencing the technology. It was also argued that older user would have to experience it to like using a private AV. This was confirmed by two experts as necessary for building trust for this user group.

"And they were very scared and said; well I don't trust the car that it can run smoothly this way, and then we started to drive, and they felt comfortable and then they felt relaxed and then they started turning their heads to the rear passengers and talking while being driven by the car. And when they exited the car and they left the car, they said: Where can I buy it, how much does it cost I want to have it. So, it was a complete change of mind with the experience. This is the key point; you need to experience the thing and then they are completely convinced." [AI]

At the same time, another interviewee representing a car manufacturer mentioned a study, which showed that reaction times were not that far apart between younger and older drivers when they needed to take over control of a low-level AV system. In addition, when referring to the Alfasy project, one interviewee mentioned that there were no big differences in the judgement of the corresponding technology between older drivers and younger drivers. Aimed at creating an age-appropriate driving assistance system, first results of the project show also that there have been positive reactions from members within the project (Alfasy, 2018).

When asked about specific adaptations, because of older user involvement, one interviewee mentioned systems, that were easier to interact with for older adults as a result of previously discussed driver distraction guidelines. Furthermore, one interviewee mentioned adaptations that included a focus on implementing measurement technology for the objectification of driver-feeling, which has been implemented in current Level 1 and 2 systems.

"Yes, running these studies for a while, we understood that people are very much different in terms of how comfortable they feel when the car is moving. So, we looked very deep into acceleration and deceleration and lateral acceleration and deceleration. So, at the lane change or in curves. So, what we have now, we have a team of some engineers, who are adding measurement technology to standard vehicles and try to objectivize the feeling of people driving a car. So, what we're doing is objectification of driver-feeling" [AI].

Physically disabled users

Apart from special adaptation vehicles, that have been mentioned previously, no interviewees mentioned specific AV technology adaptations based on physically disabled user input.

Future AV technology developments

When asked about suggestions from user-based input, that could be implemented in future AV technology developments, most suggestions were once again pinned down to general user input, where older users did participate. However, interviewees were mostly unable to point specific suggestions or developments to specific user groups. It was mentioned by one interviewee that future AV developments, based on customer studies and data analytics, would be rolled out every four to five years in service packs.

"So, what we are having in a way how we roll out these technologies is in so called service packs, which is a kind of bundle of electronics measures which come to all cars at the same time every three or four years. And with these kind of milestones and steps ahead, advancing the technology, we always look deeper into these focus groups and data analytics so for example for the moment we are preparing the 21 launch for technology, and the next launch will be somewhere between 24 and 25, and we are just now doing customer groups and data analytics for the next generation. So, four to five years in advance we do this typically." [AI]

Two interviewees mentioned the aspect of automated parking as a major focus point for future developments, based on user input. Another area of AV technology, which was mentioned as a probable future development based on user input, revolved around vehicle-to-pedestrian (V2P) communication. It was argued by one expert and one car manufacturing representative that the industry was discussing the possibility of a standard for this within a special ISO group. At the same time, the same interviewee representing a car manufacturer mentioned that research and user testing led to the conclusion that communication with a light-based solution would not be the most effective as vehicle movements and user movements distribute enough data.

"So, when you think about automated vehicle pedestrian communication, you probably initially think of some sort of lighting or something, that you put onto the outside of cars. But what we see a lot from our research is that the movement of the vehicle communicates a lot of information, and the movement of the pedestrians communicates a lot of information." […]

"And the reason that I'm mentioning this is that, this is a direct way that sort of user testing has led to a shift in how people think about these technologies and the shift is that it's now clear that most people are thinking about instead of adding lighting to the outside of cars to communicate, thinking about movement as a primary mechanism to communicate with other road users." [AI]

Other mentions of standards, which could influence the usability of AVs for vulnerable users, focused on the possibility of a general SAE standard for AVs. It was argued by one interviewee that standards could significantly increase the mobility of AVs for vulnerable users, if current targets from the European Commission were implemented. In addition, as part of the L3-pilot project, several interviewees mentioned their involvement in a code of conduct, in order to provide AV technology design tools. Furthermore, it was mentioned by almost all car manufacturers that it was likely that the corresponding company would move towards becoming more of a "mobility company", which was specified in various ways. Several interviewees mentioned their developments as part of their venture towards urban mobility, where they would focus on developing PM shuttles.

"and people mover shuttles are on the list and this is also announced; [blank] will have automated shuttle movers in 2022 and we will have a big showcase on that in 2022 so it means, what was for us a small or niche product, it's changing now to maybe be a bigger part of the production in some years maybe. [AI]

One company also mentioned efforts to focus on providing more mobility services, which also involved shared mobility with subsidiary brands. In addition, a concept for an interactive AV environment was discussed, in which AVs and assistive robots would interact with the end user.

"in January [blank] announced something called the […], which was announced at the Consumer Electronics Show. And […] is basically this concept of a […] blended environment where there's both assistive robots, automated vehicles and people interacting in the same environment. […] And what this shows is not only our transition towards being more of a mobility company, but also leveraging some of the partner robot stuff that we've done in the past, where you might have assistive robots that are also part of the traffic system. [AI]

Other factors that came forward included special recommendations related to policy subjects for AVs. The absence of a dedicated focus on older and physically disabled users was linked towards the relatively low level of SAE automation in current AVs. It was assumed that the focus should first be laid on appropriate laws surrounding the implementation of SAE Level 3 as well as the appropriate testing of SAE Level 4 and 5. Once this was reached and both the vehicle, technology and automation functionality could be adequately managed, then there would be a more suitable focus on older and physically disabled users.

"It will take time before all technological challenges and legal problems with regard to autonomous technology are solved. I currently also assume that legislation and the public authorities probably first of all need to start out and come up with standards, with best practices and applicable laws and codes for SAE Level 3 and sorting out how to appropriately test SAE Level 4 or 5 systems before we can successfully tackle certain standards which apply specifically to elderly people or disabled people in autonomous driving."

In addition, one interviewee assumed that a cost-sharing system to partially finance Level 5 AVs for physically disabled users, could see the light of day, if adequate legislation pushed for it. Besides legislative recommendations, it was also recommended that field tests involving users, would need to be more extensive. It was assumed that this could change the attitude of users towards the technology, once experienced.

Older users

Although it is expected that older users were partially involved in the aforementioned developments, future AV technology developments were nor linked nor based specifically on involving older users.

Physically disabled users

In line with previous results, no future AV technology developments were linked with involving physically disabled users.

4.3.4 People mover companies

Current AV technology developments

Interviewees were not able to go into significant detail when asked about experiences with users and potential adaptations based on user input. As mentioned before, no real direct interaction with end users is present, but this is facilitated through intermediary transport operators. General thoughts about user experiences that were collected, showed that users found the vehicles to give an extra dimension to their transport habits. In addition, non-users are supposedly getting used to the technology being around in the running projects. Both interviewees mentioned that their AV technology developments are also heavily influenced by certain standards and legislation, which are shared from existing PT systems. One interviewee additionally, mentioned the lawful obligation of having a safety steward on board.

"for now on public roads you always have someone on board to accompany the passengers. Depending on the countries, it can be called an operator, it can be called a safety steward. And this person can also help people by first explaining them if they have any questions or even physically help them if they need help to put their seatbelt on. […] Yes, this is not specific to [blank]. It's generally by law. So, for now, you cannot have autonomous vehicles on public roads, transporting passengers without a human presence.

Older users

Although, the interviewees didn't mention any adaptations specifically based on transport operators, transport operators had extensive discussions with separate user groups, which included physically and visually disabled users. Based on these discussions, general adaptations included various adaptations to improve comfort, such as smoother acceleration and deceleration and the providence of non-obligatory seatbelts. These adaptations were not per se based on specific user group input, but were considered beneficial for both older and physically disabled users

"Also with old people sitting in your shuttle, we provide them seatbelts, for example, which is not mandatory in buses. And you have probably experienced it in buses, you don't have to wear seatbelts. So we're not forced to install some but still we install some, because that's a physical way to help them."

Physically disabled users.

When asked about adaptations based on potential input from physically disabled users, one interviewee mentioned several evolvements over time. Where shuttles previously had manual wheelchair ramps, they now have implemented automated ramps, as well as special anchorage points to lock wheelchairs in a fixed position. In addition, input from visually impaired user groups led to the implementation of user buttons with braille language, showcasing clear efforts to make their vehicle as accessible as possible.

"The users are organized in groups. And I know that they are in contact with visually impaired groups, with physically impaired groups. Specifically with groups oriented on wheelchair users. And this is what triggered, you know, as I said, for example the automated ramp to get in the shuttle, the anchorage point to exactly make sure the wheelchair will not move while driving.

Future AV technology developments

Older users

When it comes to future technology developments and adaptations based on user input, one interviewee was able to talk about various developments, which are still under discussion within the corresponding company. Current discussions focused on further simplifying the onboard interface to provide users with simple directions in terms of where the shuttle is moving towards as well as providing broader seats, which are more comfortable for both older and physically disabled people to sit in.

"We're including a new screen inside the shuttle, that shows more clearly than before the stops and where the people are and where they're going to with very simple and visible signs." [PM]

Physically disabled users

Besides the wider seats, another discussion regarding people with physical disabilities, focuses on the intuitiveness of the station choosing system, as the corresponding company wants to make sure every person with a physical or visual disability is able to use the system without anyone escorting or supervising them.

"Well, the one thing that we're discussing at the moment is how people and even disabled people will be able to choose their station. Getting into when they are inside the shuttle. Yeah, but now this is not solved yet, this is under discussion. […] *But what's in discussion is, how do we have people, who are either visually impaired or who are in a wheelchair non-accompanied by anyone, able to select their station in every situation. Because for now, someone in a wheelchair, should be accompanied by someone to make proper use of the shuttle*" *[PM]*

5. Analysis

The collective results from interest organizations representing older and physically disabled users and AV technology developers can now be compared and analyzed to gain additional insights. The following analysis will first compare results regarding user involvement factors between interest organization and AV technology companies, followed by a comparative analysis of technology preferences and expectations with current and future AV technology developments

5.1 User involvement

While analyzing user involvement insights from car manufacturers, it becomes apparent that all car manufacturers used customer clinics or studies with a representative customer sample of young, middle-aged and old people to approach the standard human as much as possible. At the same time, targeted user profiles, based on customer data analytics and marketing predictions, such as expected vehicle preferences, mainly determined which users were involved in development processes. If customer clinics were used, older users were most likely a part of it. Furthermore, older users were mentioned several times as the subject for research projects co-facilitated by universities, some of which revolved around AV technology. At the same time, the targeting and subsequent involvement of users for AV technology is considered to depend on the automation level and the automation functionality. Besides the mentioned research projects, only one AV field test was mentioned, which specifically involved a larger part of older users. In addition, most interviewees could hardly think of specific AV adaptations based on older user input. As older users were also not mentioned as a specific target group when discussing AV automation factors. this implicates that older users were not considered a target group for automation factors and thus AV technology projects. Although older user could be involved if customer clinics were the choice of involvement method, older users are most likely not or very scarcely involved in AV technology development. Furthermore, physically disabled users were not mentioned whatsoever when discussing AV technology projects, implicating that this user group is also not involved whatsoever in AV technology projects.

In line with these results, older and physically disabled users were not involved in AV technology projects in the Netherlands, apart from a few PM projects. Interviewed PM companies stated that interaction with users ran through intermediate transport operators. Because user involvement ran efficiently through transport operating companies, interviewed PM companies stated that they had no direct user involvement nor any preferences to increase this involvement. Therefore, it is argued that this was one of the causes of the lack of direct user involvement and interaction between AV technology projects in the Netherlands and older and physically disabled users, besides the underdeveloped AV technology. This shows consistency in results regarding overall interaction and involvement between private AV technology developers and vulnerable users.

In line with aforementioned results, both interest organization groups also argued that older and physically disabled users would feel not represented in AV technology developments. It was thought that traditional car manufacturers would have low priorities for both user groups. Physically disabled users would have an especially low priority and people car manufacturers were more likely to come up with solutions for this group by themselves. In line with these statements, the subject of a special ergonomics suit was brought forward, aimed at mimicking an older user by limiting the movement of the engineers

that wear it. This shows that older users are most likely not involved early in the development and that car manufacturers would rather come up with solutions for users themselves instead of involving them personally. In addition, experts stressed that only one human factors engineer was argued to be present amongst several hundreds of traditional engineers. Car manufacturers were also still testing most of their systems on company engineers, although there had been an increased focus on human factors in recent years. These results further affirm that older and physically disabled users are most likely not a significant priority regarding AV technology as of today. At the same time, physically disabled users were considered to become important in the design of future PM vehicles as the industry was increasingly focusing on urban mobility and the city automation functionality. As this was considered a determining factor for intended target groups, physically disabled users are most likely to become a more significant target group for car manufacturers when PM ventures are started, in line with expressed expectations from both car manufacturers and experts.

Besides a consistency in overall project involvement, the results have also shown some overlap between expressed involvement preferences from users and user involvement methods from car manufacturers. During customer clinics, invited users would interact with prototypes and simulators. At the same time, interest organizations representing both user groups agreed that developers would need to use prototype and mock-up testing early in the development process, indicating some overlap. Both interest organization groups also recommended that panels were created, and that interaction should be physical rather than virtual. Although car manufacturers did not specifically mention the use of panels, all user involvement methods apart from customer surveys, indicated a form of physical interaction between users and developers. In addition, various ideas were suggested regarding the facilitation of user/developer interaction through either interest organizations for seniors or external network organizations. Car manufacturers have shown to collaborate with universities and assisted care facilities in research projects serving older users. This shows that car manufacturers could be willing to collaborate with other network organizations or senior organizations in the future if older users were to become a specific target group for an automation factor.

In addition, one car manufacturing representative talked about various involvement methods, which can be considered experimental revolving around virtual reality-based systems and the use of design "charays". In line with previous literature, this indicates that some car manufacturers might be more prone to use experimental systems if this would result in increased User Centered Design (UCD) or User-Sensitive Inclusive Design (USID)

5.2 AV developments

Results on current and future AV technology development indicate some overlap with mentioned technology expectations and preferences from older and physically disabled users. The results of the CARA project showed that senior drivers valued independence and considered themselves safe drivers, indicating that the idea of Level 5 autonomy was less preferred than a supportive Level 3 highway functionality. Furthermore, it was stressed that private AVs could show significant potential in supporting seniors in difficult weather conditions or traffic situations, so they would not have to give up on driving. older users would also have to experience AV technology to trust the technology
In line with these expected attitudes, the single mentioned field test focused with level 3 automation which focused on elderly users resulted in significantly positive feedback, a reduction of fear and an increase of trust towards the technology. These results confirm that older users would prefer the supportive role of Level 3 AVs and that experiencing the technology is important for the building of trust.

When further analyzing the attitude of older users, a small discrepancy becomes apparent. Although it was mentioned that complicated technology was often avoided by seniors and was given as one of the core reasons that seniors stop driving, interest organizations mentioned that seniors were very keen and interested in owning and learning about advanced technologies, including AV technology. At the same time, seniors were often not aware of low-level (Level 1 & 2) automation systems if present in their vehicles, such as ACC. Seniors would learn from these systems from hearsay, as manuals were not consulted. At the same time, car manufacturers stated that ACC speed and distance were made adjustable to serve various driver ages, based on involving both younger and older users, showcasing the influence of older users in low-level automation systems.

To build trust, AV developers should focus on a well-working system with a relatively unnoticed system presence when active. If the AV technology was operating the vehicle, it was argued that it should feel like a human driver controlling the vehicle. Based on involving users, the process of giving feedback to the driver when the driver needed to take over control, was improved upon. Furthermore, measurement technology was added to standard vehicles to analyze the acceleration and deceleration of drivers, as a result of customer studies, which partially involved older users. This contributed to the objectification of driver-feeling in level 2 AV systems, which indicated consistency with expressed preferences from older users for a safe and familiar feeling AV system. Furthermore, in line with expressed preferences for adequate safety systems for wheelchairs, adaptations made by PM companies revolved around anchorage points for wheelchairs and smoother braking behavior. Both types of interest organizations also expressed preferences for generally easy-to-use systems. In line with these preferences, car manufacturers and PM companies have shown to put efforts into easier menus and more intuitive screens respectively. This indicates that preferences for adaptations from older and physically disabled users are somewhat represented in both private and public AV technology developments. This shows that technology preferences from older users are somewhat consistent with actual AV technology development, although older and physically disabled users are hardly to not involved in AV technology development.

6. Discussion

6.1 Scientific implications

This research has led to new insights that can be considered relevant in the debate for societal implications of vehicle automation. Collected insights on user involvement methods, preferences and motives from AV technology developers has allowed into the visions that these developers have of their users and to what extent older and physically disabled users are involved and represented in AV technology developments. This adds to previously discussed literature on the methods and motives that exist for involving older and physically disabled users and extends on important factors in the interaction between AVs and older users. The following section will discuss how this research has extended on these insights.

While PM companies strive to make their vehicles as accessible as possible for all users, users are not directly involved in the development of their vehicles. Instead, transport operating companies facilitate discussions with separate user groups, which act as intermediary feedback actor. These results indicate that there is no connection between literature on involving lead users, older users or physically disabled users and preferences and methods for involving users by PM companies. This has been linked to the fact that these companies must abide by the same regulations as PT companies. At the same time, adaptations, such as automated wheelchair ramps, smoother braking behavior and more intuitive information screens have been mentioned to be implemented or still under discussion, which were linked to indirect feedback from users. These developments indicate that feedback from users, although not directly involved, can still find its way to the AV development through transport operators. So, although PM companies do not choose to directly involve users or adopt certain methods for involving users, user input is listened to and considered to a certain extent.

On the other hand, car manufacturers, that produce private AVs, have shown to make their decisions regarding which users to involve and why based on striving to approach the standard human as close as possible in order to serve as many customers as possible and to be as inclusive as possible. Furthermore, users to be involved depend on user profiles that are created through data analytics, marketing predictions. and automation factors. This implicates that user involvement prefences from car manufacturers do not align with user concepts from literature (Rogers, 1995; von Hippel, 1988) the lead user concept (von Hippel, 1988).

By contrast, other literature on involving older and physically disabled users has shown overlap with the collected results. Although older users were not regularly mentioned to be involved in AV technology developments, older users were mentioned several times as part of research projects in collaboration with external parties, such as universities and assisted care facilities. Discussed research projects were aimed at establishing new knowledge in the fields of in-vehicle health systems and the minimization of driver cessation, which were still in early development. Although the term research circle was never explicitly mentioned, these projects implicate some overlap with the 'research circle' method, which was deemed fitting to involve older users early on in designing new services (Östlund, 2008). This indicates that car manufacturers are considering opportunities of vehicle automation for older users, in line with expressed visions on the importance of older users for the future of AV technology.

Whereas older users were a regular part of customer clinics, physically disabled users were only mentioned regarding clinics for special adaptation vehicles. Some experimental user involvement methods were brought forward, including virtual-reality based systems and design tools based on anthropometry in line with literature on including previously excluded users (Gyi et al., 2004). However, these methods were not explicitly linked to involving physically disabled users
Car manufacturers and experts did also indicate that the industry was shifting towards urban mobility with an increased focus on public AVs, such as PMs. During this transition, physically disabled users were argued to become more important as a target group, which could lead car manufacturers to involve them more using experimental methods.

In line with previous literature by Yang & Coughlin (2014), the importance of learnability and acceptance aspects for older drivers were also confirmed by various interest organizations and experts. Older users were argued to not use low-level automated in-vehicle systems, but once advised on the potential benefits through hearsay or project involvement, older users would discover and start using current AV systems, being more acceptant of the technology. As no real training was provided to handle such systems, this was given as one of the main reasons for the low level of usage. Therefore, it was also confirmed by both experts and interest organizations that adequate training was needed to improve the learnability of AV technology systems for older drivers. This could increase the willingness to use AV technology, thereby potentially increasing the acceptance of the technology. The results from the CARA project further confirm that older drivers were sensitive to certain system triggers, which could lead to a distrust in the automation and the risk of an AV feature staying unused.

6.2 Research Limitations

Although the choice of snowball sampling has been deemed fitting for this research, it is also argued to be a potential cause for both external and internal validity limitations. As the sampling used can be considered nor random nor representative, this can lead to a focus on respondents with wider social networks, excluding potential interviewees that are not referred to the researcher and creating selection bias. (Cohen & Arieli, 2011). In addition, relying on links based of specific chain referrals is argued to result in similar respondents, which may not represent the entire relevant research population, which can reduce the reliability and validity of research conclusions.(Cohen & Arieli, 2011). Although the use of snowball sampling method for this research generated a relatively heterogenous sample of different organizations and companies, it is acknowledged that various interviewees could have been masked in the sampling process, which could give an inaccurate representation of the entire research population, therefore limiting the validity and reliability of this research. Although the initial sample of this research consisted of Tesla and General Motors, it was not possible to get in contact with these companies, which also limits the accuracy of the AV technology developer population and the reliability of this research. In addition, qualitative research is argued to not easily be replicated (Joppe, 2000), which further decreases the overall reliability of this type of research.

6.3 Recommendations for further research

This thesis took an exploratory approach to map methods and preferences to involve vulnerable users in AVs. Car manufacturers have shown to produce adapted vehicles for physically disabled users in partnerships with adaptation companies. Furthermore, transport operating companies have shown to interact with user groups and act as intermediate actor for transferring user input. While this research did not include any of these companies, based on snowball sampling, interviewing adaptation companies and transport operating companies is argued to be an avenue for future research. This can provide insights in the relationships between AV technology companies and collaborative companies, thus providing a better understanding of the dynamics of the AV industry.

Secondly, as most interviewed AV technology developers were settled in Germany, the choice to research representatives of older and physically disabled users in the Netherlands might have limited insights in terms of AV technology project involvement. A comparable case study focused on older and physically disabled users in Germany could be considered interesting for further research, while also using the proposed "AV user involvement framework" (see Figure 3). Furthermore, future research could focus more specifically on a certain age or type of disability to achieve a completer representation of older and physically disabled users in a specific country or culture.

Finally, in line with aforementioned limitations the ongoing COVID-19 crisis was argued by several respondents to drastically influence the rate of AV project development. The crisis has also led to drastic changes in the automotive industry and thus, part of the AV industry, caused by mandatory closure of plants and factories and supply shortages (ACEA, 2020). At the same time, the COVID-19 crisis is argued by some as an opportunity for AVs to relieve the pressure on delivery companies, while also reducing exposure risks for employees (Dawkins, 2020). In addition to this, the car manufacturing industry was argued to shift towards public AV technologies in the coming years. Therefore, research could focus on a re-evaluation of the presented findings in the nearby future (during COVID-19) and the distant future (after COVID-19).

7. Conclusion

This research has examined the role of older drivers and people with physical disabilities in the development and design of AV technologies. Having mapped important factors from representing interest organizations as well as user involvement preferences, methods and motives from AV technology companies, insights gained can be used to answer the central research question and the four sub-questions:

How are older and physically disabled users in the Netherlands involved and represented in autonomous vehicle technology developments?

1. *Which user involvement motives and methods are described in literature as important when involving older and/or physically disabled users in technology design?*
2. *Which factors do interest organizations consider important regarding the involvement and representation of older and/or physically disabled users in AV technologies?*
3. *What ideas and preferences of AV technology developers determine how and to what extent they involve older and/or physically disabled users in the design process?*
4. *How are user representations of older and/or physically disabled people influencing current and future AV technology developments?*

The first sub question can now be answered as follows with additional insights.
Important motives to involve older users are to improve the quality of products, to identify a better understanding of the surrounding environment or to grant older people more participation, based on literature insights. An additional motive to involve older users is the willingness to pay for certain technologies as older users are considered to possess more financial means than general users. An important motive to involve physically disabled users in technology design is to strive for User-Sensitive Inclusive Design (USID). In addition, research circles, interactive theatre and computer-based design tools are considered helpful tools for involving both older and disabled users in technology design.

The second sub question can be answered as follows.
Both older and physically disabled users preferred physical interaction over virtual interaction and the use of panels or focus groups to include users in the development of AV technology. Older users preferred adequate facilitation of user/developer interaction via network organizations or senior organizations. Physically disabled users preferred overall earlier involvement in the design, mock-up testing and the establishment of a continuous feedback loop. Older users mostly preferred an unnoticed system preference with easy-to-use menus and a safe and secure system. Personal contact assistance was also considered very important for older users. Private AVs would benefit seniors if a helpdesk was created for urgent matters regarding ADAS and higher-level systems in future AV developments. Public AVs could allow for a choice regarding the presence of a safety steward, potentially increasing the trust amongst older users in the technology. Older users would also prefer and need adequate training to handle AVs, whereas physically disabled users would not necessarily need training for this purpose. Instead, physically disabled users would need training if an online system for a public AV service was to be set in place. Furthermore, physically disabled users stressed the importance of adequate control systems, safety systems for wheelchairs and adequate ingress for wheelchairs in AVs.

The following paragraph will provide an answer to the third sub question.
Car manufacturers use customer clinics with a representative customer sample of young, middle-aged and old people to approach the standard human in design as possible and serve as many customers as possible. Reasons for specifically involving older users revolve mainly around material motivators, but a clear shift was mentioned towards normative motivators, due to external pressure. In addition, older users were involved, because of a higher willingness to pay more for certain technologies. At the same time, customer data analytics and marketing predictions (e.g., expected vehicle preferences) are used to create user profiles and target users. These factors are considered the dominant influential factor, which determines which users are involved in development processes. When projects revolve around AV technology, the targeting and involvement of user groups is also influenced by the automation level and functionality. Older users were not mentioned as a specific target group when discussing AV automation factors and were not regularly involved in AV technology projects, apart from several research projects and one field test. Furthermore, physically disabled users were not mentioned whatsoever when discussing AV technology projects, implicating that this user group is not involved whatsoever in AV technology projects. Physically disabled users were considered to become important the nearby future as the industry was increasingly focusing on urban mobility and the city automation functionality. As this was considered a determining factor for intended target groups, physically disabled users are likely to become increasingly involved when car manufacturers start developing urban mobility vehicles, such as PM shuttles. PM companies have focused on all users that are using PT services, which includes a special focus on older and physically disabled users in their aim to be as accessible as possible. Although not directly involving users, transport operators act as an intermediary actor, transferring user input from user groups to the PM companies after users have been part of field tests or continuous scheduled rides. Although PM companies aim their vehicles to be as accessible as possible, which can be considered a normative motivator, they do not directly interact with older users or users with physical inabilities.

The next paragraph will answer the fourth sub question. Although older users have been hardly involved in AV technology projects, user representations of older users have partially influenced current AV technology developments. These developments revolved around adjustable AV settings for speed and distance on ACC for low-level automation systems and the focus on objectification of driver feeling for a safe and familiar feeling AV driving behavior, in line with preferred adaptations from older users. At the same time, adaptations made by PM companies regarding smoother braking behavior and on-board safety systems for wheelchairs show that preferred adaptations from both older and physically disabled users are partially represented in AV technology developments, despite users not being directly involved.

The central research question can now be answered as follows.
Older and physically disabled users in the Netherlands have been barely involved in AV technology projects, apart from some PM projects. Furthermore, older users were not specifically mentioned as a target group when discussing automation factors and marketing predictions amongst car manufacturers. Older users were involved to some extent by car manufacturers if customer clinics were used, but this was most likely linked with general vehicle development. In addition, apart from several mentioned research projects, very few AV technology projects focussed specifically on older users and no AV technology projects specifically focused on physically disabled users. Therefore, older and physically disabled users are currently not seen as a significant priority for car manufacturers. Expressed involvement preferences from older and physically disabled users have shown overlap with used involvement methods. In addition, expressed technology preferences have shown overlap with a small amount of current AV technology developments. Concluding, despite being scarcely to not at all involved in AV technology developments, expressed preferences from older users are represented to a small extent in private AV technology developments and preferences from both user groups are represented to some extent in public AV technology developments.

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9. Appendices

Appendix A: Interview Design

AV Technology users

The interview lasts about an hour. Before starting the interview, consider the following questions: This interview will be treated confidentially.
• Do you agree with the use of your own name or would you prefer to remain anonymous?
• Do you agree that this interview is being recorded for transcription purposes?
• Do you agree with the publication of (parts of) this interview, or would you prefer that your exact answers to remain confidential?

About the respondent

1. What is your name and exact position within… ...?
2. Can you tell me about the AV technology projects you are involved in?
    a. Are you aware of other projects?

Involvement methods
3. From your knowledge / experience, what is the degree of interaction between AV technology developers and older / physically disabled users.
    a. Much; what are the methods of interaction?
    b. Not much / not little: if so, how does this interaction take place? Why isn't it anymore?
    c. Little / to none: Why do you think this is the case? / Why is that?

4. In your knowledge / experience, what is the degree to which older / physically disabled users are involved in AV technology projects?
    a. Much; How are users involved?
    b. Not much / not little: How are users involved?
    c. Little / to none: Why do you think this is the case? / Why is that?
5. (Much to question 4):
    a. To what adjustments (effects) did this involvement lead?

Attitude
6. How do you expect older and/or physically disabled users to view AV technology?
    a. Do they feel represented by car manufacturers?
    b. To what extent are elderly users familiar with assistance systems, warning systems, navigation systems?
7. Do you guide them in that?
    a. If so, how?
    b. Will people want to make use of that?
8. Will older and/or physically disabled be able to afford AV technology?
    a. If not, should special arrangements be made for this?
    b. What could that look like?
9. Will it be possible for older and/or physically disabled users to operate AV technology it if it is necessary to learn new behavior?

a. Is it necessary to offer special training or courses for this?
b. If yes, is this already being done?
c. If not, why not?

Technology expectations

10. What do you expect from the usability options of AVs for elderly and / or disabled users?
    a. Ideally; what does it take?
    b. In a pessimistic scenario: What goes wrong?
    c. In a realistic scenario: What are the advantages and disadvantages for the elderly and / or physically disabled users?

Involvement preferences

11. What preferences and/or requirements for involvement and participation of older and/or physically disabled users disabled users should AV developers consider?

Technology preferences

12. What preferences / requirements for adaptations of older and/or physically disabled users should AV developers consider?

Potential influencing factors

13. What (recent) technological development have influenced the usability of cars or PT services for elderly and/or physically disabled users?
14. What (recent) societal developments have influenced the usability of cars or PT services for elderly and/or physically disabled users?
15. What (recent) regulations have influenced the usability of cars or PT services for elderly and/or physically disabled users?

AV Technology developers

About the respondent

1. What's your exact name and function?
2. Can you tell me something about the human factors projects that you are involved in?
3. Does [AV technology developer] use similar methods of implementing human factors across all the technologies it develops, including general vehicle development and autonomous vehicle technologies?

User involvement preferences

4. Which types of people are envisioned as potential user groups of products and services?
5. Which types of people are envisioned as potential users of new product innovations, such as vehicles that have autonomous vehicle technologies?
6. What are the general characteristics of these users
7. How is being thought of older and/or physically disabled users
8. Are older and/or physically disabled users specifically involved?
    a. If so, in what way?
    b. If not, why not?
9. Which (reduced) capacities are considered?
    a. How?
    b. Which (reduced) capacities are not considered?
10. Which users are involved in the design/development process.
11. Why specifically the choice for this type of user?

User involvement methods

12. When developing these technologies, is there direct interaction with the (intended users?
    a. If so, in what way?
    b. If not, why not?
13. Are potential user groups involved in the design/development process of new products, services or technologies?
14. How are users involved in the design/development of new AV technologies
15. What is the reasoning for these methods?

User involvement motives

16. Have objectives been defined regarding the usability of the technology for older and / or disabled (intended) users?
    a. Is there a schedule of requirements, etc.?
17. Are there any standards that affect the usability of the technology for older and / or disabled (intended) users?
    a. If so, which ones?
18. Is there legislation affecting the usability of the technology for the elderly and / or disabled users.
    a. If so, how is this handled within <the company>?

User experiences (if applicable)

19. Based on user involvement in general, what were the experiences with users in general?
20. Based on user involvement in general, what were the experiences with non-users (fellow road users) in general?

21. Based on older user involvement, what were the experiences with older users.
22. Based on involving physically disabled users, what were the experiences with these users?

Current developments
23. Based on the experience with general users, were there any adaptations developed and implemented in the last 5 years?
24. Based on the experience with older users, were there any adaptations developed and implemented in the last 5 years?
25. Based on the experience with physically disabled users, were there any adaptations developed and implemented in the last 5 years?

Future developments
26. Based on recent suggestions from general users, are there any discussions going on regarding adaptations that could be implemented in future AV technology developments?
27. Based on recent suggestions from older and/or physically disabled users, are there any discussions regarding adaptations that could be implemented in future AV technology developments?

Appendix B: Node structure of answers

Table 2: Node structure interest organizations and experts

Name	Files	References
Expert considerations	1	2
General unawareness in-vehicle systems	1	1
Grouping users together for usability	1	1
Involvement methods	8	43
Extent of developer interaction	6	7
All vulnerable users	6	7
No interaction with technology developers	4	5
Scarce interaction between developers and municipalities	2	2
Older user	0	0
Physically disabled users	0	0
Extent of user interaction	3	4
All vulnerable users	0	0
Older users	3	4
Continuous feedback	2	2
Counseling offer	1	1
No user interaction	1	1
Physically disabled users	0	0
Extent of user involvement	2	6
All vulnerable user	0	0
Older user	1	1
International projects with end-users	1	1
Physically disabled users	1	5
Limited evaluation availability	1	1
Potential second stage	1	2
Sole testing involvement	1	2
Feeling of representativeness	5	12
All vulnerable users	2	4
Low priority for vulnerable users	1	1
Users have to take initiative	2	3
Older users	1	3
Absent for older men	1	1
Cars designed for young people	1	1
Seniors don't feel represented	1	1
Physically disabled users	3	5
Developers have no conscious thoughts of disabled people.	2	3
Disabled people don't feel represented	2	2
Interaction methods	2	5
All vulnerable user	0	0
Older user	2	5
Interaction with project technicians	1	1
Open panel application	1	2
Own magazine	1	1
Social media	1	1

Physically disabled users	0	0
Methods of project involvement	3	7
All vulnerable user	1	1
Test evaluation	1	1
Older user	2	6
Co-creation	1	1
Mockup testing	1	1
Pilot-test	1	1
Surveys within a panel	2	2
Workshop	1	1
Physically disabled users	0	0
Project involvement results	1	2
Driving behavior coach	1	1
Supportive navigation system	1	1
Involvement preferences	6	24
All vulnerable user	3	4
Local face-to-face contact	2	2
Panels	2	2
Older user	3	4
Facilitation third parties	2	3
External network organizations	1	1
Senior organizations	2	2
National senior representation car companies	1	1
Language assistance	1	1
Physically disabled users	4	16
Earlier involvement	3	4
Establish continuous feedback loop	2	2
Focus groups different user groups	2	5
Collective session with all user groups	1	1
Interplay users, experts, representing organizations	1	1
Invite user groups separately	1	2
Involve various user types	1	1
Hiring disabled users as test users	1	1
Mockup testing	3	3
Municipality as facilitator	1	1
Societal changes related to AV	5	9
ADAS education opportunity	1	1
Austrian education days	1	1
Legislation	4	7
Alliance of disabled interest organizations	1	1
European Accessibility Act	1	1
Policy decision Accessibility Public Transport	3	3
Program Unlimited Participation	1	1
Ratification of VN-treaty	1	1
Technology expectations	10	59
Expectations	10	37
All vulnerable users	7	12
Hierarchy in user priority	1	1
Less difference private and public AVs	1	1

Potential cost issues	7	7
Dependent on upscaling	1	1
Relieve budget burden municipalities	1	1
Time dependency for AVs	1	2
Older users	6	12
Decrease loneliness	1	1
Gender differences	1	1
Half of seniors don't own cars	1	1
Increased participation in society	1	1
Senior design beneficial for all	1	1
Seniors avoid certain situations	1	3
Acceptance after experience	1	1
Traffic conditions	1	1
Weather conditions	1	1
Unaware of car systems	4	4
Physically disabled users	6	13
Approval process for AV subsidy	1	1
Disabled users as heterogenous as normal users	1	1
Giving up privacy for more functionalities	1	1
Increased independence	3	4
Increased loneliness without supervision	1	1
Less dependent on inaccessible public transport	1	1
Less dependent on others	2	2
Opportunities for heavily disabled	1	1
Trouble understanding AV system boundaries	1	1
Expected attitude towards AVs	8	22
All vulnerable users	2	5
Developers are behind	1	2
Key to independence	1	1
Willingness to use if conditions meet	2	2
Older users	7	15
Challenge understanding AV technology	2	2
General liking of AVs UK	1	1
Hesitant	3	4
Interest advanced system options	1	1
Learning interest advanced technologies	2	3
Little privacy worries	1	1
Positive after experiencing it	1	1
Safe drivers	1	2
Physically disabled users	1	2
Divergent attitudes based on age	1	1
Similar to ordinary Dutch users	1	1
Technology preferences	11	57
Design recommendations	5	19
All vulnerable users	3	7
Avoid complicatedness	3	7
Older users	1	5
Focus on broad audience	1	2
Unnoticed system presence	1	3

Physically disabled users	3	7
Digital accessibility	1	2
Need for financial arrangements disabled users	3	4
Personal guidance	1	1
General AV system preferences	7	21
All vulnerable user	7	14
Helpful ADAS systems	3	7
Cruise-control	2	2
Parking sensors	2	3
Tracking system for maintenance and theft	1	1
Public AV services	5	7
Older user	3	7
Keep independence	3	7
Physically disabled users	0	0
Vehicle adaptations	7	17
All vulnerable user	3	4
Training	3	4
No need for special training disabled users	1	1
Training delivered with AV itself	2	2
Training developed by senior organizations	1	1
Older users	3	10
Detailed arrangements for accessibility	1	1
Feedback after driving	1	1
Personal contact	3	6
Personalized financial offers	1	1
Safe and secure technology	1	1
Physically disabled users	3	3
Adequate ingress for wheelchairs	1	1
Adjustable control systems	1	1
Safety systems for wheelchairs	1	1

Nodes AV technology companies, Experts & Governmental Organizations

Table 3: Node structure AV technology companies, experts and governmental organizations

Name	**Files**	**References**
Current AV technology developments	11	71
Adaptations based on users	6	18
Adaptations based on disabled users	1	4
Anchorage point for wheelchairs	1	1
Automated wheelchair ramp	1	2
Buttons with braille language	1	1
Adaptations based on general users	4	11
Adjustable AV settings	1	2
Car symbol comprehension	1	1
Driver distraction guidelines	1	1
Increased ACC speed support	1	1
Location for driver assistance HMI	1	1
More informative screens	1	1
Smoother acceleration and deceleration	1	1
System feedback signals to driver	2	2
Timing & appropriateness acoustic stimuli	1	1
Adaptations based on older users	2	3
Easier-to-use menus	1	1
Objectification of driver feeling	1	2
Experiences with users	7	20
Experiences with general users	6	8
Car usage similar to competition	1	1
Extra dimension	1	1
Non-users get used to it	1	1
Potential negative experiences longer testing	2	2
Rather positive feedback	1	1
Unsafeness feedback	1	1
Users positively surprised	1	1
Experiences with older users	6	12
Fear reduction	2	4
Need to experience AV technology for trust	4	5
Small differences in different age groups	2	3
General developments	4	9
Attention noises	1	2
Non-obligatory seatbelt providence	1	1
Pause feedback steering wheel (Steering Support	1	1
Smooth braking behavior	2	3
Too big focus HMI improvements	1	1
Vibrating steering wheel (Lane Keeping)	1	1
Influential aspects	10	24
Influential legislation	9	16
2007;46;EC	1	1
National testing laws	4	4
No awareness of current AV legislation	5	5
PT regulations for people movers	2	2
Safety driver regulation	0	0

Safety steward regulation	2	4
Influential standards	6	8
EC efforts for AV standards	1	1
ISO 26262 for vehicle development	1	1
ISO 92 41 210 HCD interactive systems	1	1
No AV standards	3	3
SAE standard for AV accessibility	1	2
Expert considerations	2	21
AV industry business aspects	1	2
OEMs keen on selling personal vehicles	1	1
User focus based on business model	1	1
Challenges of AV technology	1	5
Challenges in HMI development	1	1
Little diversity on work floor	1	1
No guidance in using AV systems	1	1
No knowledge of non-standard human	1	1
Struggle for HMI standardization	1	1
Future considerations	1	3
Integration of people movers in PT	1	1
L3-Pilot	1	1
No focus vulnerable users	1	1
No more private vehicles	1	1
Needed improvements	2	9
Need for dedicated projects	1	1
Needed AV training	2	3
In-car adaptivity training	1	1
Objectification of driver-feeling	1	2
Room for human factors improvement	1	3
Subjective observations	1	2
Importance stakeholder aspects	1	1
Little public interest AVs	1	1
User-related challenges	0	0
Challenging to involve older users	1	1
Engineers envisioning discrepancy	1	3
Large unawareness in-vehicle systems	1	1
Potential trust issues	1	2
Future AV technology developments	9	48
Considerations	8	28
OEM discussions	6	15
Training concerns	1	1
Underdeveloped AV technology	6	12
Use of long-term field trials	1	2
Policy and Legislation	4	4
Needed legislation changes	3	3
Public financing AV technologies for disabled people	1	1
Research	4	9
Standard possibilities	4	8
AV-to-road-user communication standard	2	3
SAE AV standard	1	1
Technology research opportunities	1	1
Potential adaptations general users	5	7
Automatic valet parking	3	3
External light bar for V2U communication	1	1

Service packs based on customer groups and data analytics	1	1
Simpler interface	1	2
Potential adaptations vulnerable users	2	4
Increased intuitiveness station selection system	1	2
No future developments	1	1
Wider seats	1	1
Transition AV to mobility company	4	9
Interactive AV environment (Woven City)	1	2
Mobility service provider	1	2
OEM people mover shuttles	3	5
Policy considerations	5	56
AV considerations	5	36
AV legislation	2	3
Large differences AV legislation in EU	1	1
Municipality exploration of implementation	1	1
National experimental fund	1	1
AV user involvement	2	11
Different user approach	1	1
Few user-involved AV-projects	1	5
Limited involvement civilian initiatives	1	1
No specific vulnerable user focus yet	1	1
No user involvement in evaluation	1	1
RDW brings stakeholders together	2	2
Private AV developments	5	10
AV tests with company people	2	2
Early innovation cycle	2	3
Infrastructure problems private AVs	1	1
No investments in private AV projects	1	1
V2I innovation potential	1	3
Public AV developments	3	12
AV grants steward choice	1	1
Costs for PT and municipality	2	2
Focus on controlled systems	1	1
Ground floor ingress	1	1
Initial technology pilot projects	1	1
Large interaction developers	1	1
Large interaction developers (2)	1	1
National leader AV projects	1	1
Reducing stops	1	1
Simulation studies	1	1
Wheelchair in shuttles standard	1	1
Municipality preferences	3	9
Clear business case	2	2
MAAS projects	1	1
Personal transport vulnerable users	3	4
System wide accessibility	1	2
Municipality problems	4	11
Difficulties project selection	1	2
Large distance developers vs users	1	1
Shortages for small municipalities	1	1
Too little human factors perspective	1	1
Too progressive legislation	1	1
Worries of societal interests	2	5

User involvement methods	10	57
Extent of user interaction	4	8
Extensive discussion with transport operators	1	1
Importance of early on user involvement	1	1
No differences in user group interaction	1	1
No direct interaction with users	2	2
No preferences direct user involvement	1	1
Struggle with early user involvement	1	2
Interaction methods	5	6
Intermediary transport operators	2	3
Newspaper Ad	1	1
Observations at locations	1	1
Studies with assisted care facilities	1	1
Involvement methods	8	35
Combination digital, physical tools	1	1
Experimental methods	3	6
Computer-based design based on anthropometry	1	1
Design "charay"	1	3
Virtual reality-based systems	2	2
General methods	8	25
Customer clinics	6	8
Customer surveys	3	3
Field tests	3	4
Focus groups	5	8
Advanced group for wish composing	1	1
Electronics groups for exploring possibilities	1	1
Ideation and co-creation with small groups	1	1
Simulation studies	2	2
Research projects	2	3
Co-creation study rural mobility elderly	1	1
Research on IVHS regarding cardiac issues	1	1
Research projects to minimize driver cessation	1	1
Reasons for method(s) of involvement	4	8
Bonding with customers	1	1
Customer need satisfaction	1	1
Customer understanding of vehicle	2	3
Integration of involvement methods	1	1
Standardization	1	1
Understanding customer expectations	1	1
User involvement motives	5	9
All three motivators present	1	1
Material motivators	2	2
Normative motivators	1	1
Shift towards normative motivators	1	1
Willingness to pay	2	4
User involvement preferences	8	84
Visions of general users	8	44
Influential factors user involvement	5	7
Baseline user condition needed	1	1
Design for standard human	3	4
Promotion of brand values	2	2
Objectives	4	5
Every public transport user	2	3

Usability maximization	2	2
User groups profile creation	6	32
Automation factors	4	11
Automation functionality	2	4
City automation functionality	1	1
Whole society	1	1
Highway automation functionality	2	2
Mid aged, wealthy households	1	1
Automation level	3	7
AV technology accessible for everybody	2	2
Different AV solutions for user groups	2	5
Customer data analytics	1	2
Behavior extrapolation future systems	1	1
Size of customer base	1	1
Marketing perspectives	4	12
Customer characteristics	1	2
Expected vehicle preferences	4	5
Luxury level preferences	3	3
Most-sold vehicles	1	2
Targeting philosophy	2	7
Large target user groups	1	2
No exclusion of user groups	2	4
Targeting users similar for AVs	1	1
Visions of vulnerable users	7	40
Disabled user preferences	7	22
Adaptation of base vehicle to disabled user needs	3	5
Focus on reduced sensory capacities	4	5
Focus on wheelchair transportation	3	8
Important for urban mobility	1	2
No specific meetings about disabled users	1	1
Special purpose vehicle development with partners	1	1
Older user preferences	6	11
Dependent on vehicle type	1	1
Elderly focused project	1	3
Medical examination sensory impairments	1	1
Pre-screening simulator sickness	1	1
Importance of older users for OEMs	3	4
Important for improved ingress and egress	2	2
Important for the future of technology	1	1
Respect for older users	1	1
Solution for car problems seniors	1	1
Special ergonomics suit	2	2
Vulnerable user thoughts	3	7
Adaptation for 10%	1	2
Far away from AV adaptation	2	3
No requirement to involve in customer clinic	1	1
Specific focus vulnerable users	1	1