CHALMERS
UNIVERSITY OF TECHNOLOGY

Creating a Smart City for People with Disabilities

A Qualitative study on how to make Smart Mobility Solutions following an Inclusive Design approach

Master's thesis in Interaction Design & Technologies

AMANDA JONELL
ANETTE MERITÄHTI

Department of Applied Information Technology
CHALMERS UNIVERSITY OF TECHNOLOGY

REPORT NO. 2017:11

Creating a Smart City for People with Disabilities

A Qualitative study on how to make Smart Mobility Solutions following an Inclusive Design approach

Amanda Jonell
Anette Meritähti

Department of Applied Information Technology
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

Creating a Smart City for People with Disabilities:
A Qualitative study on how to make Smart Mobility Solutions following an Inclusive Design approach

AMANDA JONELL
ANETTE MERITÄHTI

Technical report no 2017:11
Department of Applied Information Technology
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

Acknowledgments

We would like to, from the bottom of our hearts, show our gratitude to all the people who have contributed to this thesis in different ways.

To our academic supervisor, Staffan Björk, who have provided us with guidance, feedback and support during this whole process. Thank you for giving us the confidence we needed.

To all the teachers and professors at the Interaction Design and Technologies program who have contributed to giving us the tools we need to go out and start our carriers within this very exciting field.

To Dr. Bernd Heinrichs from Cisco openBerlin Innovation Center. Your contributions to our work have been tremendous. Thank you for always helping us find solutions when we felt stuck. Having your support during this whole process has been invaluable.

To all the people who participated in the research and data gathering for this study in any way. We have learned so much from you and this thesis would not be possible without you.

To all the wonderful people we met during our stay in Berlin that in one way or another contributed to our experience.

To our friends and families, for endless support and encouragement when we needed it the most.

Lastly, we would like to thank each other. None of us will ever forget this experience.

Abstract

This report describes a study that examines which factors that should be considered in a Smart City project, when designing smart mobility solutions, for it to be more adequate for people with disabilities. The main focus was on autonomous mobility solutions in relation to public transportation and taxi services. Participants from both Sweden and Germany suffering from mobility impairment, hearing impairment, cognitive disability, visual impairment and deaf-blindness answered a survey, were interviewed and observed, in order to understand their needs, wishes and habits. This showed that the participants have different needs regarding how they can retrieve information and interact with technology depending on their different disabilities. To show these diverse requirements, personas and scenarios were created. The personas were placed in the different scenarios to further examine these users' needs, but also what problems that can occur during their travels and the effect of their attitudes towards autonomous mobility solutions. Through an iterative process, these personas and scenarios worked as a foundation to form guidelines on how to create Smart Mobility Solutions for people with disabilities. The study resulted in eight guidelines with references to literature, research and the personas and scenarios. The main goal for the participants is that the solutions should facilitate independence, giving them the same conditions to travel as people not suffering from a disability. The personas, scenarios and guidelines could also in the future work as a design tool to use in Smart City projects to include these user groups early in the design process.

Keywords: Inclusive Design, Interaction Design, Autonomous Vehicles, Smart Cities, Mobility Solutions, Internet of Things, Disabilities in Public Transportation, Design Guidelines

Table of content

1. Introduction

This chapter will provide a general introduction of the motivation, the objectives of the research and aim of the thesis. It will also introduce the research question and limitations of the project, the ethical considerations to consider and lastly present the stakeholders.

Interaction design is a forthcoming field with influences in many different kinds of businesses. With the world's expansion and interest in digital solutions, it is important to incorporate and elevate the user's experience in different ways and fields. With interaction design, one can design interactive products and systems that enhance and ease the way the users communicate, work and interact (Preece et al., 2002).

In a city like Berlin with its historical architectural diversity, a person with a disability might run the risk of not being incorporated in designs and IT-solutions when creating a *Smart City*. Being a Smart City can be defined as *"territories with a high capacity for learning and innovation, which is built in to the creativity of their population, their institutions of knowledge production, and their digital infrastructure for communication"* (Allwinkle & Cruickhank, 2011, p 3). Whether the solutions are used in a household, at work or in public places, they all have a diversity of users that needs to be included in the creation of new solutions. This especially when it comes to public places. This is the foundation of this project's intended goals. Creating smart mobility in smart cities is a key challenge, and so, as interaction designers with a background in cognitive science, the hope is to contribute to creating smart digital solutions for people with disabilities in relationship to mobility and accessibility.

The Smart City approach, by the Senate Department for Urban Development and The Environment (2015), is Berlin's way of finding solution to the ecological, social, economic and cultural challenges, that comes with the increased number of people moving to the City, through the use of intelligent technology. Cities will increasingly rely on machine-to-machine data transmissions as they seek to reduce costs and interconnect their activities. This is where Internet of Things is expected to connect a huge number of objects, which in turn will create a massive amount of data (Smart City Research, 2017).

This study is carried out based on an Inclusive Design process. Inclusive design, strives to understand and recognize the vast diversity of the population when making design decisions regarding systems, devices and environments and thereby including as many people as possible. Public transportation, as its name suggests, is for the public where people with diverse disabilities are included. However, the transportation system has to start focusing on understanding people's accessibility and mobility needs, so that the requirements from these people are not ignored by traditional solutions. In the year of 2011, over one billion people were estimated to be living with some sort of disability. This is about 15% of the world's population.

110 million people have serious difficulties in functioning, while 190 million people are living with "severe disabilities" (Domingo, 2011). In terms of accessible solutions to technology, people with diverse disabilities, are often overlooked (Cooper et al., 2014). By including as many potential users as possible early on in the design process, the design solutions would prevent additional expenses and adjustments, such as adding a ramp to stairs for wheelchairs.

1.1 Aim and research question

The aim of the project and thesis is to contribute to the distribution of knowledge regarding how to include people with disabilities in the design process when creating digital Smart City solutions. This with a specific focus on autonomous vehicles in public transportation and taxi services. This is done by presenting results that show how a Smart City can also be a Digitally Inclusive city.

A research question was formulated based on the aim of the study:

"Which factors should be considered in a Smart City project, when designing a smart digital mobility solution, for it to be more adequate for people with disabilities?"

These identified factors will be presented in form of design guidelines.

1.2 Limitations

There are some aspects to be recognised as limitations within this thesis. This especially, in regard to different ways of communication. As the project was executed in Germany and with German citizens, there was a language barrier that could, in some cases, prohibit the authors from fully understanding and gather information if participants did not have any knowledge of the English language. Some limitations could also occur regarding communication with participants with certain disabilities such as hearing impairment. This as the authors holds no knowledge regarding sign language.

The end product(s) do not contain code or have not been implemented to an interface during this project. The outcome was a package containing guidelines, personas and user scenarios that hopefully will serve as a helping tool for future implementations of digital solutions for different stakeholders. The guidelines, personas and scenarios have gone through multiple iterations of evaluation during this project, but could always evolve and be built upon afterwards.

Because of the complexity, this project cannot consider every disability. The authors did limit the disabilities to five different types of impairments to consider, where people do not need permanent personal assistance every day. The five types of impairments are Mobility impairment, Hearing impairment, Cognitive disability (Aphasia), Visual impairment and Deaf-Blindness.

1.3 Ethical Considerations

Regarding terminology in this study, the terms disability and impairment are used. It is important to be aware of the meaning behind the words when talking about or referring to a specific group of people. Using wrong or disrespectful language can make people feel excluded or create barriers between people. The use of words and terminology describing people with disabilities have changed over time. The term disability is used in this study since movements like The Disability Rights Movement themselves use the word Disability in their organization name. Also, based on the author's research regarding this topic, impairment and disability seems to be the least offensive terms to use according to people suffering from different types of disabilities. The authors also use "people with disabilities" rather than "disabled people" since it is less objectifying. When designing for people with disabilities, it is important to not think of them as a small bereaved group, but rather a part of our whole diverse community.
When conducting research studies, there are general ethical regards that need to be considered. The following section will present the main points (Gajjar, 2013):
Honesty & Openness: One should strive for honesty in scientific communication, such as report data, methods and publication status. Be open and share data, results, ideas, tools and resources.

Objectivity: One should strive for avoiding bias in experimental design, data analysis, data interpretation and other aspects of research where objectivity is required.

Respects for Intellectual Property: Respect patents, copyrights and other intellectual properties.

Confidentiality: One should protect confidential communications, such as personnel records and patient records.

Social Responsibility: One should strive to promote social good and prevent or mitigate social harms through research, public education, and advocacy.

Non-Discrimination: One should not discriminate colleagues or participants because of sex, ethnicity, or other factors that are not related to their scientific competence and integrity.

Legality: Know and obey relevant laws and institutional and governmental policies. This also in regarding discrimination laws for people with diverse disabilities.

In addition to stated ethical regards, specified considerations should be made when conducting research and working with people with disabilities (National Disability Authority, 2009):

1) One should consider different possible practical ways in which people with disabilities can be included in a research strategy. This, by example:

- Using disability-proof research methods at the design stage.

- Adapting the methods, the length and intensity of participation based on the needs of participants.
- Provide alternative ways of communication for research participants with visual, hearing, speech or cognitive impairments.
- For people with visual impairment, consider using audio tapes or use large prints in the material.
- For people with hearing impairments, one should consider providing written material as well as providing information in form of sign language.
- One should make sure that physically accessible locales are used.

2) One should consider the diversity of participants, in form of age, gender, social class and other relevant variables, instead of categorizing only in terms of disability.

3) In regard to the research topic, research questions and research design, one should consult as appropriate with people with disabilities or their representative groups. (National Disability Authority, 2009)

When working on a thesis project together with a company, ethical implications needs to be considered regarding revelation of sensitive data. Possible conflicts between our intended academic outcome and the intended outcome of the company must also be considered.

1.4 Stakeholders

Cisco openBerlin Innovation Center in Berlin, Germany is part of a global network of Cisco Innovation Centers, each with its own specialization. At the openBerlin innovation center, the focus is on transportation, manufacturing and logistics. Together with a dynamic group of partners, openBerlin performs co-innovation to create technology and business solutions with the help of rapid prototyping. By making the most out of data and digitalization, openBerlin help local and global organizations improve their business outcome. They are doing this in three ways (Cisco, 2017):

- Demonstrating how to solve business problems and help creating new markets and transformational digital business opportunities
- Rapid solution and product prototyping
- Research and investments

One of the companies Cisco openBerlin innovation center is working together with is *Local Motors*, a company who specializes in reimagining motor vehicles and how they are made. Local motors work from an open platform of innovation. They invite all kinds of people to help solving challenging problems. After the ideation, Local Motors select the most inspiring ideas and then their engineers, designers and makers start constructing ways to turn them into reality (Local Motors, 2017). Local Motors have a solution called OLLI (Local Motors, 2017), a self-driving electric vehicle the user is ordering to a location of their choice through an app. Olli is

designed to make shared transportation systems around the world more effective, by making every location a bus stop since you can ride Olli from door to door.

Regarding the end product of this study there are two different types of stakeholders that can have use of it in two different ways. The main stakeholders of the scenarios and personas are the authors of the report who will use the personas and scenarios as methods in order to be able to answer the research question in the form of guidelines. The guidelines are the answer to the research question, which is the most important delivery, together with the report, for *Chalmers University of Technology*. However, the other types of stakeholders are the earlier mentioned companies who will use the product in a different way. The product then needs to be altered to fit their needs since different companies have different employees who work in different ways and in different projects. Because of this, the personas need to be more generic. This alternation of the personas will not be presented in this report.

1.5 Thesis Outline

Chapter two will present the Background with an introduction to Smart Cities, Information Communication Technologies, Internet of Things, Ambient Intelligence, Mobility and Multimodality. It also goes through definitions of disabilities in Sweden and Germany. Chapter three contains the Theory section, presenting Interaction Design, Cognitive Science, Inclusive design and related paradigms, as well as Related work. Chapter four presents Methodology within Interaction Design and discusses pros and cons with the different methods. It further explains the Inclusive design process. Chapter five describes the Execution of the project, starting off with presenting the initial planning, literature research and data gathering, following up with presenting the requirements and the practical design iterations. Chapter six presents the Result of the study in form of personas, scenarios and design guidelines. Chapter seven is the discussion about the project regarding for example methods, process, the result and future work. Chapter eight presents the conclusion of the project.

2. Background

This section will present Smart Cities and the smart city vision. It will explain what signifies a smart city and the goals for such a city, and also present the Smart City Berlin project in more detail. As mentioned in the introduction, there is a problem with not including people with disabilities in the smart city projects today, so this section will also describe the benefits with including them from the beginning. To gain some more understanding of the technologies behind a Smart City, Information Communication Technologies (ICTs), Internet of Things and Ambient Technology is briefly explained. Mobility and transportation is a very important part of Smart Cities, thus, a section about Autonomous driving vehicles is presented.

2.1 Smart Cities

More than half of the world's population now lives in urban areas, and this shift to a primary urban population is predicted to extend over the next couple of decades (Chourabi et al., 2012). The European Union has devoted continuous efforts to come up with strategies for achieving urban growth in a "smart sense" for its metropolitan areas (Caragliu et al., 2009). For cities, the basic technical, physical and material difficulties such as waste management, lack of resources, air pollution, traffic loads, human health concerns and insufficient, weak and aging infrastructures are common problems. To ensure acceptable conditions in this rapid urban population growth, it is required to understand the concept of a Smart City. Since all of these challenges are critical to deal with, many cities around the world is prompted to find smarter ways to manage them. The cities doing so, is classified as Smart Cities. A Smart City can be conceptualized as an icon of a sustainable and liveable city (Chourabi et al., 2012).

Cities allows for astounding innovations. The challenges facing cities can be effectively dealt with through *Information and Communications Technologies* (ICTs) (G3ict & World Enabled, 2016). Technology is essential when it comes to smart city services. A smart city is reliable on a compilation of smart computing technologies that is applied to decisive infrastructure services and components. ICTs are key drivers of smart city initiatives (Chourabi et al., 2012). Smart Computing signifies the new generation of integrated software, hardware and network technologies that can provide IT systems with real-time awareness of what is going on in the real world and use advanced analytics that help people make smarter decisions and optimizes business processes. *Real-time situation awareness* is about being aware of what is happening around us and understand what that information means now and in the future. It is about what information is important for a specific goal (Inova Solutions, n.d.). Solutions must have the means to understand what is happening and respond without delay.

Deakin & Al Waer (2011) presents four ICT factors that defines a smart city:

- Applying a broad range of digital and electronic technologies to the community
- Using ICT to change life and working environments in the region
- To integrate these ICTs in government systems
- The territorialisation of practices that brings technology and people together that increases the innovation and abilities that they offer (Deakin & Al Waer, 2011).

Ambient intelligence is described as invisible (embedded) computational power in everyday devices and other physical objects such as intelligent mobile devices (Emiliani & Stephanidis, 2005). The type, content and functionality of emerging products and services will be heavily affected by ambient intelligence. The way people will interact with the products will also be affected, and this will bring multiple new requirements for the development of information technologies. The concept of universal access is critical when addressing this challenge (Emiliani & Stephanidis, 2005).

The Internet of Things (IoT) enables new ways of communication between people and things, and also communication between different things themselves. The Internet of Things represents a world of networked smart devices, where everything is digitally interconnected. It is a technological revolution in communications and computing. Everyday objects, the "things", becomes smart and are able to sense, interpret and react to the environment. This is made possible by the Internet and rising technologies such as Radio-frequency Identification (RFID), embedded sensors and real-time localization (Domingo, 2011). It is important to think about optimising security, performance and privacy performance in these solutions (Chaouchi, 2013).

The way to define the concept of a Smart City differs all over the world. There are conceptual variants that have replaced the word Smart with other adjectives such as digital or intelligent. Hall (2000) defines a Smart City as *"A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens."* Washburn et al (2010) defines it as *"The use of Smart Computing technologies to make the critical infrastructure components and services of a city - which include city administration, education, healthcare, public safety, real estate, transportation, and utilities - more intelligent, interconnected, and efficient"*. Caragliu et al (2009) believe that a city is smart when investments in human- and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance.

To describe the difference between a smart city and industrial cities, Chourabi et al (2012) writes that systems in industrial cities was mostly skeleton and skin, while post-industrial cities (smart cities) are like organisms developing an artificial

nervous system, which enables them to behave in intelligently coordinated ways (Chourabi et al., 2012).

Different visions for a smart city project can end up being in conflict with each other. To be successful, however, cities have to combine multiple visions. Nam & Pardo (2011) gives one example: Increasing accessibility for transportation can be disadvantageous to the urban environment, while improvement of air quality could result in limited accessibility. So the challenge in this case is for the city to maintain economic growth, while still being accessible and improve quality of life at the same time. One policy approach to handle these challenges is what Nam & Pardo (2011) calls "decoupling". Here, policies need integration. One useful way to persuade citizens to change their transport choices can be to link health to transport policies, by including references to healthy lifestyles and related interests. As a result of this, transport policies integrate other policy areas such as healthcare, public safety and economic development (Nam & Pardo, 2011).

2.1.1 Making Berlin a Smart City

Berlin is one of many cities in Europe determined to develop as a smart city. By the year of 2030, the number of people living in the city of Berlin will have increased with 250.000 people (Senate Department for Urban Development and The Environment, 2015). This will increase the requirements for mobility, adaptation of infrastructures as well as the demand for housing. This means that Berlin faces a variety of challenges for the future; the growing city, the aging city and the city going through structural change all require interdisciplinary approaches to find the solutions to the challenges. The Smart City approach, by the Senate Department for Urban Development and The Environment (2015), is Berlin's way of finding solution to the ecological, social, economic and cultural challenges through the use of intelligent technology. They describe the project of making Berlin a smart city as follows:

Over 300 research groups and research-based companies are working on projects and theories for the city of the future in Berlin. Almost all faculties of Berlin's universities and higher education institutes possess Smart City research expertise of some sort. There are also other independent research institutes in the city with this expertise and knowledge.

Viable cities are those who achieve a significantly higher or stable quality of life, still using the same or a lower level of resources. The only way this can be achieved is by an urban management using innovative information and communication technologies (ICTs), which then can link up different sources of information. This allows for the creation and use of symbiosis, and achieves a powerful increase in efficiency and involves both citizens and investors in the construction of the city, to make it attractive, viable, strong, and dedicated to the common good. This will in turn increase the quality of life.

Digitalization is described by The Senate Department For Urban Development And The Environment (2015) as *"the capturing of the active and passive features of analogue processes of everyday life by means of suitable sensors and their transfer into digital information which can be further processed by electronic means."* Digitalization infuses almost all areas of urban life and plays an important role in public administration. This process is going to be intensified in Berlin over the next few years.

Making processes that have until now been analogue digital, the general public and the public administration will save time, effort and money and resources will be free to be used for dealing with other important tasks. Analogue services in the leisure sector, production processes, transport and public administration will increasingly be replaced entirely or complemented by internet-based services. The interaction between human beings and their environment, are already increasingly mediated and influenced by sensors and environment recognition systems, for example autonomous parking.

Intelligent vehicles in Berlin share their positional and operational data with other vehicles or service provider companies, and this is called Car2X communication (The Senate Department for Urban Development and The Environment, 2015). This allows other road users to anticipate dangerous situations more effectively and quickly, and the data can be combined with other data platforms and made accessible for others. Giving the public information about traffic jams, where there are free parking spaces and different public transportation alternatives, provided this way, also increases the traffic flow.

The Senate Department for Urban Development and The Environment (2015) have broken down the fundamental requirements for the city of Berlin into the following areas of action:

- Smart Administration and Urban Society
- Smart Housing
- Smart Economy
- Smart Mobility
- Smart Infrastructure and Public Safety

This can be compared to a project conducted by the Centre of Regional Science at the Vienna University of Technology, which identified six main dimensions of a Smart City (Caragliu et al., 2009):

- Smart Economy
- Smart Mobility
- Smart Environment
- Smart People
- Smart Living
- Smart Governance

All of these areas are facing challenges that arise from the cross-sector issues of demographic change, social integration, innovation orientation, digitalization and

resource efficiency. The different areas of actions should not be viewed as separated, rather should focus be at the points where they intersect and overlap each other, as a way of tackling these issues.

The Senate Department for Urban Development and The Environment (2015) goes on by saying that successful innovation can best come to surface when it is cross-disciplinary, especially a crossing between ICT, health, energy technology and transport and mobility. In Berlin, there are plenty of opportunities to cooperate between and across research opportunities, universities and business. The various domains become smartly linked through a targeted policy of grants and subsidies that are intended to bring sectors together that usually do not work together.

For social participation, mobility is essential. In a city, people are dependent on making journeys both in their working lives and their private lives, this with as little interruptions and adversities as possible. In Berlin, ensuring mobility is out of most importance. This means that Germany's largest city can enjoy social and spatial cohesion and that is the basis for maintaining but also strengthening the economic performance of Berlin (The Senate Department for Urban Development and The Environment, 2015). For transportation networks to keep up with other fast-growing cities, they need to be constantly updated in order to keep attracting people and ideas (Caragliu et al., 2009).

2.2 Mobility

The field of mobility research contains research on the spatial mobility of humans, non-humans and objects, the circulation of information and the study of the physical means for movement. This includes infrastructures, vehicles and software systems that allow travel to take place (Sheller, 2011). There is a new union between physical movement of people, vehicles and things, wireless distributed computing and communication, and tracking technologies, as mobile connectivity begins to occur in new ways across a wide range of mobile devices and smart devices (Sheller, 2011).

Airports, buses, ships and trains that are filled with international students, business people, backpackers, holidaymakers, commuters, asylum seekers and retired people makes it seem like the whole world is on the move. At the same time, the Internet has grown more rapidly than any other previous technology with critical impacts throughout most of the world, and allows for new forms of mobility (Sheller & Urry, 2006).

Mobilities have always involved expert systems, but they are now highly specialised. Such systems are now much more interdependent and attached with each other so that individual journeys depend upon multiple systems, which all need to function and collaborate successfully with each other. Systems are much more dependent upon computers and software today, and software, according to Sheller & Urry (2006), writes mobility. For particular mobilities to take place, there has been an

extensive generation of specific software systems that need to communicate effectively to each other (Sheller & Urry, 2006).

2.3 Autonomous Driving Vehicles

As presented earlier, one major area for smart city projects is the area of transportation and mobility. Autonomous driving cars have been a dream for a long time for researchers and enthusiasts within the field of robotics. The benefits self-driving cars promise to bring to society include prevention of road accidents, comfort, convenience and optimal fuel usage (Petrovskaya & Thrun, 2009). For a long time, the goal has been to achieve full autonomous driving in real urban settings. There have already been attempts to operate autonomous vehicles on public streets. Most of the times, however, these efforts have been reduced to a subset of the test of fully driving. For example, only driving on the highway, only parking or only breaking in time (Levinson et al., 2011).

How to track vehicles is something that has been studied for decades. Some approaches focused on vision alone, while others made use of laser range finders, and sometimes a combination of them both (Petrovskaya & Thrun, 2009). The vision based navigation approach was studied in the early 80's and was based on static image processing and the experience gained from that. Since there was not much accessible computational power during this time, it was common that the system took a picture, analysed the picture, then blindly drove some distance before it was stopped again to take the next picture (Franke et al., 1999).

In the beginning, most autonomous vehicles were designed for highway traffic since this scenario is somewhat simple in comparison to city traffic. On the highway, lanes are generally well marked and they are built with slowly changing curvature. Other vehicles are the only potential obstacles to be considered and traffic lights are large and openly visible (Franke et al., 1999). Later, the need for people to explore the possibility to develop an intelligent system that behaves more like a human driver emerged. The vehicle does not only need to keep the distance to the car in front of them, it has to stop at stop signs, traffic lights, give way to other vehicles and avoid collisions with animals or kids running out to the street. The complexity of this urban environment makes the task of vision much more difficult as compared to vision on highways (Franke et al., 1999). The real-time systems that have to interoperate for a vehicle to be able to operate in urban situations are environment perception, localization, planning and control. Also, a powerful vehicle platform with applicable sensors, networking, software and computational hardware is vital (Levinson et al., 2011).

When it comes to the shift of trying to bring autonomous driving vehicles from non-urban environments to urban environments, the most important change is obligation of the situational awareness of both the dynamic and static parts of the environment (Petrovskaya & Thrun, 2009). The vehicle needs to have the ability to recognise objects. Generally, two steps in the process of recognition is applied; detection and

classification. There are two classes of objects that are relevant for autonomous vehicles. The first being elements of the infrastructure, such as road marks, road boundaries, traffic lights and traffic signs. The other class is traffic participants, such as pedestrians, bicycles and vehicles (Franke et al., 1999).

Driving is a social activity for humans. People are using both subtle and not-so-subtle cues in traffic (Urmson et al., 2008). One example is how drivers indicate their desire for other vehicles to change the lane by changing their speed and the distance between themselves and the vehicle. Also, gestures and eye contact needs to be interpreted in certain situations where normal rules of the traffic has to be violated for a more efficient flow in traffic or for example to let emergency transport pass by. Some will argue that for autonomous vehicles to be smoothly integrated into our society, they would need to be able to interpret these gestures (Urmson et al., 2008). However, it is also argued that it can be possible to deploy vehicles even if they cannot be aware of these social, subtle cues. By conducting tests, it has been shown that humans adapt quickly and interpret, reason and make presumptions within the autonomy system. This shows that there is a possibility that humans will adapt to the robotic conventions rather than the other way around (Urmson et al., 2008).

2.4 Disabilities

This subsection describes disabilities and their different definitions. It will discuss the differences between Sweden's and Germany's definitions, present legal definitions and also shortly describe the five different disabilities that are part of this study.

2.4.1 Definitions of disability

A universal definition of 'disability' is a theme that has been discussed a long time without result, although not for the lack of trying. The World Health Organisation (WHO) (2011) have made countless efforts in trying to establish a definition, WHO's outcome resulted in the International Classification of Functioning, Disability and Health, or ICF. Despite the effort, by the year 2004, there was still no international universal legal definition of disability (Gegener, 2004).

One could argue that there are three ways of separating the definitions of disability, the legal definition, the social definition and the medical definition, all on each own end of a spectrum. Countries within the European Union have some similarities between the social definitions of disabilities. However, countries legal definitions of disabilities are far more variant and dependent on the societies different measures of employments, income standards and possibilities to social assistance (Gegener, 2004).

2.4.1.1 Legal definitions of disability

As this thesis includes collaboration between stakeholders in both Sweden and Germany, the two different countries legal definitions will in the following sections be presented and compared.

Germany's legal definition of disability

§ 2 SGB IX states, that a person is to be considered suffering a disability if their psychological health, physical functions or mental capabilities is most likely to diverge for more than a period of 6 months, based on the condition that is typical for the relevant age. A person is to be considered suffering from a severe disability, if their disability degree is at least 50 % and either legally staying in Germany or have original residence or work in Germany. § 2 (2) SGB IX states, that the degree (or percentage) of a significant disability is to be determined according to a listing of diseases and impairments, as well as guidelines arranged by medical and legal experts (Gegener, 2004).

Sweden's legal definition of disability

Sweden holds a specific law preventing discrimination of disabilities, which was adopted in 1999. Within the Act of Lag 1999:132 "Prohibiting employment discrimination based on disability", 2 § includes a short definition of disability. 2 § "Disability means permanent physical, mental or intellectual limitation of a person's ability to function as a result of an injury or illness existed at birth, has arisen since then or can be expected to occur" (SFS 1999:132). The Act of Lag 2001:526 "Government authorities under the government shall design and conduct their activities in consideration of the disability policy objectives", 1 § also includes sections regarding accessibility (SFS 2001:526). It states that the authorities shall ensure that people with disabilities receive full participation in social life and equality in living conditions. It also states that the authorities in particular shall work to ensure that their premises, activities and information are available to people with disabilities.

Differences of legal definition of disability

Both the German and the Swedish definition of disabilities are related to impairment, though they cover somewhat different aspects of it. The German definition leaves out the phrasing of impairment when accentuating the deviance from a "typical" condition, but not in the definition of a person with a severe disability. With this definition a person with a severe disability, would example be a person with one leg or one arm, but could also be a person with severe facial disfigurements. The German definition of disability exclusively covers people who currently suffer from a disability. The Swedish definition concentrates on functional limitations as the result of impairments. In contrast to the German definition, the Swedish definition does not demand functional limitations to be durable or severe to be considered a disability, as well as it includes both current disabilities and disabilities in the future.

2.4.2 Different disabilities

This subchapter will present some examples of different disabilities.

Visual impairment

Visual impairment includes low vision as well as blindness. *"Low vision is defined as visual acuity of less than 6/18, but equal or better than 3/60, or a corresponding visual field loss to less than 20 degrees in the better eye with best possible correction (ICD-10 visual impairment categories 1 and 2); blindness is defined as visual acuity of less than 3/60, or a corresponding visual field loss to less than 10 degrees in the better eye with best possible correction (ICD-10 visual impairment categories 3, 4 and 5)* (Resnikoff et al., 2004, p 845)." Blindness is a severe vision impairment that cannot be corrected by standard glasses, contact lenses or even surgery. A person's ability to perform everyday activities is hindered by this impairment. The definition of "Legal blindness" is when the vision with best correction in the better eye is worse than or equal to 20/200 or the visual field is less than 20 degrees in diameter (Cdc.gov, n.d.). Cataract, Glaucoma, AMD (age-related macular degeneration.), Corneal opacities, Diabetic retinopathy, Childhood blindness, Trachoma are some diseases that can cause visual impairment (Resnikoff et al., 2004).

Hearing impairment

Morton (1991) writes that hearing impairment can be caused by many different injuries and diseases and can thereby be expressed at any age and be classified in many ways. For example, prelingual or postlingual, conductive or sensorineural, syndromal versus nonspecific, and genetic versus acquired. If the loss of hearing exceeds 25 decibels (dB), it is significantly impaired. If a person has lost at least 80 dB in both ears, he or she is deaf but can be helped by a hearing aid or surgery. This loss is severe enough to make it impossible to successfully process auditory information. Prelingual deafness that are untreated will also interfere with speech, and can in extreme cases lead to the condition formerly known as deaf mutism (Morton, 1991).

There are multiple different hearing aids available for people with hearing impairment. In-the-Canal (ITC) and Completely-in-the-Canal (CIC) are aids that are contained in a tiny case that fits partly or completely into the ear canal. They are the smallest available aids. In-the-Ear (ITE) has all parts of the aid contained in a shell that fills the outer part of the ear. Behind-the-Ear (BTE) have all the parts of the aid contained in a small plastic case that rests behind the ear and the case is connected to an earmold by a piece of clear tubing. Receiver-in-Canal look similar to the behind-the-ear aid but have the speaker if the hearing aid placed inside the ear canal, and thin electrical wires replace the acoustic tube of the BTE aid. Extended Wear Hearing aids are devices that are nonsurgically placed in the ear by an audiologist, worn up to several months at a time. Middle Ear Implants are implanted in the space behind the eardrum that mechanically vibrate the middle ear structures, containing two parts; one implanted portion and one external portion (Asha.org, n.d.).

Deaf-Blindness

People suffering from deaf-blindness differ in their degree of vision and hearing loss (Dalby et al., 2009). They also differ in level of independence, communication mode, language development and at what age the deaf-blindness started. Because of this diversity among people suffering from deaf-blindness, it is important to identify the needs of this group of people on an individual level.

There are at least two groups that people suffering from deaf-blindness can be categorised into (Dalby et al., 2009): The ones that are congenitally deaf-blind, who have experienced the beginning of their impaired hearing and sight from birth to the age 2. Then there are the ones with acquired deaf-blindness, that started to experience the impairment later in life. Intrauterine infections (like congenital rubella), congenital brain damage and chromosomal abnormalities, such as CHARGE syndrome are some of the common causes of congenital deaf-blindness. Genetically inherited disorders (such as Usher syndrome), acquired brain injury, as well as aging, postnatal or early childhood infections can also cause acquired deaf-blindness (Dalby et al., 2009).

Mobility impairment

Mobility impairments include a range of impairments from lower body impairments to upper body impairments. Lower body impairments may require the use of canes or wheelchairs, and upper body impairments can include none or limited use of the upper limbs and head. Many different types of neuromuscular or orthopedic impairments can impact mobility, such as amputation, paralysis, stroke, multiple sclerosis, arthritis and spinal cord injury (Washington.edu, n.d.). A broken bone or a surgical procedure can temporarily impact a person's ability to walk and travel (Washington.edu, n.d.), therefore it is important to remember that mobility impairments can be both permanent and temporary.

Cognitive disability

Cognitive disabilities as a concept are quite wide and somewhat vaguely defined. It can in a broader sense be described as; a person with a cognitive disability have a harder time performing one or more mentally demanding tasks, than the defined "average" person (Friedenberg & Silverman, 2006). There are many different kinds of cognitive disabilities. Genetic disorders and traumatic injury in the brain are a common cause for a damaged connection between the biology and mental processes. However, there are more insidious cognitive disorders that are caused by the brain's chemistry and structure (Friedenberg & Silverman, 2006).

The level of people's cognitive disabilities will affect the amount of necessary assistance in the everyday life. A person with severely reduced cognitive capabilities might need additional assistance with most or all aspects of the daily life, whereas people with minor cognitive disabilities may function with no additional help at all. It could be argued that some web content cannot be comprehensible to people with severely reduced cognitive capabilities, no matter how hard a designer tries

(Friedenberg & Silverman, 2006). However, there are still some aspects of the designs that could be developed and adjusted to increase the accessibility of the content structure to people with less profound cognitive disabilities.

2.5 Smart Cities and inclusion of people with disabilities

Because of the rapid growth of smart city programs worldwide, governments, citizens and technology companies are presented with unique opportunities. However, this growth also brings the risk of further deepening a digital divide for people with disabilities and also the aging population. G3ict & World Enabled (2016) are presenting why it is important to include people with diverse disabilities in smart cities projects:

Even though governments have been making extensive technology investments in smart cities, little explicit focus have been put into technological products and services that are inclusive of all citizens and end-users. Most smart city programs have failed to establish policies that are making sure that the offered services are accessible to the aging people and people with disabilities. If smart city services are not accessible, they will maintain the exclusion and isolation of people with disabilities. People with disabilities are already widely excluded from the reliance on technology in the daily life. In all countries, they have much less access to technology than the rest of the population. By the year of 2016 in the United States, 19 percent of the population have a disability, but they make up for 40 percent of the population without access to broadband.

A greater reliance on technology in smart cities along with the already existing divide from the general population (such as poorer health, lower education, fewer economic opportunities) together with the growing digital divide, will intensify the negative outcomes for people with disabilities. Smart city digital services can be made more accessible by for example making content available in multiple formats and languages, and create remote services for people who is homebound or geographically isolated.

The fastest adopted human rights treaty in history became the United Nations Convention on the Rights of Persons with Disabilities (CRPD) in 2008. Thanks to this, access to technology has become increasingly understood as an issue for human rights. Most countries in the world have parties in the CRPD. CRPD requires countries to make sure that persons with different disabilities can access the country's transportation, public facilities and environment, as well as the different ICTs.

Governments that are open to incorporating accessible technology in their smart cities initiatives will end up with more innovative, stable and impressive results in areas such as education, healthcare and transportation. Including accessibility and inclusion when technology companies are part of building a smart city, will give them an advantage over competitors that do not. These technology companies will

provide products that support prosperous, personalized, fundamental services that will serve a broader population and can be used in a much wider range of environments.

Widening the range of public services that are electronically available also helps them become more personalized and up-to-date. The growing number of flexible smart city solutions that support individual demands and preferences will benefit business, employees and citizens. Smart city initiatives can make use of technology investments to influence the design, development, attainment and wider deployment of accessible ICTs. This can reduce the digital divide for people with disabilities. People have a better chance of remaining productive with the help of accessible smart city solutions (G3ict & World Enabled, 2016).

2.6 Multimodality

"Multimodal" is according to the English Oxford Living Dictionaries *"characterized by several modes of activity or occurrence."* This can for example be that information is presented both visually and auditory, or that interaction can be carried out both through buttons, gestures and voice command.

Gilakjani et al., (2011) talk about the benefits of multimodal learning. They say that words in combination with pictures are better than words alone and people to learn better from it. When talking about words, they include written and spoken text, and when talking about pictures they include static graphic images, animation and videos. The use of both of these categories lets the brain process more information in the working memory. Split attention occurs when the user is forced to pay attention to information that is far apart (for example if the information is not presented at the same time or the information is far apart on a screen). Multimodal applications are more effective when the user's attention is focused and not split. Related content should be presented together in time visually for learning to be more effective. Multimodal learning is also more effective if it only includes content that is relevant to the user's objectives. It should exclude redundant information. Also, since not everyone learn at the same pace, it is beneficial if the user can control the pace of the presented information and interact with it (Gilakjani et al., 2011).

Multimodal interaction paradigms combine several modes, for example both gesture and sound. This is a good approach to enhance usability and accessibility (Kleinberger et al., 2007). Ideally when designing an ambient system would be to make the user able to interact with the system as they would with other humans. The system should interact with humans in a multimodal way using speech, gestures and other forms of instinctive communication (Kleinberger et al., 2007). It is a challenge for a robot or system to understand a user's natural interaction. But it is necessary for enabling new users to use the robot or system smoothly and intuitively (Austermann, 2010). It is easier to implement a set of hard-coded commands to control the system, but it is troublesome for the user because it does not allow the users to use their natural interaction style. Therefore, it would be beneficial to enable

the system to learn to understand the user's natural way of giving commands and feedback by instinctive interaction through for example speech or touch (Austermann, 2010).

Kahn (2006) writes that the disadvantages of multimodality includes that there are no universal standards for having all biometrics technologies seamlessly work together, also that it can drive up the price of the solution and that if a stronger biometric is used in conjunction with a weaker biometric, the result is not necessarily a stronger combined system. However, he also mentions advantages such as that multimodality solves the problem of data distortion. For example, if a fingerprint has been scarred and cannot be scanned (distorted sample), another modality like facial recognition can prevent high false rejection rates (Kahn, 2006).

3. Theory

This chapter will present the areas Interaction Design, Cognitive Science, Inclusive Design and other related design approaches. The chapter also presents related work done regarding designing ambient intelligence and Internet of things for people with disabilities, and also work within smart city solutions regarding mobility and transportation.

3.1 Interaction Design

Preece et al., (2002) defines interaction design as *"designing interactive products to support people in their everyday and working lives."* This involves creating user experiences that add to the way people interact, communicate and work (Preece et al., 2002). Cooper et al., (2014) means that the awesome power of interaction design lays in its ability to give technology users a memorable, effective, easy and rewarding experience as they communicate, work and play. They also describe interaction design as *"the practice of designing interactive digital products, environments, systems, and services."* Cooper et al., (2014) means that interaction design focuses on something that traditional design principles don't explore which is the design of behaviour. It is most concerned about satisfying the needs and desires of the people who will interact with a service or product. These needs and desires can be viewed at narratives, with emotional and logical progression over time. Digital products must also express behavioural narratives of their own, on a more human level and not only at the levels of logic and data entry and presentation (Cooper et al., 2014).

Some developed digital products may work effectively from an engineering perspective, but this may not at all match how real people will use the system. Interaction design aims to help to reduce this problem by bringing usability into the design process. Essentially, it concerns developing interactive products that, from the user's perspective, are easy, effective and enjoyable to use (Preece et al., 2002). By creating something usable, it generally means to make something easy to learn, effective to use and to provide an enjoyable user experience. This is a central concern of interaction design (Preece et al., 2002). When talking about the user experience, it involves every aspect of how people use a product. The way the product feels in the user's hands, how well they understand how it works, how they feel about it during usage, how well it serves their purpose, how well it fits into the context in which it is used. People value the product if all of these experiences are engaging and productive (Alben, 1996).

To be able to design usable interactive products, it is required to consider who is going to use the products and in what context. Another concern is to understand the activities people are performing when interacting with the products. What different kind of interfaces and the arrangements of input and output instruments to use depends on what activities it need to support (Preece et al., 2002). This makes the overall crucial aspect for an interaction designer to investigate how to optimize the

user's interaction with a system, environment or product, so that they match the user's activities that are being supported and extended. To answer this, the designer has to get an understanding of the users. This involves considering that people are good and bad at, what might help people with the way they are currently doing things, what might provide quality user experiences, listening to what people want and involve them in the design process and iterate with user-based techniques during the design process (Preece et al., 2002).

It is a risky perspective for a designer to think that they understand the human mind because they themselves are human. Psychologists realized a long time ago that investigating one's own mental processes results in very little concrete knowledge growth (Saariluoma & Hannakaisa, 2009). They realized that their goals of objectivity and openness were endangered. Freud introduced many psychological processes to the public, and he studied other people, not himself. For the same reason psychologists made the decision to go beyond their own experiences and insights to advance their understanding of the human mind in their field of study, interaction designers should too (Saariluoma & Hannakaisa, 2009). Paying close attention to the larger environment and seemingly unimportant details of how people really live can often result in astonishing insights. Putting trust in what people feel, believe and do as they experience a product could lead to unexpected opportunities (Alben, 1996). Products that are developed without trustworthy scientific understanding of the human mind and behaviour, could result in the user battling hours with products that does not fit their cognitive and behavioural abilities, their interests or needs and desires. This is particularly true with users that do not fit the "average user" stereotype (Saariluoma & Hannakaisa, 2009).

3.2 Cognitive Science

Cognitive Science is the multi- and interdisciplinary scientific study of the mind (Friedenberg & Silverman, 2006). Definitions of the field often emphasize its multidisciplinary roots. Disciplines that are mentioned as contributors to the foundation of cognitive science are anthropology, education, engineering, artificial intelligence, linguistics, human-computer interaction, neuroscience, philosophy, medicine, sociology, psychology robotics and more. But cognitive science is not just seen as a superset of disciplines, rather as an emergent discipline in and of itself (Schunn et al., 1998).

The term cognitive science does not refer to a summary of these disciplines, but rather to their intersecting work on specific problems. It is a collaborative effort among researchers working in the different fields and what unite cognitive science are the topic of the mind and the use of scientific methods (Friedenberg & Silverman, 2006). Each field brings a unique set of perspectives and tools. When it comes to studying something as complex as the mind, no single perspective is enough or correct. Cooperating and intercommunicating among these disciplines can teach so much more (Friedenberg & Silverman, 2006).

Cognitive scientists view the mind as an information processor (Friedenberg & Silverman, 2006). Cognitive science's theoretical perspective on the mind centres on the idea of computation, which can also be called information processing. Information processors represents and transforms information, so according to this perspective, a mind must incorporate some form of mental representation and processes that pursues and shape information (Friedenberg & Silverman, 2006).

3.3 Inclusive Design

Inclusive design, strives to understand and recognize the vast diversity of the population when making design decisions regarding systems, devices and environments and thereby including as many people as possible. Definitions of the diversity of people include a variation of capabilities, as well as desires and necessities.

Inclusive design is about designing mainstream products and services that can be used by as many people as possible without the need for special adaption. Inclusive design accepts the fact that it is not always possible or appropriate to design solutions to address the needs of the entire population (Inclusivedesigntoolkit.com, n.d.). *Image 1* illustrates the target audience for Inclusive Design.

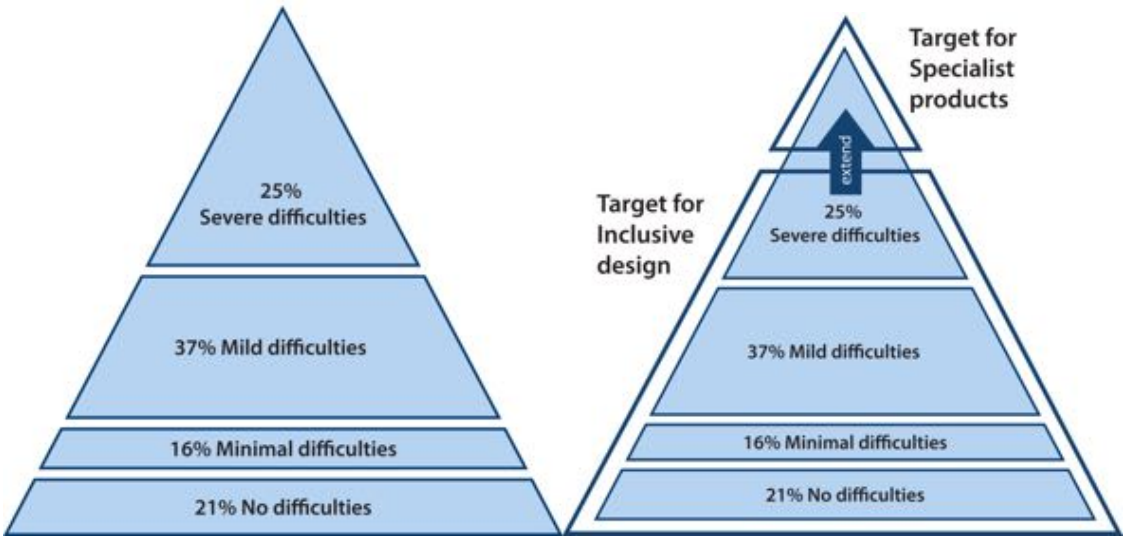

Image 1. *The left pyramid shows the full range of ability variation within a population. The second pyramid shows the target of Inclusive Design versus the target for specialist products. Image source: http://www.inclusivedesigntoolkit.com/whatis/whatis.html*

When designing from a non-inclusive design perspective, the end solution can result in excluding a large number of potential users, as well as induce a lot higher expenses. There are many designs where the lacking incorporation of important sufficient information can be seen. This especially, as designers more than often have an initial instinct to create designs based on their own abilities and preferences. The result is that whoever is not able to fit in the criteria of the designer's perspective, will be automatically excluded from the design. This is simply because of the

designer's lack of knowledge of people's needs or knowledge of how to incorporate the needs themselves (Keates & Clarkson, 2003).

In many cases environment settings entails solutions of accessible design in the form of add-ons to previous designs or reconstructions of them. This can also be seen when working with *Adaptable design*, where its solutions often looks added, are stigmatizing and more than often includes additional expenses (Follette Story, 1998). These kinds of additional solutions are often used instead of designing by the principles of inclusive design from the start.

When designing based on an Inclusive design approach, there are some conflicted areas of norms and attitudes that are necessary to be addressed. This as the foundation of norms often are defined by what might be called "the typical, average or normal". However, "normal" is not a term that necessarily correlates with the Inclusive design principle. Analytical tools like Norm Critique, has its purpose to understand the underlying power structures equality and inclusiveness within a society (Jonsson & Lundmark, 2014). One example of this could be equal access to health care, work or education. The purpose is to move away from the individual that are perceived to be outside the categorisation of "normal" and instead focus on the analysis of societal structure, thus questioning what really should be perceived and defined as "normal".

The notion of inclusive design and with including as many people as possible in the design might sound great in terms of its ethical accommodation, but it does not come without challenges. When designing accessible design, the design is structured to meet predefined requirements for people with disabilities. The possible issue that can occur in this context is that to achieve the accessible design, separated design features for those categorised as "special" users, are added (Follette Story, 1998). Ergo, in the hopes of achieving accessible and maybe even inclusive design, the design itself could actually segregate and divide users with disabilities, from the able-bodied (Newell et al., 2009).

When talking about people with diverse disabilities, there is a risk of stereotyping them solely by their disability, even if they in every other aspect might be diverse in terms of culture, wealth, education, values and attitudes. Often within design, the same solutions such as prostheses and wheelchairs are offered to people with a specific disability, regardless of their age differences or their attitudes towards their disability (Newell et al., 2009). In regard to the earlier described legal definitions of disability, it is important to remember that it is only based on the legal context and a person that has an impairment might not define and view themselves as disabled.

3.3.1 Inclusive Design Process

In an Inclusive Design Process, the project starts with a challenge, which is captured as a perceived *need*. The design process aims to transform this need into a solution that can successfully satisfy the need.

One way of achieving this is to follow these steps structured by an iterative approach, which is common in interaction design projects. This process is divided into the following steps (Centre for Excellence in Universal Design, 2017):

- *Discover* - the systematic exploration of the perceived need to ensure the right design challenge is addressed, with due consideration of all stakeholders; leading to the first output, an *understanding* of the real need.
- *Translate* - the conversion of this understanding into a categorised, complete and well-defined description of the design intent; leading to the second output, a *requirements* specification.
- *Create* - the creation of preliminary concepts that are evaluated against the requirements; leading to the third output, *concepts*.
- *Develop* - the detailed design of the final product or service, ready to be manufactured or implemented; leading to the final output, *solutions*.

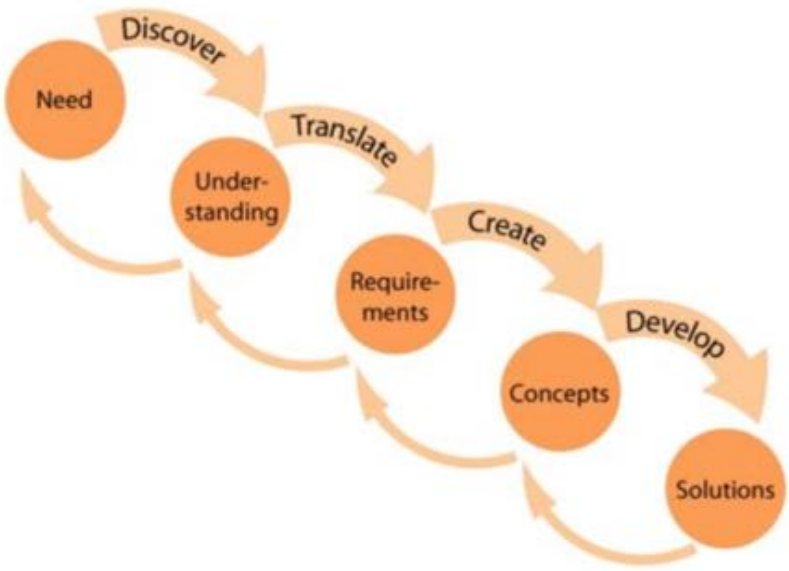

***Image 2**. An illustration of an inclusive design process.*
Image source: Centre for Excellence in Universal Design, 2017.

3.4 Related Design Theories

This subchapter presents some design theories related to Inclusive Design.

3.4.1 Universal Design

Universal Design is closely related to other design principles, such as, universal usability, inclusive design and design for all. All of the mentioned approaches embrace the consideration of how to make technology based on availability and usability to accommodate as wide range of people as possible, including ability, age, education, and language (Lawton et al., 2014). Universal Design is a design process focused on constructing products, such as devices, systems and environments, based

on its usability for people with as wide range of abilities as possible, as well as wide range of situations as possible such as conditions and environments (Lawton et al., 2014). The concept of Universal design originated and progressed by Ronald L. Mace, a designer and architect from USA (Center for Universal Design NCSU, 2017).

Despite that the original idea of Universal design was to include as many people as possible in the design solution, discordance has emerged about both its implication but also its future outcome. Some emphasises the original concept of Universal Design as an approach to designing where as many people as possible are included, whereas others, consider it as a way of designing products specified for people with disabilities (Bringolf, 2008). As disability issues are both sensitive topics as well as highly discussed on a jurisdictional level, there are those who perceive the future of Universal designs to belong in a regulatory framework. Another prediction or prospect for Universal Design to move forward is more research and scientific methods (Bringolf, 2008).

3.4.2 Design for all

Design for all, is the European counterpart to Universal design, with the focus on ICT. It is a goal to motivate national centers around Europe to establish the Design for all approach. Though, these are more visualized as virtual than physical centers (Keates & Clarkson, 2003)

3.4.3 Universal Access

Accessibility is referring to the design of systems, devices and environments for people whom experiences diverse disabilities (Lawton et al., 2014). The concept of accessibility is to create solutions that aid access for people with disabilities. Universal access or access for all and Universal design are often referred to in a similar way. However, Universal access has an even greater focus on ICT. The term Universal access is also often used in the field of assistive technology, particularly in regard to interfaces for computers and similar devices. This to make the ICT of the products systems and services usable and accessible to people with greater reduced capabilities (Keates & Clarkson, 2003).

3.4.4 Transgenerational Design

Transgenerational design is a concept coined and defined in 1984 in The U.S. by professor James Pirkl and the University of Syracuse (Special Collections Research Center, 2017). The concept originated from the idea that the population is ageing and product design should thereby be designed to be more accommodating to a wide-ranging age span and abilities (Pirkl, 1994). As opposed to both Universal design and Design for all, Transgenerational design does not concentrate on specifically disabilities, but rather an approach led by the market (Pirkl, 1994).

3.5 Related Work

This section will present a smart city challenge where people worked on different transportation solutions in The U.S. The chapter also presents research and projects carried out regarding designing technology for people with disabilities.

3.5.1 The Smart City Challenge in America

Heavy traffic, lack of parking spots, complex ways to plan trips, unsafe biking and walking conditions are some of the challenges travellers in cities face today (U.S. Government of Transportation, 2016). The Smart City Challenge was launched in December 2015, where the U.S Department of Transportation (U.S. DoT) asked cities across America to share their ideas for how to create an integrated smart transportation system that would use applications, data and technology to help people and goods move cheaper, faster and more efficiently. The U.S. DoT has leveraged nearly 350 million dollars the last year for advanced transportation technologies. The Smart City Challenge served as inspiration and take-off for cities looking to transform their transportation systems to benefit people's lives. The aim was for the cities to express their most urgent transportation problems and envision daring new solutions to those problems that could change the transportation in American cities by meeting the needs of all residents, no matter ages and abilities, and reduce the digital division, allowing everyone to be connected and have the ability to take part of what the city offers. The U.S. Department of Transportation (2016) presents some results and lessons learned from the challenge:

One goal is to connect rather than divide. In cities, policies regarding planning, infrastructures and socioeconomics have maintained historic racial and economic divides, which have isolated neighbourhoods and enabled economic segregation. Cities must plan for a future transportation system that meets the needs of all residents, to bridge the digital divide and avoid repeating the same mistakes.

The seven finalists of the challenge had big plans, everything from a plan to implement autonomous shuttles, to equip buses, cabs and cars with vehicle-to-vehicle Dedicated Short Range Communicators (DSRC) technology. The finalists in the challenge presented the following ways to ensure that everyone would get access to the smart city technology (U.S. Department of Transportation, 2016):

- Improving connections to transits, either by car and bike share or autonomous shuttles
- Expanding access to free public Wi-Fi on buses, cabs and public spaces
- Creating applications for non-English speakers and people with disabilities

Portland wanted with their contribution to the contest develop a mobile app that aims to benefit people with disabilities. This app would offer trip planning based on accessibility. By highlighting locations with audible traffic signals, it would support the people with visual impairment. It would also provide data about where people

with disabilities are traveling, which will help developing future updates of the city's transition plan.

3.5.2 Ambient Intelligence and IoT for people with disabilities

In 2005, Emiliani and Stephanidis (2005) wrote a paper about the anticipations of ambient intelligence and how it will affect people with disabilities - concerns and insights that are still relevant today. They write that it is anticipated that the evolution of information technologies towards an ambient intelligence environment will be a complex process. The factors that will play demanding roles are:

- The types of technologies (and combination of technologies) that will be embodied in the environment
- The type, nature and scope of the new applications and services that will emerge
- The contexts of use to which the information society will extend
- How usage can be extended to all user groups

Ambient intelligence technologies are anticipated to have fundamental significance on all aspects of human life and possibly their activities; therefore, it is critical that the perception of ambient intelligence, as well as the design and development approaches is, according to Emiliani & Stephanidis (2005), being influenced by a universal access perspective. People with disabilities can be overly dependent on their families or other assistants because of the lack of support services such as building access, transportation, communication and information. This can prevent them from working, being active and socially included (Domingo, 2011). The Internet of Things can help with support and assistance that people with disabilities need in order to gain a good quality of life and be better included in the economic and social life. Assistive IoT technology tools are effective in increasing independence and enhance participation for people (Domingo, 2011). The participation and inclusion of people with disability in social, political, cultural and economic life can be supported by the environment. IoT constructs enabling environments by giving people with disabilities assistance in transportation, building access, information and communication (Domingo, 2011).

Combining mobile communications, sensors and RFID seems to be very promising to enable more applications to contribute in building the IoT. SeSaMoNet is a navigation and environment description system for users with visual impairment. It is a portable, easy to use, orientation and navigation aid that was made possible to build because of the spread of mobile technology such as handheld devices, personal digital assistants and smartphones, as well as wireless communication, text-to-speech, databases and RFID (Biader Ceipidor et al., 2009).

The main benefits that ambient intelligence environment will bring for all user groups, including people with diverse disabilities include the availability of a broader range of interactive devices that can possibly meet a wider variety of user requirements, and also the availability of applications that can contribute to

improving critical aspects of the user's quality of life. The main challenges these environments are likely to bring regarding providing accessibility refer to research and development issues (Emiliani & Stephanidis, 2005).

Domingo (2011) presents some interface and assistive device requirements that will help to assist people with disabilities (mostly directed towards smart homes):

People with Visual impairment require specialized Human Machine Interfaces (HMI), a operational subsystem that allows them to control home equipment such as doors, lamps and television, they will also benefit from voice control installed devices. There is also a need for devices for indoor navigation, with an obstacle detection system based on voice-synthesized instructions.

People with Hearing impairment require touch screens to read text and get access to graphical information.

People with *Physical impairment* require specialized HMI, such as head tracking devices that perceives different types of head tilting, or facial detection, gesture recognition, eye-movement controls and facial expression recognition, depending on how serious the paralysation is. Other solutions can be intelligent wheelchairs that determine direction based on how the user moves his or her face (Domingo, 2011).

One significant challenge in this area regarding people with disabilities is according to Domingo (2011) self-management, which is how capable the IoT is to manage its own operation without human interference based on *self-configuration* (the automatic configuration of components), *self-healing* (the automatic discovery and correction of faults), *self-optimization* (the automatic monitoring and control of resources to ensure optimal function in regards to the defined requirements) and *self-protection* (the proactive identification and protection from arbitrary attacks). Domingo (2011) means that self-healing is especially important since people with disabilities usually depend on the IoT device to compensate for their disability.

Emiliani & Stephanidis (2005) claims that to reach universal access within ambient intelligence technologies and environments there is a need for multidisciplinary and joint research efforts within disciplines such as human-computer interaction, human factors, social sciences, requirements engineering, usability engineering and software quality. It is also critical to have direct and active participation of representatives from different user groups to help shape ambient intelligence technologies and applications based on their reflections to anticipate their needs (Emiliani & Stephanidis, 2005).

4. Methodology

The methodology chapter will begin with describing what it means to do research through design work, and goes on to describe what it means to work with a wicked problem. The chapter also describes the Inclusive design process and presents different methods to work with when conducting a project in Interaction Design.

4.1 Research through design

Research through design is a research approach where new knowledge is required from the design process (Frayling, 1993). This can be done through development work, for example by customising a piece of technology to do something no one has considered before, and communicating the results (Frayling, 1993). Gaver (2012) describes it as situations chosen for their topical and theoretical potential, and where the design results are demonstrating the designers' experience about valid ways to address the problems and possibilities in those situations. Reflection of these results acknowledges pragmatic and conceptual insights. The results of this work often take the form of artefacts and systems, and include a variety of methods, conceptual frameworks and theories that is presented separately (Gaver, 2012). It is common that design researchers borrow conceptual perspectives from other disciplines and try to investigate how they can be applicable for design. Examples are notions of affordances, situatedness and context. The borrowed concepts or theories often inspire new designs (Gaver, 2012).

4.2 Wicked problems

A wicked problem is defined as a problem that is challenging, improbable or impossible to solve, often because of its constant change of requirements or its inconsistency. One of the first to formalize the theory was Horst Rittel together with Melvin Webber (Rittel & Webber, 1973). They formulated ten specified characteristics for wicked problems in social issues:

1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no stopping rule.
3. Solutions to wicked problems are not true-or-false, but good or bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial and error, every attempt counts significantly.
6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.

9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
10. The planner has no right to be wrong.

To be able to process these wicked problems, a project can follow an *Iterative approach*, until one or more possible solutions that could be defined as good, is found. Iterative design focuses on dividing the design process into shorter steps, where each step of design and evaluation is iterated, to better understand and challenge the hypothesis. In connection to design research, does Allan Collins describe it as; *"The role of design research is to provide an in- depth understanding of what is happening as a particular design is implemented in a learning environment in order to refine the design through multiple iterations"* (Shaughnessy & Kennedy, 2008).

4.3 Methods to use in Interaction Design projects

This subsection describes different methods to use when doing research and design projects within the field of Interaction Design. It goes through research methods, ideation methods, prototyping methods and evaluation methods.

4.3.1 Research methods

In the beginning of an interaction design project it is important to conduct research to get a greater understanding about the problem area. This chapter present some available research methods.

Literature research
The *literature research* method identifies essential attributes of materials and areas by having the researcher read through, analyse and sorting literature. The qualitative analysis of literature has its strength in its way of distinguishing the past trends and foreseeing future models. In comparison to other methodologies, it does not directly deal with the object that is being studied, it instead indirectly accesses information from a variety of already existing literatures (Lin, 2009). Langemar (2008) writes that if you read other people's research before start conducting your own, there is a risk of being "primed", which means *"perceptual focused because of some cognitive schemata has been actualized"* (Langemar, 2008, p 48, freely translated). However, completely excluding it from the project may cause the designer or researcher to reinvent the wheel, or making the same mistake someone else has already made and reported.

Task analysis
Another method that can be used for research is *Task analysis*. Task analysis is used as a method to reduce human error (Embrey, 2000) by exploring the user conducting tasks. There are plenty of different types of task analysis methods, but nearly all of them provide at least a description of the observable aspects of the one who is operating something's behaviour at different detailed levels. They also provide some indications of the structure of the task. Those techniques are called action oriented

approaches (Embrey, 2000). There are also cognitive approaches, which focus on the underlying mental processes of observable behaviour, such as problem solving and decision making (Embrey, 2000).

Interviews

Patton (2002) says that in many cases the researcher can learn more by studying a smaller number of carefully selected participants, rather than by gathering standardized information from a large, statistically representative sample of the population. This is usually the case with *qualitative research*.

Conversations are a basic mode for human interaction. Through conversations, we get to know more about people and their lives, their experiences, hopes and feelings. An *interview* is a conversation, where the interviewer asks questions, and listens to the answer, to learn about the world of the person being interviewed. The knowledge is constructed in the interaction between the interviewer and the interviewee (Kvale, 2007).

There are multiple different kinds of interviews, such as *structured interviews*, *semi-structured interviews*, *unstructured interviews* and *group interviews*. Which of these interview techniques to choose for a project depends on the desired outcome. If the researcher for example needs to be able to clearly compare answers from the interviewees in an easy way, structured interviews might be a good choice since it has the predetermined questions ready beforehand. If the interviewer knows what questions to ask but still want to leave space for improvised follow up questions, a semi-structured interview would work the best. If the interviewer has some idea about what to ask but want the interview to be more improvised and are open for it heading in different directions, then they should conduct an unstructured interview. Sometimes, due to for example time constraints, a group interview will be the most efficient. It can also be a good idea since the interviewees can get inspired from one another and tell things they would not have thought about if they were alone. It is, however, important to consider that some people might not feel comfortable answering all questions honestly with a group of other people present.

Observations

To be able to get the chance to learn about people's behaviour, that they for different reasons would not tell in an interview, the researcher can conduct *observations*. The reason for this is because people might feel uncomfortable talking about certain things, it could also be because they might not know that it would be helpful information, or that they simply are not aware that they are doing certain things. In *covert observations*, people are not aware that they are being observed, which means that the observation is more likely to capture what is really happening. If people are aware they are being observed it is called *overt observations* (Patton, 2002).

A lot of books have been written about ethnographic fieldwork and methods, but still there is no agreed set of principles that completely guide the researcher on how to carry out their work and what methods are applicable in every situation

(Blomberg et al., 1993). According to Crabtree et al. (2012) a key part of ethnographic studies is to develop competence in the work carried out in a certain setting, trying to see that work as the people in that setting sees it. The researcher should use the tools available to make sure they understand the setting in which the observed activity and users are present.

Surveys
Another approach to sample information about people and their behaviour is through *surveys*. Surveys refer to a number of methods such as telephone interviews and mail questionnaires, where data is collected and analysed using statistical techniques (Gable, 1994). The survey approach investigates relationships that are common across organizations and other groups and thereby provide generalizable statements about the object of the study, by studying a representative sample from the organization or group. It is however important to know that the survey approach often only provides a glimpse of the situation at a certain point in time, contributing with only little information on the underlying meaning of the data. There is also important to know that some variable that might be of interest to the researcher may not be measurable through this method alone (Gable, 1994).

4.3.2 Walk-through

When the designer has a good idea of who the target group is, what their goals are and what tasks are needed to reach that goal, they can use a method called *walk-through* (Rubin & Chisnell, 2008) (sometimes also referred to as cognitive walkthrough). This method is useful for exploring the user's route through an early concept or prototype and thereby sees how the user is getting along with the product. It is common that the designer guides his or her colleagues through real user tasks, while some team members record the difficulties that the user encounters. It is also possible to bring in a real user to execute the walkthrough.

4.3.3 Personas

A *Persona* is a description of a fabricated person, used as a tool to increase focus on the users and their possible requirements throughout the design process. It is used by looking at the attitudes of the persona and context, related to the work's specific area of focus or domain (Nielsen, 2013). Lene Nielsen (2013) divides personas in four different main perspectives;

The goal-directed perspective, made by Alan Cooper, categorizes the method as Goal-directed design and states that it is used to make the designer understand the user. The main essential to the method, is that the fabricated persons are not typical or average, but rather a one of a kind characteristics (Cooper et al., 2014).

The role-based perspective, by Jonathan Grudin, John Pruitt and Tamara Adlin, is also goal-directed, but focuses on behaviour. The role-based perspective is immensely data-driven and includes gathered data from quantitative and qualitative sources (Grudin & Pruitt, 2002). The perspective focuses on the role of the user in the

organization. It is a beneficial method to use, as the mind's cognitive ability to connect and arrange fragments and partial information to form a whole visualisation of people around us, and with the personas the designer can get a greater understanding of users in reality.

The engaging perspective; by Lene Nielsen, has its roots in using stories to increase involvement and insight. The theory is that by understanding the character and its story, it is possible to create a realistic description of a fabricated person. The purpose is to make the designer move away from perceiving the users as stereotypes and seeing them as someone they cannot identify themselves with (Nielsen, 2013).

The fiction-based perspective, a category containing a collection of different types of personas that is often used as a tool to explore design and to start discussions about the field (Nielsen, 2013). Different types of fiction-based persona perspectives are; *Ad hoc personas*, that are based on the designer's insights and experience to create an empathetic focus (Norman, 2004). *Extreme characters*, that are meant to help design insights by exploring the boundaries of design (Djajadiningrat et al., 2000). *Assumption personas*, that are based on the design team's own presumed understanding of their own users (Adlin & Pruitt, 2006).

Alan Cooper (2014) provides guidelines for the process when creating personas. This, in form of 8 steps:

1 Group interview subjects by role: *This step includes grouping the interviewees based on their roles. Depending on what kind of focus user, the difficulty in grouping them can vary. Example organisations are usually grouped based on job roles, but regarding customer products the roles can be subtler such as family roles or attitudes.*

2 Identify behavioural variables: *Identity the observed behaviours for each role. By focusing on their Activities, Attitudes, Aptitudes, Motivations and Skills, important distinctions between behaviours can emerge.*

3 Map interview subjects to behavioural variables: *By mapping the behavioural variables listed from the interviewees, one could be able to see the relations between the different behaviours of the interviewees.*

4 Identify significant behaviour patterns: *Once mapped the behaviours, one should identify the behaviour patterns. If interviewees are mapped together in multiple behaviours, they are lightly a sign of a common behaviour pattern.*

5 Synthesize characteristics and define goals: *Based on gathered data from the research process, goals are defined and characteristics are created. The synthesized characteristics are details from gathered data. These should include details such as; activities and motivations behind the behaviours, frustrations and pains in relation to current solutions, skills and experience, as well as relevant interactions with other people, products, or services.*

6 Check for completeness and redundancy: *By reviewing the personas made so far, some personas might be redundant as their goals and attitudes are too similar, and could therefore be removed. It might be needed to do additional research to fill in the gaps.*

7 Designate persona types: *This is a key step, to turn the qualitative data into a set of design tools. To design a solution to accommodate multiple needs can be challenging. Therefore one should prioritise the personas based on the primary user target. The different types of personas are often categorised as Primary, Secondary, Supplemental Customer, Served and Negative, and are often prioritised in that order.*

8 Expand the description of attributes and behaviours: *The final step is to expand the attitudes and behaviours of the personas, by creating the persona narrative, as well as adding a photograph to make the persona more alive.*

Personas most often include photos and illustrations. Which is the best choice between a photograph and an illustration have been debated. A study by Frank Long (2009) investigated the difference regarding memory when comparing photographs and illustrations in form of drawings. The study showed that when using photographs, remembering details about the persona was easier for the reader, compared to drawings (Long, 2009).

As the description of a persona includes elements of fiction, there have been some criticism towards the usage of personas, as some find it hard to see the relation between the way data is gathered and processed and the actual real user (Nielsen, 2013). The method has also been criticised not describing real people, as they are only based on characteristics. Furthermore, the method has been criticised for averting designer from meeting the real users, something that is assumed to result in a greater understanding of the needs of the users.

4.3.4 User Scenarios

Another method, which is often used in combination with personas, is *User scenarios.* A user scenario describes a simple story of a user performing a task or action that the user wishes to achieve. The level of detail can differ depending on project and situation, however the important part is to find out; who, how, what, when and where (The Interaction Design Foundation, 2017). Thus, finding out what the user actually wants and needs. Designing user scenarios can help the designer to both evaluate and refine requirements, but also to communicate ideas to other project members.

4.3.5 Ideation

The purpose of *brainstorming* is to come up with new ideas and to expand the mind of creativity. The amount of brainstorming methods is countless and they are often tweaked and/or merged together (Kelly, 2000).

The 6-3-5 method (Rohrbach, 1969) is an easy to learn group-brainstorming method,

where each six (6) participants have to write down three (3) ideas within five (5) minutes. This is a good method to use as it is both easy to learn and all participants is automatically included and given the chance to share their idea. However, there is an issue with writing down ideas, as it can be hard to summarize the whole idea in a good and complete way.

Time Travel method (Woodhead, 2010) is another group brainstorming method, with the purpose to think outside the framework of time. During these brainstorming sessions, questions are asked such as *"How would you deal with this if you were 100 years in the future?"* These kinds of brainstorming methods can help expand the views of a solution or possible design. However, there is a risk that the ideas become too unrealistic to use in the presence and therefore needs more evaluation and iteration than other methods.

Reverse brainstorming (Elmansy, 2016) have the purpose of exploring solutions and ideas from a different angle. This could example be, instead of asking the question *"How could one solve this?"* one can ask *"How could one possibly achieve the opposite effect?"* or *"How could one cause this problem?"*

Once done with a brainstorming session, it is important to analyse and evaluate the new ideas. The *KJ-method*, gives great opportunities to organize and evaluate ideas (Martin, 2012). The KJ-method works by going through 3 steps. First step is writing down all the ideas from the brainstorming session, this preferably on note-pads. The second step is to group the different cards in categories that the participants feel is connected in some way. When all participants are pleased with the grouping, all groups should be named. The third step is to link the different groups to each other, connecting them by relevance, interest or similar. This method is great to use as it delivers a good overview of ideas and thoughts.

4.3.6 Prototyping

When prototyping in a design project, there are plenty of different methods and techniques to use. Most likely, before the prototyping starts, *sketches* are made.

Buxton (2007) describes sketching as followed: *"Sketching in the broad sense, as an activity, is not just a by-product of design. It is central to design thinking and learning."* (Buxton, 2007, p 118). The act of sketching is necessary in the design process, since it promotes ideation, communication and reflection. According to Buxton (2007) sketches suggest while prototypes describe, and sketches question while prototypes answer. Sketches dominate the early ideation stages, and prototypes are more concentrated at the later stages. Sketches also allow the designer to communicate his or her ideas to others. The designer sketch to work through a design, to explore possible ideas, and can also explain the design to others in a more concrete way. However, Buxton (2007) means that it is just as hard to learn to acquire the skills to converse fluently with a sketch, as it is to learn to speak in any other foreign language.

Moggridge (2006) says that the designer should prototype early and often, making each iterative step a little bit more realistic. It is much easier to handle errors and redesign early in the process, before too much time and money has been put into making the product. A simple sketch or a lo-fidelity prototype out of paper can detect many of the problems. The design should be thoroughly thought of, and should have gone through multiple iterations of design and testing, before moving on to implementation. Lo-fi prototypes are more focused on content, form, structure and functionality requirements. They are designed to be made and then be thrown away quickly (Benyon, 2010). Because of the "throw away" aspect, it is sometimes called *Rapid prototyping* (Benyon, 2010), and they are thrown away because the implementation will be in a different form or language. Lo-fi prototyping help generate more ideas and suggestions for design. The challenge with paper prototypes is that it is not very robust and cannot handle many details (Benyon, 2010).

Scenarios as prototyping tool suits well if the designer need to learn more about the structure and qualities of the problem area. This can be achieved by using scenarios to try to see the situation in many different ways, and by interacting with the concrete elements of the situation (Carroll, 1999).

Prototypes can be divided into *Spatial prototypes* that focus on the form and appearance of the product, and *Temporal prototypes* that focus on the behaviour and the interaction (Mellis, 2009). Another division can be made between *Intangible prototypes* which refers to the content of the prototype, and uses e.g. sketching, scenarios and video prototyping methods, while *Tangible prototypes* are three dimensional objects, which could be electric but do not have to be (Mellis, 2009). These different forms mean different levels of complexity for the designer. For an interaction designer both spatial and temporal form of the prototype is very important, since both the appearance and the behaviour of the product affect the user experience. Prototyping with example tangible electrical objects is more complex than sketching a spatial intangible prototype, and needs more pre-knowledge.

When choosing how to prototype, in terms of forms and material, it depends on how close the designer can and want to get the representation to the actual end product. Paper prototypes are fast and cheap to create, they can be somewhat interactive with the help of for example the *wizard of oz technique* (Salber & Coutaz, 1993), and are easy to work with in iterations. The designer can learn what types of function it needs, what content it should contain and how it can be interacted with. However, it rarely makes the design look like and feel like anything close to the end product. Clay, foam and cardboard can take the design a step closer to achieve this, and are still pretty cheap and easy to redo. With these materials, the designer can learn a little bit more about the shaping, movability and relations between objects in form of scale and position.

Hi-fidelity prototypes (Coyette et al., 2007) resemble the end product more, and can have easy navigation and good feeling of the interaction, but it demands that the designer learn to use the necessary software or hardware, and the prototype is harder to change after evaluating it. *Video prototyping* (Mackay, 1988) is also a very useful prototyping tool in interaction design. The designer can vary the type of video prototyping as well depending on what it is that he or she wants to showcase. It is especially suitable in interaction design is since it allows people to see the product used in context, and how people are interacting with it in a given context.

Prototyping and cognition

Cognition is not only an activity that occurs inside our head, but also distributed through the whole interactive situation - including mind, body and environment (Wilson, 2002). Advocates of distributed cognition mean that what is cognitive extends beyond the individual and comprises other people, artefacts and the environment. People solve problems by offloading tasks onto appropriate artefacts in their environment (Hartmann, 2009). This is why designers can use prototypes to be more effective in their reasoning, ideation and communication. Sometimes our physical body works faster than our mental mind does (Hartmann, 2009), so physical prototypes could favour the designer, as compared to trying to reason about a design problem in abstract, "offline". Offline cognition happens when we talk about something that is not present. When people offload cognition into the environment, it basically means that people use the environment as an external memory (Myin & O'Regan, 2009; Andersson, 2007).

4.3.7 Guidelines

Guidelines are recommended as a cheap and useful basis for incorporating the needs of people with shifting abilities into design at an early phase (Watson, 2001). Goals are often conceptual and broad in nature, when goals are broken down into something detailed enough to use as a basis for design ideas, they turn into objectives. The least conceptual pragmatic part is usually the design guidelines. Goals and objectives provide context and accuracy for the design guidelines. When creating guidelines, it is important to define terms that might not be readily understood (Watson, 2001).

Two different types of guidelines are *prescriptive guidelines*, which are strict and regulatory, and *descriptive guidelines*, which provide input into the design process and are more flexible (Watson, 2001). The descriptive guidelines grant more creativity and can be more adaptable, but can on the other hand be too open for interpretation so that even the design solution becomes vague and runs the risk of not accommodate the design issues. These guidelines often give the appearance of only "encouraging" or "discouraging" design decisions. Prescriptive guidelines are not as open for interpretation. But they might restrict the exploration of different design options, and sometimes even make it impossible to create a good and creative design solution. When a project has a requirement that needs to be incorporated into the plan, it usually results in this type of guideline (Watson, 2001).

Some of NICE's key principles for developing guidelines are (National Institute for Health and Care Excellence, 2014):

- Guidance should be based on the best available evidence of what works
- It should be developed by independent and unbiased committees of experts
- Once the guideline is published, it should be regularly checked and updated if new evidence arises
- The processes, methods and policies should remain up-to-date

National Institute for Health and Care Excellence (2014) writes that in order to base the guidelines on the best available evidence, a wide range of different types of evidence and information is used. This is for example scientific research using a variety of methods and information gathered from practitioners and people using specific services.

4.3.8 Evaluation

When evaluating, the designer and/or researcher can observe a user handling the product. *Usability testing* (Rubin & Chisnell, 2008) make use of techniques to gather empirical data while observing representatives from the end user group use the product while performing realistic tasks. There are two main approaches to the testing (Rubin & Chisnell, 2008); the first involve formal tests conducted as true experiments for confirming or disproving a specific hypothesis. The second, less formal approach use an iterative cycle of tests with the intention of exposing usability flaws and gradually shape the product that is being tested. This can be carried out in a controlled environment, since the designer might need to keep track on amount of errors the user makes or, it can be necessary for the user to think aloud about what they are doing while operating the product.

Think aloud is a method used to draw conclusions of the process(es) used while reasoning when trying to solve a problem and make decisions for problem resolution. It provides direct verbalisation of cognitive processes (Fonteyn et al., 1993). Having a user think aloud as they perform tasks will give the researcher valuable insights to why a problem exists and how the user is trying to figure that problem out and work around it. It reveals important clues about how they are thinking about the system or product and if the way it works matches up with the intentions of the design (Rubin & Chisnell, 2008). However, participants of the test will filter their thoughts to different extent, which may make them leave out information. The researcher should not expect to be able to know everything that is going on in the participant's mind. It is also important to remember that thinking aloud will have the test take much longer time than it would without it (Rubin & Chisnell, 2008).

It is also possible to do the evaluation out on the field, because it can be important for the designer to see how the product is used in the real world and in its supposed natural context. Patton (2002) writes that evaluation clearly will show what would

have been most important to study, if the designer would have known the result from the evaluation beforehand. This is why it is so important to work based on an iterative design process, because a lot of new questions will arise after the evaluation, and with more iterations the designer will have the chance to get answers to these questions.

Another evaluation method is *Heuristic evaluation*, or expert evaluation, which is a review of a system by a usability specialist or human factors specialist. These specialists should have little to none involvement in the project. The review is following accepted usability principles, also called heuristics, and is also based on the previous professional experience of the specialist (Rubin & Chisnell, 2008). The advantage of this method is that it is cheap and does not require a lot of resources. The disadvantage is that the designer does not get the point of view from a real end-user.

For getting user input regarding the organisation of content, vocabulary and labelling in the user interface, a very inexpensive but still effective method to use is *Card sorting* (Rubin & Chisnell, 2008). The researcher can give the participants cards showing content without titles or categories, and have the participants to the naming and labelling, which is a method called *open card sorting*. *Closed card sorting* is when the researcher gives the participants already existing preliminary categories and asks them to sort content or functions into each category.

After iterations of evaluation, it is important to consider the validity. Validity is one of the most important concepts in research, and to reach validity one should consider questions like *"Does this study really answer the question it posed?"* (Graziano & Raulin, 2013).

5. Execution

This section presents the practical execution of the project, starting with the initial planning of the project, then explaining the process of the literature study. The chapter goes through the stakeholder involvement, to later present the data gathering phase, the analysis of the data and the process of creating the personas, scenarios and guidelines. Each phase presents the outcome of that particular phase in the end of that section and how that affected the continuing work process.

The design process carried out in this project, which was influenced by the inclusive design process presented in *Chapter 3.3.1*, is visualized in *Image 3*.

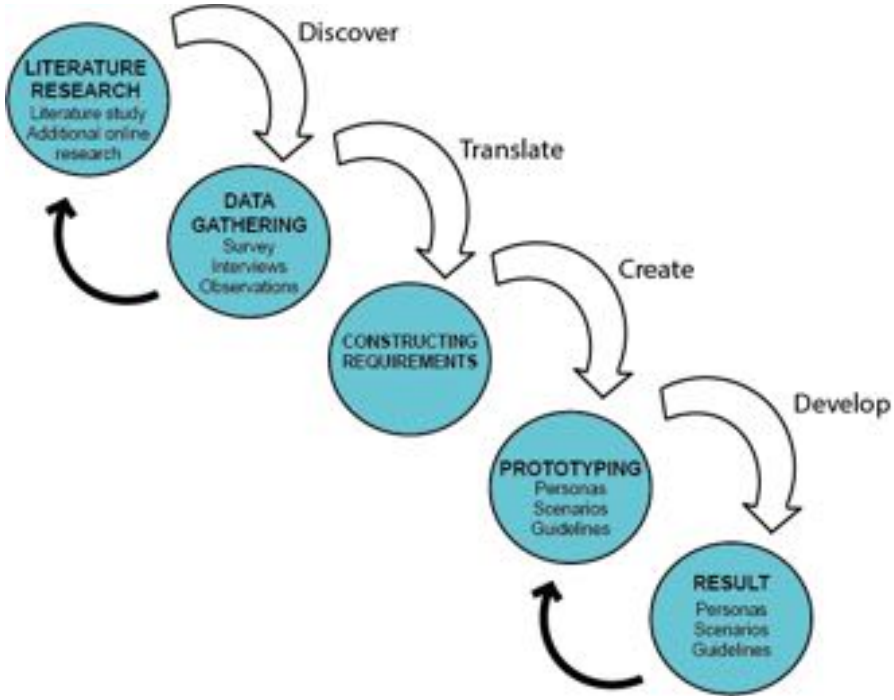

Image 3. *A visualization of the design process and its iterations carried out in this project.*

5.1 Initial Planning

In this chapter, the initial plan for the project is presented.

The project was planned to be carried out for 20 weeks and be stationed in Berlin, Germany. The first two weeks of the project was to be carried out in Gothenburg, Sweden, where the focus was to start off the research phase with literature studies.

The design process was planned to follow a Human-Centered Design approach with an Inclusive Design influenced perspective.

The outcome of the project was planned to be guidelines regarding designing smart digital mobility solutions for people with disabilities. Also, to create an improved design solution for OLLI presented in the introduction [*see Chapter 1.4*] based on user

testing and research. There was no plan to implement the design, rather, to create prototypes that the company Local Motors could use for their implementation of the solution. Considering the needs of people with disabilities early on would lead to designs that are more flexible and safer for everyone using the solution.

The initial time plan is presented below:

- Research phase (mid-January / mid-February) (Going to Berlin 24th of January)
- Literature research
- Investigating other Smart Cities in Europe and their digital mobility solutions
- Task analysis
- User analysis

- Ideation phase (mid-February / end-February)
- Brainstorming sessions with Team at Cisco and other stakeholders

- Design phase (March / mid-April) Lo-fi prototyping with testing and evaluation
- Design suggestion
- User-testing
- Evaluation
- Iteration

- Report phase (mid-April / May)
- Report findings

5.2 Literature Research

This subchapter presents how the literature study was carried out, as well as the plans of working with the stakeholders.

5.2.1 Stakeholder involvement and adaption

Cisco openBerlin Innovation Center was the main stakeholder in this project. However, since the Innovation center collaborates with multiple other companies, other stakeholders were also involved in this project. Early on, Local Motors automotive solution OLLI was introduced as an interesting autonomous vehicle to work with, and after meetings with Local Motors the authors and the design team at Local Motors agreed on a cooperation where the intended outcome of the project would benefit their company, and the authors could have access to OLLI as a subject of research and analysis. The authors, in collaboration with the design team of Local Motors, decided to combine their working theories and knowledge and together design the interface of OLLI. Later in the project however, the plans changed and instead this project would use OLLI and its hypothetical use cases as inspiration and Local Motor could use the personas, scenarios and guidelines to develop OLLI and its User Interface so that it would be more accessible for a broader range of people.

The authors were also introduced to Technische Universität Berlin, the Technical University of Berlin, and a project carried out by their division of Distributed Artificial Intelligence Laboratory. The project was a Smart City project aiming to

study possible automotive solutions in the city of Berlin. As this project was in an initial state, further details about the project are not currently obtainable for the public. The authors got to meet representatives from this project and also their Interaction Designer. It was agreed that a collaboration of the two projects would be beneficial for both parties. The outcome of this project would help their project to think about inclusive design and integrate solutions for a wider group of people, and in return their project would contribute with use case scenarios and context for this project.

5.2.2 Literature study

A literature study was carried out in the beginning of the project in order to gain more knowledge about the problem area and to research related work within Smart City projects (especially in relation to transportation), the concept of Internet of Things, automotive vehicles and different types of disabilities.

To gather information about the subject area, search words and phrases such as *"definitions of disabilities", "legal definitions of disabilities", "smart cities", "smart cities Europe", "smart city and transportation" "smart city mobility", "automotive vehicles", "autonomous vehicles", "self-driving vehicles", "transportation and people with disabilities", "designing for disabilities", "internet of things" "internet of things disabilities", "mobility", "public transportation", "autonomous public transportation", "multi modal information", "multi modal interaction", "ambient intelligence", "how to create personas", "how to evaluate personas", "how to create guidelines", "evaluation methods guidelines", "evaluation methods personas", "personas with disabilities", "interview methods for hearing impaired", "interviewing people with disabilities", "downsides with written interviews"* was used. The literature regarding these topics was searched in databases such as Google Scholar, Sciencedirect and through Chalmers online library. Some information and literature was also provided by stakeholders such as information about the Smart City Berlin project from the Technical University of Berlin.

Information about methods, cognitive science and interaction design was also gathered from earlier course literature. The literature about methods was used to adopt the best methods for this type of project. Personas was also studied in depth in order to know the pros and cons about the different types of personas, and knowing which ones would fit the outcome of the project best. There was however a problem finding literature regarding methods to evaluate personas, scenarios and guidelines.

After finding information about smart city projects and related work, the research question was reviewed and changed. This was done since the initial research question did not mention smart city projects, and the concept of smart digital mobility solution on its own was too vague. The first formulation read as followed:

"Which factors should be considered when designing a smart digital mobility solution more adequate for people with a disability?"

It was then changed to:

"Which factors should be considered in a Smart City project, when designing a smart digital mobility solution, for it to be more adequate for people with disabilities?"

After reading up on different disabilities and what different needs the people can have, it was decided to focus on visual impairment, hearing impairment, mobility impairment, deaf-blindness and cognitive disabilities that affect the speech- reading- and writing ability.

Since the study was planned to include interviews as a data gathering method, additional literature about different interviewing techniques was searched for. This because the authors had no experience in interviewing people with cognitive disabilities of this sort, or people with hearing impairments. Some websites targeting people conducting job interviews were found that included proposals on how this could be carried out. It was of importance to ask the participants beforehand how they would prefer to communicate during the interview, and also always provide a written copy of the questions. This resulted in a change of the time plan and more time was set aside for data gathering.

5.2.3 Result of literature study and stakeholder involvement

The presented research from the literature study showed that there is a rapid growth of smart city programs worldwide. Smart City mobility solutions are therefore an emerging topic. The literature study also showed that there is a great diversity between people depending on disability. It is important to create solutions that contribute to making people more independent, and the Swedish discrimination law says that people with disabilities should be fully part of society and have equal living conditions. Governments, citizens and technology companies are presented with unique opportunities because of the growth of smart city programs. However, this growth also brings the risk of further deepening a digital divide for people with disabilities and the aging population. Smart city initiatives can make use of technology investments to influence the design, development, attainment and wider deployment of accessible ICTs. This can reduce the digital divide for persons with disabilities.

After conducting literature studies regarding autonomous vehicles in connection to Smart City solutions, it was apparent that there is a shortage of studies regarding people's attitudes towards autonomous vehicles in connection to public transportation. Literature was found regarding autonomous vehicles, but these was mostly about the usage of autonomous vehicles in private sectors, as well as literature regarding assisted living (Internet of Things) connected to people with disabilities. This, in combination with the conjecture that autonomous vehicles in the

future will be used in public transportation settings, resulted in the decision to within this project focus on autonomous vehicles in *public transportation and taxi services*. Initially, the plan was to focus the research on transportation on a more generic level including private use.

New plan

Because of the new knowledge that was gathered through the literature study, the initial planning was changed. This new time plan is illustrated in *Image 4*. In the beginning, the plan was to follow a Human-Centered design process, with the inclusive design inspired perspective. But after conducting the literature study, an Inclusive Design process was discovered. The decision was made to carry out the study based on this process, instead of a Human-Centered design process, since it already have the focus of inclusive design and work a lot with iterations. It works in multiple iterations going through some of the steps more than once, with the possibility of going back and forth between steps.

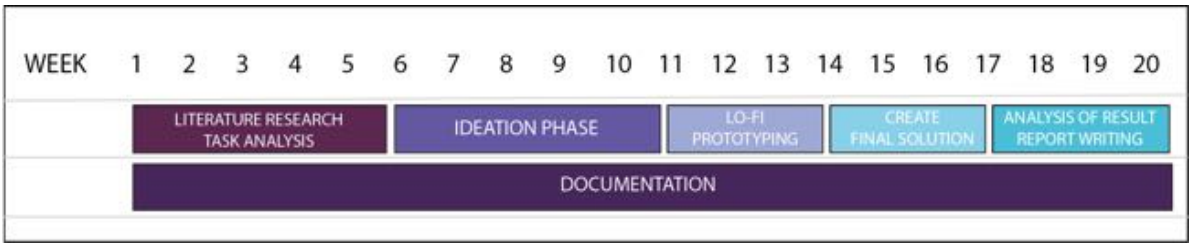

Image 4. *A visualization of the new time plan.*

After gaining an accurate understanding of the problem area, the plan was to contact representatives from the user groups for interviews and observation if possible. The plan was also to gather data through an online survey. With this method it is possible to collect a lot of information from many different types of users in an easy way without much logistic effort. This method also provides the possibility to reach potential users from other locations and gives the opportunity to include and collect data from people that might not be able to meet in person for an interview. Interviews and observations were chosen to gather more profound qualitative data about the user's behaviours and feelings. Efforts were made to look into the possibility to have a German translator present, and also a translator that speaks sign language. The data gathered in this phase was going to work as a foundation for the requirements based on the understanding of the users. After the data gathering phase, it was planned to move into the ideation phase, both internally and with representatives from Cisco and Local Motors.

After the requirements were constructed the plan was to start to create prototypes on a conceptual level. Based on the literature found in this phase of the research, and also the different stakeholders that wanted to be involved, it was decided that the end product to be delivered would be a "package" including personas, scenarios and guidelines for how to design mobility solutions for people with diverse disabilities. The guidelines would be the main result answering the research question, and the

personas and scenarios would be help for the authors to create the guidelines, but also as an end product for the stakeholders that they could use in smart city projects. The scenarios_role was to display a problem for a user or multiple users, and a conceptual solution to the problem based on our knowledge of the user group's requirements.

After iterating the scenario's conceptual solutions, the development of the end solution would be carried out, which is the package solution with scenarios, personas and guidelines. The choice was made to use rapid lo-fi prototyping in the beginning of the prototyping phase, and deliver refined lo-fi prototypes in the end of the project. It was decided not to create hi-fi prototypes since scenarios and personas can be easily understood as lo-fi prototypes, and it gives more time to iterate and evaluate them. Regarding the personas, the decision was made to work with the goal-directed perspective and role-based perspective since the goal-directed perspective deals with non-typical users and the role-based perspective focuses a lot on behaviour.

Because of the decreased involvement of the initial stakeholders, this plan was also in the end altered. The actual time plan carried of the project is illustrated in *Image 5*.

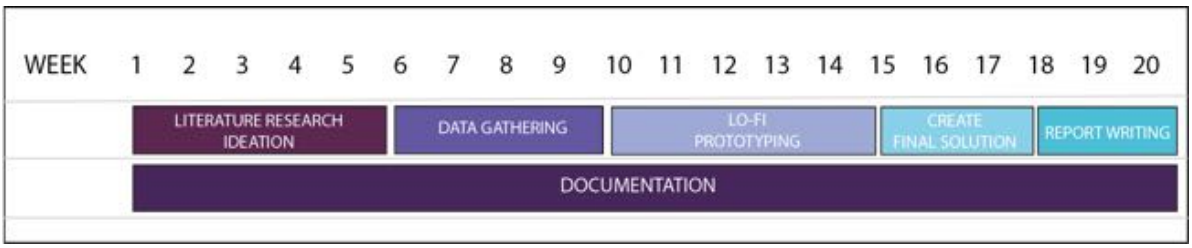

Image 5. *The actual time plan for the project.*

Due to these stakeholder changes, some of the planned activities and methods were not used. One example of this is that the initial stakeholders were not part of brainstorming sessions.

5.3 Data Gathering

After the literature research, the data gathering phase begun. It started with a survey to gather information about different users and their attitudes. After the survey, different kinds of interviews were carried out to get a deeper understanding of the user's thoughts and needs. Some observations were also conducted. The result of the different data gathering methods will be presented at the end of this chapter [*see Chapter 5.3.6*].

5.3.1 Survey

An online survey was created with Google Forms [*see Appendix 1* for English version]. Organisations for members with different disabilities in Sweden and Germany were contacted through e-mail with information about the project and the

study's research question. They were asked to distribute the survey to members of their organisation. The organisations had members with hearing impairments, sight impairments, deaf-blindness, mobility impairments and the cognitive impairment Aphasia. Some organisations shared the survey through their Facebook page, some published it on their intranet and others distributed it by email.

The questions were first written in Swedish and later English. On demand from one German organisation, a person speaking fluent English and German also translated the questions into German.

The purpose of the survey was to gather information about people's traveling habits, their feelings toward traveling with public transport and also their attitudes towards new technology and automatization. The importance of the driver of the vehicle and potential problems that can occur while traveling was also examined.

The survey resulted in twenty-four responses. The group with most responses was people with hearing impairments, second was people with deaf-blindness, third people with mobility impairment and people with sight impairments. 70% of the answers were from Swedish residents and 30% from German residents. When contacting the organisation for people with cognitive disabilities (aphasia), they agreed to share the survey but also informed that people with this disability can have problems with answering survey. There was no response to the survey from this group. Focus then turned to trying to find ways to include this group in the interviews.

Type of disability	**Answers to survey**
Deaf-Blindness	4
Hearing impairment	15
Visual impairment	2
Mobility impairment	3
Cognitive disability	0

Table 1. *The amount of people answering the survey. In total 24 responses.*

In the survey, the participant was given the option to submit their e-mail address if they wanted to take part in an interview. Eight people filled in their e-mail addresses and were contacted with information regarding the interviews. The participants

were also asked how they would like to carry out the interview in regard to their disability. Since the authors were located in Germany during the study, the Swedish participants were informed that the interviews could be held over for example video chats such as Skype.

5.3.2 Additional research

During this phase additional information was gathered, by exploring websites of different organisations such as *Synskadades Riksförbund* and *Svensk Kollektivtrafik*. The information that was searched was different organisational requirements or demands that they have on public transportation and taxi services. Other additional research was conducted online to gather information about how to design usable interfaces for people with different disabilities. This research is called *additional online research*, not to be confused with the initial literature study conducted in the beginning of the project.

5.3.3 Interviews

After the compilation of the survey answers, the interviews were conducted. The interview questions were written in English and Swedish [*see Appendix 2*]. The purpose of the interviews was to gather more qualitative data from people regarding their feelings towards traveling with public transportation and taxi services, their thoughts regarding autonomous vehicles, what positive and negative experiences they have in relation to public transportation, and also to get a deeper understanding of different scenarios that can occur for them while traveling. In total eleven people were interviewed.

Pilot Interview

One pilot interview was conducted to test the interview questions. The user in the pilot interview was a person with mobility impairment. This interview was semi-structured and in person where one of the authors asked the questions while the other one took notes and could also ask follow-up questions. The pilot study showed that the structure of the questions was good and some follow up questions arose naturally. It was easier for the person being interviewed to come up with negative experiences rather than positive experiences, and therefore the order of those questions was switched. The pilot study also showed that when asked about the importance of the driver of the vehicle, the answer was focusing on the importance of being friendly and nice and that the driver should drive carefully. The main reason for asking that question was that the authors wanted to examine the user's attitude towards driverless vehicles. Thus, the question was changed to asking if the user have read or heard the discussions on autonomous vehicles and their thoughts regarding this concept. Before the pilot interview, the questions regarding driverless vehicles was formulated:

Of what importance is the driver of the vehicle to you? Why?

This question, as well as the related question in the survey resulted in answers like *"it is good if the driver is friendly."* and *"he or she should drive calmly."* After the pilot interview, the question was changed into:

Today there is a lot of discussions about driverless vehicles, namely autonomous driving vehicles without a human driver. Have you heard about this? What are your thoughts about this? What positive and negative aspects can you see with this concept?

This so that the answers to the question would be more relevant to what was actually being examined and to gather data that would be relevant to answering the research question.

The different types of interview methods

Since this project focused on a relatively broad group of people with different types of disabilities, the choice was made to adapt the interview methods to fit the specific user's needs and wishes. Therefore, five different methods for interviewing were used: Mail based text interviews, Online chat interviews, semi-structured face to face interviews, telephone interview and verbal semi-structured Skype interview. As previously explained in the report [*see Chapter 5.2.2*], websites proposing how to interview people with for example a hearing impairment suggested that the interviewer should ask the participants how they want to communicate during the interview. When the participants were contacted regarding the interview, they themselves could request the interview form they felt most comfortable with, since there was no interpreter available. The interview techniques needed to be adjusted by the interviewer's and the participant's capacity to communicate to each other.

"Mail based" structured text interviews

Since some of the people that were being interviewed was either completely deaf or had very limited hearing, there was no possibility to have verbal interviews. When asked how they would prefer to answer the interview questions, some wanted to have the questions sent to them in text format, and then they could answer them in their own pace before sending the document back with their answers. The people were informed that there was a possibility that follow up questions could occur based on their answers, and in that case the authors would send those back to the interviewees.

Online Chat semi-structured interviews

One option that was presented to the interviewees with hearing impairment was to use Skype (written) or Messenger to carry out the interview by writing text but still conducting the interview in real time. This so that the interviewers could easily and naturally ask follow-up questions to the interviewee and also directly explain or add information if something was unclear to the interviewee. None of the asked participants wanted to conduct the interview with video, which would have been preferable for the data gathering of the study since body language and gestures could be of importance.

Classic semi-structured interviews

For the people with mobility impairment, verbal interviews face to face were held. With this interview technique, the interviewers could both hear the actual answer to the question, and also observe body language, gestures, facial expressions and listen to the pitch of the voice. These interviews were only held in Berlin with German participants. One interview was a group interview with two interviewees present at the same time, and one interview was with only one interviewee present. The audio from these interviews was recorded.

Verbal semi-structured Skype interview

For a person with sight impairments that was located in Sweden, a verbal Skype interview was held since it was not possible to meet in person. This method was seen as the best option to meeting the person face to face, since it is still possible for the interviewers to observe body language and facial expressions, while also being able to directly ask follow-up questions and clarify if something was not perceived correctly from either part. The audio from this interview was recorded.

Telephone interview

One telephone interview was held with a participant with aphasia. This interview was not recorded but one of the interviewers was taking notes while the other one asked the questions. The participant had another person present as help with communication during the interview.

Type of disability	**Number of people interviewed**
Deaf-Blind	2
Visual impairment	2
Hearing impairment	3
Mobility impairment	3
Cognitive disability (aphasia)	1

Table 2. *The number of people interviewed with each disability.*

Interview technique	**Number of people interviewed**
Pure text	4
Written chat (messenger)	2
Face to face	3
Skype	1
Telephone	1

Table 3*. The number of people interviewed with the different techniques.*

Transcription of interviews
The audio from the classic semi-structured interviews and the audio from the verbal semi-structured Skype interview were transcribed before analysis. Everything was written down exactly how it was said, and if it was impossible to hear something in the recording it was noted in the transcription text.

5.3.4 Stakeholder involvement

The authors took a step back to figure out if it was possible to answer the research question without the stakeholders. A decision was made to define the authors as the main stakeholder of the project. The initial stakeholders would still be part of the project, but not to the same extent as initially planned. The decision was made to include OLLI as an inspiration for an autonomous shuttle in the scenarios and guidelines, but that the authors would not be part of actively designing the interface together with Local Motors.

5.3.5 Observation

To get a better understanding of the user's habits and needs, covert observations were carried out. Addresses for organisations for people with visual impairment were researched, and the plan was to hopefully observe people with visual impairments traveling to and from the organisation's location. The authors sat down at the closest station but this was a time-consuming method that did not result in a lot of valuable data. Mainly, it was hard to identify people with visual impairments if they do not use a white cane, so it is difficult to know who to target and observe. However, a couple of unprepared observations were carried out in Berlin, where people with mobility impairment and sight impairment were observed while traveling with public transportation, mainly around subway stations and on subways. In total two observations was made outside vehicles and two observations inside the vehicles.

5.3.6 Result from Data Gathering

The response from the survey was unevenly distributed between the different groups of disabilities, where there was a clear majority of people with hearing impairment that answered the questions of the survey. None with cognitive disabilities answered the survey. The number of participants being part of the interviews was more evenly distributed between the different groups of disabilities. Because of time constraints and the fact that it was hard to get more participants to be part of the study, the decision was made to move forward with the existing gathered data for requirement construction. In general, the observations did not provide much data about the users' needs and habits in comparison to the survey and interviews. A summary of the gathered data is presented below.

Common
The clearest motivation, need and wish from all the participants were the ambition of independence.

Regarding the most used vehicles by the people participating in the study, no common denominator could be found for all disabilities. However, it showed that the need for the taxi service for people with disability could be based on the difficulties of the participants' ability to navigate in their surroundings. For example, people with hearing impairment can have difficulties to retrieve some information, but they still have the ability to move without limitations as for example people with deaf-blindness and mobility impairment who are limited when it comes to moving without problems.

What could be found as a common denominator regarding problems that can occur during the travels is that most problems do not occur inside the actual vehicle, but rather before entering, during changes to connecting vehicles or when they are exiting the vehicles. Most participants felt like one big problem is that important information is not received because it is not communicated clear enough for the different user groups. The most mentioned downside regarding traveling with public transportation was the crowding as a result of many people traveling at the same time. Also, that when unexpected situations occur, such as delays or cancelled routes, the information about this is poorly mediated. The way the participants wanted this information to be mediated differs depending on disability.

When it comes to the ticket system, most people thought that seasonal tickets of different kinds worked the best. A lot of people thought that the ticket machines are hard to use and provide unclear information.

Participants said that the role of the driver is to help with providing information regarding changes, reassure them that they are on the right vehicle, or for example when a ramp is needed. Here, the traveller can ask for information on their terms, instead of just receiving information. When given the question if they sometimes have to ask other travellers for help, people answered that if something unexpected occurs, such as for example technical problems or if an elevator is out or order, they have to ask other travellers for help.

The majority of the participants were positive towards the digitalisation of society, based on the fact that it enables communication and finding information that contributes to independency. However, the demand is that accessibility should be considered and be a part of the technical development. The ones who had a more negative attitude towards the digitisation, were so because of the risk of everything being impersonal, and that they have an idea of technique not being able to be spontaneous and therefore cannot act in unpredictable situations. There is also a fear of new technology saving too much personal information about users.

When interacting with technology, touch buttons were the most common way to do so. People with visual impairments and people who suffer from deaf-blindness mostly used voice command. The demands for interaction differ depending on type of disability. Overall, the users of technology want to be able to reach information in different ways depending on what is most natural and works best for them.

New technology that people rely on is mostly connected to navigation of different sorts. This was the most common and important function for the participants. The smartphone is an important instrument for them to be able to use different navigation tools. Wishes from the participants when it comes to different tools or mediums that can help them while traveling were mostly that the existing solutions and tools should work better. For example, that information (both visual and auditory) must be updated faster and be presented in a clearer way.

The participants had in general a positive attitude towards autonomous vehicles, but safety was the most important aspect. The perception that technology is not able to be spontaneous and act in unpredictable situations is also a concern. The user wants to be able to feel trust in the vehicle.

In emergency situations, people requested light and movement indications such as shaking or vibrations for people who cannot hear or see. One requirement gathered from the additional online research was that there must be ways to notice if an alarm goes off without hearing sound (Partnersamverkan för en förbättrad kollektivtrafik, 2012).

Visual impairment

In the interviews with people with visual impairments, it was explained that if they are familiar with the start position and end destination of their travels, they usually could travel by themselves. If they are going to a new place that they are unfamiliar with, they needed to have someone waiting for them at the destination. It also happened that they ask the driver to let them know when they are getting close. Thanks to new technology and the smartphone, they have become more independent and *"part of the society"* since they are able to navigate by themselves in an easy way. This is very important since they do not like to have to ask other people for help and feel like a burden. This was also shown during the additional research, where the wishes were stated to provide better outcalls for lines, destinations, and stations. The participants were positive towards the concept of autonomous vehicles. One interviewee said, *"I am looking forward to the day when driverless vehicles have reached the level of development so that me as visually impaired can trust them."* How to assure safety was also a discussed topic, during the additional research. Synskadades Riksförbund (2015a) emphasizes the importance of a well thought of design both inside and outside the vehicles to ensure usability and to ensure safety.

When observing people with visual impairment that were using white canes, they were not traveling alone. There was always someone else with them. If this was a

coincidence or in some way indicates that public transportation solutions that exists today is too complicated to use for people with severe sight impairments is impossible to answer at this stage.

Hearing impairment
The negative aspect the participants with hearing impairment could experience was the crowded vehicle, which in turn made it even harder for them to hear any auditory outcalls. They also have negative experiences regarding bad intermediation of information connected to delays or cancelled routes. It is experienced both as negative and positive when other travellers have given them a nudge on the shoulder when information about exiting the vehicle has been called out and they have not heard it. They are glad that other travellers are helpful, but some also feel that it should not have to be like that if they could receive the information themselves.

The biggest problem is that the helping technology that already exists today is often broken. This group that mostly rely on visual information screens will suffer when they are out of order or show the wrong information. Also, the information that is displayed visually is not updated as fast at the information given through audio. The participants in this interview had a positive attitude towards the digitalization since digital tools help them with communication. However, participants also told that problems can occur for people with hearing impairments, since there can be technical problems with electrical conduits that disturb their hearing aids. This was also a requirement gathered from the additional online research from *Partnersamverkan för en förbättrad kollektivtrafik* (2012) that solutions must work well with technical hearing aids.

When it comes to autonomous vehicles the attitudes are a little bit mixed. On one hand, some feel like autonomous vehicles would be great, but only if security still remains. Also, they feel like it is sometimes easier to get information digitally than from a human. On the other hand, there might be a risk that when excluding human behaviour, reaction and choice of action, other drivers might not counter the behaviour of the car in a way that *"they normally would do."*

Deaf-blindness
The use of public transportation differs between the participants. One participant cannot travel with today's public transportation solutions at all. This participant is dependent on the taxi service for people with disabilities or having someone they know drive them. The biggest issues for this group is that it is hard to communicate with the driver or other travellers if they need information, the screens have bad resolution and too low contrast between text and background, and they also need better and faster information about delays and changes. The insecurity of not knowing if they are on the right vehicle is also a problem. They all feel like the digitalisation is a positive evolution, but it is important that accessibility follow this development. They feel like people who need extra or specific help is often excluded

in the new solutions. They are very dependent on their smartphone, and one said that *"the smartphone has revolutionized my life."*

In regard to autonomous vehicles, they are positive but there need to be different ways of interacting with it for example if they need to access information. What way of interaction that works best is depending on the difference of degrees between their visual and hearing impairment.

Mobility impairment

For the participants with mobility impairments, there was a difference in the experience of traveling with public transportation depending on the level of mobility of the person. Without any ability to walk at all, the trip has to be more thoroughly planned in advance, for example by searching for information about broken elevators at certain stations. This causes frustration and often forces the people with mobility impairment to take detours. The additional online research from Partnersamverkan för en förbättrad kollektivtrafik (2012) said that people in wheelchairs should not have to take detours.

One problem and source of irritation for people with mobility impairment is that people that do not need to use the elevator still do. They felt like the elevator should be used by people in wheelchairs, strollers and elderly people. People who can use stairs but still use the elevator causes them to have to wait an unnecessary amount of time. They also expressed that there is a problem regarding vehicle floor and platform not being on the same ground level. Another frustration is that they get people's bags in their faces when people are standing up around them. They don't know the solution to this other than having more separate space for wheelchairs.

Regarding tools or mediums that could help them in their travels there was more specific requests from people with moving impairments who wished for separate spaces for wheelchairs and better ramps to enter vehicles. It was noticed during the observation that there is no specific place for the wheelchair on the subways, as it often is on buses. There is only an open space without good tools to grab onto and where people are often standing. This open space is only located at one part of the wagon. The trains are long and the time while the doors are open is short. Still, the person in the wheelchair needs to locate that specific part of the train and go to that door to enter.

In addition to this, the additional online research from Partnersamverkan för en förbättrad kollektivtrafik (2012) showed that there should be enough space to rotate wheelchairs on vehicles, handrails to hold on to, no thresholds, stairs or narrow or heavy doors and the floor and ground should be even and hard. Also, handles buttons and levers should be easy to reach and use and displayed information should be adapted to short people and people in wheelchairs.

The participants with mobility impairment had a positive attitude towards autonomous vehicles. One motivation is that human drivers can get tired and make mistakes, while machines do not.

Cognitive disability
The participant with aphasia did not travel with public transportation because it was too stressful and hard to travel without help. The participant only travels with the taxi service for people with disabilities but have a lot of negative experiences from this. Mostly, this was connected to communication issues between the driver and the participant, since the participant can have problem communicating their information, and it was also a challenge to assimilate the information given by the driver. Since people with aphasia can have trouble expressing themselves and this can be even harder if they are put in a stressful situation, the fact that drivers did not have patience to wait for the user to formulate the right information turned traveling into a negative experience.

When booking the trip with taxi service for people with disabilities, the participant could book it without help if the destination was saved in the application. If there was a new address that was not saved and needed to be typed into the system, the participant needed help to book the trip. When asked the questions regarding how they feel about autonomous vehicles, the reply was *"That would be the perfect thing for me!"*

The additional online research from Partnersamverkan för en förbättrad kollektivtrafik (2012) showed that information should be short, simple and easy to read, information about how to use devices need to be easy to understand, locations must be easy to find, and signs should contain easy illustrations or pictures.

5.4 Constructing Requirements

To analyse the data collected through the additional online research from different websites the *KJ method* was used. The answers gathered from the survey were compiled for each question, as well as for each type of disability. This was done to easily examine the potential common issues and/or values in the answers. For each question, a deduction was made based on the most frequent answers and common opinions. This structure of analysing the data was also made with the data collected through the interviews. By compiling all answers from each type of disability, it was possible to find the common denominator.

After analysing the interviews and survey separately, the summaries for each type of disability were then compared as well. Furthermore, all deductions from each question and disability were put together, to further see potential similarities of the answers. All similarities that were found between the different disabilities were compiled in a separated list. This method was chosen, to analyse the potential common issues that might occur for all the different types of disabilities, as possible

complementary requirements to the more specific requirements for the different types of disabilities.

The KJ method was used to refine requirements from the survey, interviews and observation, and also from the information gathered through additional online research from different organisations. The KJ method helped group the different problem areas and get a better overview. *Image 6* shows some of the groups identified from the KJ analysis.

***Image 6**. Picture from the KJ analysis.*

5.4.1 Results

The analysis resulted in a list of requirements from the additional online research, the interviews, observation and the survey. Requirements that lacked relevancy to the research question were removed from the list of requirements, also requirements that was too repetitive, too loosely based in the research or pure technical requirements. Many of these requirements are still important to consider in other projects, and the full list is presented in *Appendix 3*. The requirements presented below are the remaining requirements that was used to move forward in the project:

Visual impairment

- They need to be able to catch connecting vehicles in public transportation as fast as anyone else
- They need the possibility to request audible information

These requirements have been gathered from Synskadades Riksförbund (2015a):

- Well thought of design of vehicles, stations, platforms, terminals which facilitates accessibility, usability and assure safety is needed
- Better automatic outcalls for lines, destinations, and stations is needed
- They need more clear and evident signs
- Every system for planning the trip, traffic information and also purchase of tickets needs to be fully usable for travellers with impaired sight.

These requirements have been gathered from Synskadades Riksförbund (2015b):

- They need better color contrast between text and background on screens and signs
- The screen resolutions need to be improved

These requirements have been gathered from Partnersamverkan för en förbättrad kollektivtrafik (2012):

- Interfaces must follow rules for visual impairment, for example use speech synthesis
- All information that is shown for people who can see, must also be available for people who suffer from visual impairment in other ways

Hearing impairment

- They need information about cancelled or late vehicles visually just as fast as it is informed through audio
- If delays or other problems occur, they need visual information about alternative routes and where people can find them
- Make sure not to use electrical functions that somehow disturb user's hearing aids
- There should be hearing loops in all vehicles and waiting areas
- When the stop button is pressed, they want both clear audio and visual feedback
- Provide blinking lights and some sort of movement/shaking indication in emergency situations
- Provide blinking lights and/or some sort of movement/shaking indication when important information is presented to the travellers to catch their attention

These requirements have been gathered from Partnersamverkan för en förbättrad kollektivtrafik (2012):

- Solutions need to work well with technical hearing aids (no disturbance so that they have to turn them of)
- There must be ways to notice if an alarm goes of without hearing sound

Deaf-blindness

- Smart city solutions need to contribute to increased independence
- Solutions need to communicate its location in different ways to the user
- They need multimodal information on the actual vehicle about delays, change of route and other unforeseen events

- People with impaired hearing need to access audible information on their terms
- The screen for ticket/payment systems need to contain clear contrast between text and background and have the possibility to adjust the size of the text.
- Interaction with interfaces must be available both through buttons and voice command
- Avoid a gap between the vehicle and the platform since it can be hard for people with impaired sight to calculate the distance

Mobility impairment

- They need necessary information about vehicles and platforms beforehand when the users are planning their trip
- The floor of the vehicle and the platform need to be on the same ground level
- They want a separate space for people in wheelchairs in the vehicle
- People in wheelchairs do not want to take detours or other inconvenient ways to get to vehicles

These requirements have been gathered from Partnersamverkan för en förbättrad kollektivtrafik (2012):

- People in wheelchairs should not have to take detours
- Handles, buttons and levers must be easy to reach and use
- Display of information should be adapted to short people and people in wheelchair

Cognitive disability

- They need to be able to communicate in own pace
- They need saved addresses in booking system to be able to book on their own

These requirements have been gathered from Partnersamverkan för en förbättrad kollektivtrafik (2012):

- Information should be short, simple and easy to read
- Information about how to use devices need to be easy to understand
- It has to be easy to find all the different locations

Graphical User Interface Requirements

These requirements were gathered since the initial plan was to be part of designing the GUI of OLLI. *These requirements have been gathered from Developer.gnome.org (2014).*

- Don't use labels that are spelled differently but sounds the same for people who use screen readers
- There should be the possibility for the user to choose the size of the text themselves
- Make sure information do not disappear or become hidden before the user are finished with it (for example on digital screens that changes with time)
- Don't hardcode timeouts or other time-based features. Some users may read, type or react more slowly than others

- Minimize the user's memory load
- Provide high contrast between text and background
- Provide the ability for the user to magnify the display

These requirements were used in the next step of the process, for inspiration for the brainstorming of future solutions and the prototyping of Personas, Scenarios and Guidelines.

5.5 Prototyping

During this part of the process, Personas, Scenarios, and Guidelines were created and iterated. Working with them simultaneously in multiple iterations was a way of evaluating them. The process is visualised in *Image 7*.

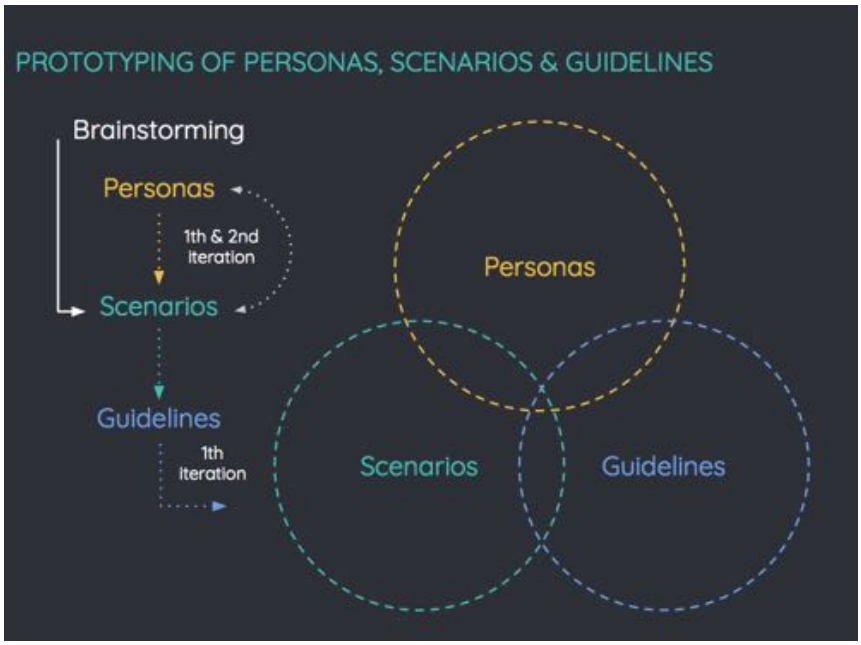

Image 7. *A visualisation of the prototyping process with its different iterations.*

5.5.1 Phase 1

With the formulated requirements as inspiration, an individual brainstorming session between the authors was held. The brainstorming methods that were used were *6-3-5 method*, *Reverse brainstorming* and *Time travel method* [*see Chapter 4.4.5*]. Initially during the planning of the project, the decision was made not to include the *Time travel method* due to the risk of the ideas being too far-fetched and unrealistic. However, as the findings from the Literature research resulted in a shifted focus of the project to autonomous vehicles in public transportation and taxi service settings, a concept of future use, the method contributed to ideas of possible solutions outside the boundaries of current time.

The purpose of the brainstorming session was to generate ideas of possible future solutions, based on the compiled requirements. The solutions would later on be

added to the scenarios, as they too should display possible situations in future settings. By using the compiled requirements as a foundation to the ideas, the ideas of possible future solutions could be accommodating to the personas, creating tasks and situations in the scenarios where the personas would succeed.

Result
Some ideas that came up during the brainstorming were different kinds of scanning solutions that would clearly show where the scanning tool was located on the vehicle. This was mostly directed towards taxi services. This solution could be used to scan tickets and thereby unlock vehicles. This would serve as an indicator that the person was entering the right vehicle, since it would not unlock otherwise. Other ideas that came up were facial recognition that unlocks cars, that is based on the user having a picture of themselves in the booking application. Regarding navigation for people on stations and platforms, many ideas was based on having the smartphone as help where the user can more easily adapt the way of interacting and receiving information to suit their needs. For example, some people might want to be guided by sound and others by a visual map.

5.5.2 Phase 2

The process when creating the personas was influenced by Alan Cooper's (2014) 8 steps of how to create a persona [*see Chapter 4.4.3*]. As the number of participants that was part of the study was both limited and unevenly distributed throughout the different disabilities, some of the steps in Cooper's process was either altered or excluded completely.

Personas: First iteration
The initial plan for creating the personas was to conduct a workshop together with the design team at the Technical University in Berlin. Due to external factors this workshop was never conducted. Phase 5.2 was initiated by a series of decision regarding the quantity of personas, as well as the range of their diverse disabilities.

Based on the disabilities of the participants in the data gathering, the different types of disabilities were limited to 5 types:

- Visual impairment
- Hearing impairment
- Deaf-blindness
- Mobility impairment
- Cognitive disability

This decision was influenced by the principles of Inclusive design, which claims one should create design solutions that are accommodating to as many people as possible, however not for the extreme cases [*see Chapter 3.3*]. Therefore, the choice was made not to further specify the disabilities.

Initially the decision was made to create two personas for each disability, where one would include a moderate degree of the disability and the other a severe degree of the disability. However, this was reconsidered early on even before the start of creating the personas (phase 5.1). This, as one example of the sources during the research showed that people with visual impairment, have only a small percentage that are completely blind (Neads.ca, n.d.) Therefore, the choice was made to remove the two different degrees of disabilities and instead create only one persona for each disability.

During the first iteration of personas, the participants from the interviews and survey were grouped based on their roles, such as family roles and attitudes. Following this, behaviours for each role were identified, focusing on the activities, motivations and skills in relation to public transportation and taxi services today, as well as autonomous vehicles and societal digitalisation. Furthermore, a mapping of the different behaviours was made for each type of disability. This was done to be able to see the relations between the different participants and was used as a base to identify behaviour patterns. The behavioural patterns were then used as the foundations of the personas. Details from the gathered data such as activities, frustrations and negative experiences regarding current transportation solutions and their most common way of interaction with technology, were then added.

The following step of creating the personas was to compile a list of the potential requirements. The information was based on what a design team might need from a persona and what information might be needed when designing an autonomous vehicle or its connecting systems. The list of information was also based on analysed data gathered from the interviews and survey.

When mapping the behaviour for the persona with mobility impairment, it became apparent that the information gathered from the participants in the survey and interviews was very different. This both in regard to attitude and personality, as well as in needs and wants. The decision was therefore made to create two separate personas with mobility impairment, to better represent the potential users [*see Chapter 6.1*]. This resulted in one persona that was more representative of the selection group with a *role-based perspective* and one more extreme persona, which was more based on Cooper's *Goal-directed perspective* on personas [*see Chapter 4.4.3*].

Result
The different information that was included in the persona was divided into seven sections, as shown below.

1. Basic overview information: *Name, Age, Occupation, Status, Location, Disability, Archetype* and *Personality categories* (3 describing words).

2. Motivations regarding transportation: *Price, Comfort, Speed, Independence* and *Environmental*. These are presented through a grading system of importance.

3. Goals: Both generally in life, as well as regarding transportation.

4. Frustrations: Both generally in life, as well as regarding transportation.

5. Bio: Short description of their life story, their disability and their view of autonomous vehicles.

6. Personality: These are shown in form of two opposite personality adjectives, where the description is shown on a spectrum in between.
Extrovert – Introvert
Thinking – Feeling
Analytical – Creative
Conservative – Liberal
Passive – Active
Digital – Analogue

7. Technology interaction: *Physical buttons, Touch buttons* and *Voice command*. They are presented through a grading system of most used.

8. Accessibility considerations: Points to be considered in regards of accessibility to the specific persona and his or her disability.

Name of persona	Type of disability
Harry Smith	Deaf-Blindness (Acquired deaf blindness)
Chrissy Andersen	Hearing impairment
Adriana Matthew	Visually impairment
Charles Clarkson	Cognitive disability (Aphasia)
Sebastian Harold	Mobility impairment (in a wheelchair)
Henrietta Adams	Mobility impairment (in a wheelchair)

Table 4. *Overview of personas*

Scenarios: First iteration
When creating the scenarios for the personas, the first step was to decide the setup for the scenarios. This was done by briefly answer the following points: *who*, *how*, *what*, *when* and *where*, starting with *who*, *what* and *where*.

First it was decided what vehicles the different personas would travel with. This to include as wide range of potential situations as possible that might occur when dealing with the different kinds of vehicles. The choice of different vehicles was made by the selection of public transports that exists in Germany and Sweden today, with the alteration that all vehicles being autonomous in the scenarios. The vehicles that were to be used were; *bus, train, tram, taxi* and *shuttle*. The Shuttle vehicle was added and influenced by other already existing solutions from companies like Local Motors. Their project with the vehicle OLLI (shuttle) [*see Chapter 1.4*] was incorporated into the scenarios as a potential solution as an autonomous vehicle.

Result
Adriana: Shuttle (Influenced by OLLI) Private, will go from *Home* to *School*
Harry: Bus and taxi, will go from *Home* to *Work*
Sebastian: Shuttle (Influenced by OLLI) Public, will go from *Home* to *Basketball game*
Henrietta: Train and tram, will go from *Home* to *Bingo*
Chrissy: Tram and bus, will go from *Work* to *Home*

5.3.3 Phase 3

Personas: Second iteration
During the first iteration of Scenarios, it was apparent that there was some information in the personas that was not transparent enough, such as attitudes and frustrations and therefore had to be adjusted by rephrasing them to make them clearer. It also became apparent that further accessibility considerations could be added to the personas when incorporating them in the scenarios. For complete result of second iteration see *Appendix 4.*

Scenarios: Second iteration
When the second iteration of the personas was once more added to the scenarios, the level of detail in the scenarios became quite deep. This resulted in scenarios that were quite long and therefore had to be shortened. The decision was made to remove information, such as redundant descriptions of reasons for the personas state of mind, as well as information about reasons of traveling that did not affect the setup and overall outcome of the scenario. Since the removed information did not contribute to presenting the goal of the scenarios or the overall goal of the project, this version of the scenarios will not be presented in this report due to redundancy.

5.3.4 Phase 4

Guidelines: First Iteration
As a first iteration of guidelines, a compiled list of requirements was made based on previous literature studies, additional online research and gathered data from interviews, observations and the survey. In addition to this, requirements were also compiled based on the created scenarios. This as some situations that occurred in the scenarios, showed the importance of different kinds of solutions in regard to accessibility. The compiled requirements were then rearranged, grouped based on similarity and association, to later be named. During this process, some of the

requirements were removed with the motivation that they lacked relevance to answering the research question, and were not within the field of interaction design. Also, some minor requirements based on only one or a few people's opinion that could not find support in the research or other people's answers was also removed.

Result
As shown in the overview of categories below, the requirements were divided into two main categories, inside the vehicle and outside the vehicle. This because for example requirements for distribution of information at first seemed to differ depending on the physical context.

INSIDE the Vehicle
- Presentation of multimodal information
- Interaction with vehicles system/Interface
- Ticket system
- Navigation
- Other

OUTSIDE the vehicle
- Presentation of multimodal information
- Interaction with vehicles system/Interface
- Ticket system
- Navigation
- Entry and Exit
- Planning

For the full result from the first iteration of guidelines, see *Appendix 6*.

Personas: Third iteration
During the third iteration of personas, the focus was to rearrange the information, to create a clearer view of the different types of sections. The decision was made to divide the previous *Section 3. Goals* into two separate ones. The new sections were named *Life goal* and *Goals for Traveling*. Even though more general goals make it easier to relate to and get a picture of what kind of person they are, the decision to divide them was made to make it more clear what is to be defined as personality and what is to be defined as attitude towards traveling and transportation.

Result
Some examples of how this change looked like are shown down below. For the full result from the third iteration of personas, *see Appendix 5*.

Goals for persona Charles:
- To be able to travel independently without help from others
- To one day perform at Poetry Slam with one of his original poems
- To bring his granddaughter to Natural History Museum in London

Was changed to:

Life goal for persona Charles:

- To one day perform at Poetry Slam with one of his original poems

Goals for traveling:

- To be able to travel independently without feeling stressed or overwhelmed
- Not being overloaded with information and ways to interact
- Being able to communicate what he wants without being misunderstood

Goals for persona Adriana:

- Play guitar on stage with Ed Sheeran
- Bungee jump from the Royal Gorge Bridge, Colorado, United States
- Be successful enough in music so that she can buy a house for her mother

Was changed to:

Life goals:

- Play and sing a duet on stage with Ed Sheeran

Goals for Traveling:

- She wants to travel independently, without feeling like a burden for other people
- To easily be able to navigate herself at new locations
- Since she is very time optimistic, she needs to get to her destination just as fast and smooth as people who can see well

Scenarios: Third iteration

Based on the first iteration of guidelines, taken from occurred situations in the second iteration of scenarios, some debatable aspects could be seen. As the different scenarios included different personas with different needs, some guidelines were more directed to specific disabilities. A test was made to modify the scenarios, by adding situations in all scenarios that would show all the guidelines. However, this resulted in strange and somewhat forced setups in the scenarios. Therefore, the decision was made to create one single scenario setup, called *scenario for all*, where all personas would do the same tasks but with solutions based on their individual needs and accessibility considerations. A common denominator in the answers throughout all different disabilities from interviews and survey was that the change between different vehicles was troublesome. Therefore, it was important to expose the personas to these types of situation in the scenario. However, because of this, in combination of trying to include as many of the different types of vehicles as possible, the scenarios became very long and detailed, and was therefore not used as references in the guidelines. Instead, this scenario became the inspiration for the persona Harry's new scenario [*see Scenario 3* in *Chapter 6.2*].

To try and analyse how the different types of personas, disabilities and accessibility considerations would act and behave in relations to the different types of vehicles, separate scenarios was made where all personas would use the different types of

vehicles in separate scenarios. Thereby, one could compare the different interactions and actions between different personas when using the same type of vehicles. However, this resulted in exclusion of situation where the persona would change between different vehicles, and they were eliminated as references in the Guidelines.

5.3.5 Phase 5

Guidelines: Second Iteration

The second iteration of the guidelines included rephrasing the requirements into guidelines. Under each subcategory, the different related suggestions or guidelines were presented in a descriptive way. As the compiled requirements were both diverse and specific to certain disabilities, the choice was made to divide the guidelines in further sub-guidelines. For each sub-guideline, an example was made to show situations where the guidelines could be perceived.

Result

After this iteration, six main guidelines and twenty-one sub-guidelines were created. One example of how the guidelines looked like is shown down below. For the complete result from this iteration, see *Appendix 7*.

INSIDE the Vehicle

Presentation of multimodal information

1. **All information should be presented in a multimodal way**
    a. **Information presented should be both auditory and visual**

    Example: When unforeseen events occur, for example delays or changes of routes, travellers must be informed both through speakers and screens. Svensk Kollektivtrafik writes that all information that is shown for someone who can see must also be available for someone who cannot see. In the survey, users also pointed out that they need multimodal feedback when the stop button is pressed (for example visual, auditory, vibrations). If a person with hearing impairment does not get visual feedback, he or she will not know if the driver has received the information that they want to get of at the next stop. Svensk kollektivtrafik writes that the information should be short, simple and easy to interpret. This was also requested by people with cognitive disabilities in the interviews.

    b. **Provide information visually just as fast as the audible information is given**

    Example: People with hearing impairment should not have to wait for visual information that people who can hear will access directly. In the interviews and survey, people with hearing impairments gave multiple examples of how they have been on the train and other travellers have left the train because they got information about occurred errors through speakers that the people with hearing impairment could not receive.

    c. **Make sure that information does not disappear or become hidden before the user are finished with it**

Example: Dev Gnome writes that information presented to users should not disappear before the user is finished with the information. It is not a good idea to hardcode timeouts or other time-based features, but instead let the users by themselves decide when they are finished with the information. Work with confirmations or let the user access the information again if they want. In the interviews, people with cognitive disabilities expressed concern about not being given the time to properly comprehend the information before it disappears. In the survey, people with deaf-blindness disliked the fact that people without disabilities receive information that they missed, and they could not access again, which causes a lot of stress for them, especially since they sometimes have problems with the communication with other travellers and can't just ask them what is going on.

d. In case of emergency situations, work a lot with multimodal ways to communicate the danger

Example: Make sure that all travellers are aware of the situation. For example, catch the attention of people with hearing impairment who might not pay attention to screens, by providing blinking lights or some sort of movement/shaking indication. This was requested from users in the survey. Svensk kollektivtrafik writes that everyone must notice if there is an on-going alarm.

5.3.6 Phase 6

Guidelines – Third iteration

The previous iteration of guidelines included very specific sub-guidelines, adapted to specific situations. To make the guidelines more general and thereby more applicable to different situations, the sub-guidelines were compiled and the examples of hypothetical situations was removed. This was also done to remove the risk of one focusing on the specific examples of solutions given in the hypothetical situations. Compiling the sub-guidelines resulted in the removal of the two main categories *inside* and *outside the vehicle*.

Result

The change resulted in a new structure of the Guidelines, now including *Name* of the guideline and a short description of the guideline. The examples on how the guidelines could be used from previous iteration were removed and instead more background information about the motivation for the guideline from the literature study was added. Every guideline now had references to the literature, two examples of this are shown down below. To see the whole result from this iteration, see *Appendix 8.*

4. Provide information of surroundings

Provide alternatives for traveling routes and information about surrounding events such as traffic jams, delays and accidents

If delays or other problems occur, provide multimodal information about alternative routes and where people can find them. The Senate Department for Urban Development And The Environment (2015) writes that giving the public information

about traffic jams, where there is free parking spaces and different public transportation alternatives, provided this way, increases the traffic flow. It is important to remember that this information needs to be mediated in different ways so that people with diverse disabilities can access the information. This can be done already when the users are planning their trip in the application, when the user is at the station or when the user is already traveling on a vehicle. The vehicle can retrieve information about accidents along the way and can calculate a different route. To provide travellers of the vehicle of this information before actually arriving to the site of the accident, will be beneficial and effective for all. For people with cognitive disabilities such as aphasia, it is important to get unforeseen information as early as possible since improvisation can be hard, if not impossible, for some people with this condition. If a user with visual impairments because of unforeseen events ends up at a place that is new for them, they need to know this as early as possible so they that can on their own terms, and based on their own needs better navigate the new area.

7. Present multimodal information

All information, inside and outside the vehicle, should be presented in a multimodal way.

G3ict & World Enabled (2016) wrote that smart city digital services could be made more accessible by for example making content available in multiple formats. Synskadade Riksförbund (Visually impaired federal federations in Sweden) writes that there is a need for audio-visual outcalls regarding both the different stops and the destination. In the interviews and survey, it was requested that information should be presented at least both auditory and visual, and that the visual information should be given just as fast as the auditory information. Around every third participant asked in a study presented by SRF believes that there is a need for more or better outcalls on the vehicles. Almost every fourth person asked wants more and better outcalls at stations and platforms. When presenting information to travellers, make sure that the information does not become hidden before the user is finished with it, which was expressed as a problem in the interviews and survey, and is also one of the guidelines given by Dev Gnome. Working with multi-modal ways to communicate danger, changes and unexpected events are very important. In addition to audio and text information, a way to catch travellers' attention at for example an emergency situation can be with lights and vibrations. Feedback should also be given to the user in multimodal ways, for example knowing that the stop button reacted to the touch by showing is visually, with audio and also vibration. For people who suffer from deaf-blindness for example, the ability to retrieve multi-modal information on an individual level would be beneficial.

Personas: Fourth iteration

During the iteration of Guidelines, a discussion was held regarding the value of the Persona Henrietta (mobility impairment). This, as the persona Henrietta did not contribute to the guidelines in an individual way. The physical challenges for the two personas with the same disability were quite similar, and therefore the question was raised whether to keep Henrietta as a reference to the guidelines. However, the challenge would then be how to change the persona Sebastian to include Henrietta's attitudes toward technology and personality. The decision to create two separate

personas with mobility impairments was based on the extreme diverse attitudes shown from the interviews and survey. To change the persona of Sebastian would include compromising the representation of the participants, however to remove Henrietta would also compromise the representation. Therefore, the decision was made to include both Henrietta and Sebastian as personas. The solution was to focus more on Henrietta's needs regarding environmental attributes and physical solutions such as ramps and elevators.

In this iteration, the decision to use photos of real people for the personas was made. The motivation for doing so was that they could be more relatable and easier to remember. It was decided to use royalty free stock photos for this. In Addition to this, the decision was made to remove the section of *archetype* in the persona, and to only use the three describing words of personality.

Scenarios: Fourth iteration
This iteration of the scenarios focused on adding two more scenarios to the collection. So far, every scenario had only included one persona at a time, but now the decision was made to create two more scenarios that included more than one persona. This was done as a way to clearly showcase and motivate the need of multimodal interaction and multimodal information.

Result
This iteration resulted in two more scenarios where more than one persona is situated in the scenario at once. One of the scenarios contains the personas of Harry, Charles, Adriana and Chrissy, where they all are trying to locate the extra buses replacing the trains and trams after a thunderstorm. This, to clearly show how they need information about the same thing in different ways [*see Scenario 8 in Chapter 6.2*]. The other scenario contains Harry and Sebastian taking the early morning bus to work. This scenario shows entering the vehicle, some struggles that can occur on the bus, and exiting the bus from two different perspectives. Their disabilities are very different and therefore they have different needs. This scenario showcases these needs but can also show what they have in common [*see Scenario 7 in Chapter 6.2*].

5.3.7 Phase 7

Guidelines: Fourth iteration
This iteration of the guidelines focused on referencing each guideline to the personas and scenarios. Since the personas and scenarios helped the development of the guidelines, and the work on all three results was carried out simultaneously, it was a natural step in the process. The finished scenarios were referenced in the guidelines where they naturally fit and where they had been served as inspiration. Sometimes multiple personas and scenarios fit in a guideline, but to not make the guidelines too long, just some of the examples were referenced in each guideline.

Result
Two examples from the guidelines after this iteration ere shown. To see all of the guidelines from this iteration, see *Appendix 9*.

7. Provide multimodal interaction
It should be possible to interact with the vehicle's interface(s) and surrounding or connected interfaces in multiple different ways.
Kleinberger et al. (2007) writes that "Multi-modal interaction paradigms that combine several modes (e.g., gesture, sound) are a good approach to enhance usability and accessibility." (Kleinberger et al., 2007, p 107). Different users prefer different ways of interacting with interfaces, this especially when it comes to people with disabilities. Some ways of interaction that is natural for one group of people could be impossible for others. Therefore, it is important to provide easy and multiple different (multimodal) ways to interact with the vehicle both from the outside and the inside. The vehicle should clearly signal to the user where interactive functions are located. With autonomous vehicles, there should be ways for the traveller to request information if needed, if possible equivalent to asking a driver for information. Feedback from the interactions should also be given in multimodal ways.

It is a challenge for a robot or system to understand a user's natural interaction. But it is necessary for enabling new users to use the robot or system smoothly and intuitively. It is easier to implement a set of hard-coded commands to control the system, but it is troublesome for the user because it does not allow the users to use their natural interaction style. Therefore, it would be beneficial to enable the system to learn to understand the user's natural way of giving commands and feedback by instinctive interaction through for example speech or touch (Austermann, 2010).

All personas include information regarding preferred interaction, whether it is physical buttons, touch buttons and/or voice command. The different needs of ways to interact depend on their preferences in regard to their disability. In *scenario x* (placeholder text), Harry interacts with the vehicle by facial scanning to unlock the car and this also is a way for him to get feedback that it is in fact the right vehicle. In *scenario x* (placeholder text), Charles unlocks the vehicle by scanning a QR-code. These are only two ways of showing how two different interactions can achieve the same goal for two people with different disabilities. This being said, it is still possible for one solution to be accommodating for other disabilities as well. What is important to think about is to not use interactive functions that will exclude groups of people. For example, Charles with his aphasia would have problems if the only option were to use voice command.

5.3.8 Phase 8

Guidelines: Fifth iteration
The last iteration of the guidelines focused on changing the titles and short descriptions of some of the guidelines. More references to the literature study were

also added, for example the Swedish law of discrimination and references to more generic screen interface guidelines for the last guideline. The main focus was to create more understandable designations for the titles, for example regarding expressions such as "accessible", which can be interpreted both as suitable for people with disabilities, but also as something that is easy to reach. Also, the term "surroundings" can be interpreted loosely in different ways. In addition to this, the new scenarios containing multiple personas were added into the guidelines as references.

Result

The result in the changes of the titles and designations is presented down below. For the complete end result of the guidelines, see *Chapter 6.3 Result* in this report.

PROVIDE INFORMATION OF *SURROUNDINGS*
Provide alternatives for traveling routes and information about surrounding events such as traffic jams, delays and accidents
was changed to:
PROVIDE INFORMATION OF *CHANGES AND UNFORESEEN EVENTS*
Provide alternatives for traveling routes and information about surrounding events such as traffic jams, delays and accidents

CONNECT SMART *DEVICES*
Connecting smart devices and sensors to vehicles and traffic situations (IoT) will ease the travels of the users, as it can be more personalized.
was changed to:
CONNECT SMART *OBJECTS*
Connecting smart objects/things and sensors to vehicles and traffic situations (IoT) will ease the travels of the users, but consider already existing solutions.

PROVIDE *ACCESSIBLE* SCREEN INTERFACES
Design screen interfaces to be accommodating for people with diverse disabilities.
was changed to:
PROVIDE SCREEN INTERFACES *USABLE FOR PEOPLE WITH DISABILITIES*
Design screen interfaces to be accommodating for people with diverse disabilities.

6. Result

This chapter presents the result of the study. It starts off by presenting six different personas, followed by eight different scenarios that include these personas, and lastly presenting the design guidelines. The design guidelines are the factors that should be considered when designing a smart city mobility solution to be more adequate for people with diverse disabilities. These guidelines are the answer to this study's research question. The study has three different results (personas, scenarios and guidelines) that are based on each other, and that have been developed simultaneously. The guidelines are more general than the personas and scenarios, which are more domain-specific. This means that the guidelines could be more applicable in other smart city projects than the personas and scenarios, which are specifically targeted towards autonomous vehicles.

6.1 Personas

The process of creating the personas was inspired by Cooper's eight steps for developing personas [*see chapter 4.4.3*]. They are based on answers from the survey and interviews in the data gathering phase. There is one persona each that represents users with visual impairment, hearing impairment, deaf-blindness and cognitive disabilities (Aphasia). There are two personas representing people with mobility impairment.

The personas are designed to have a balance between communicating motivations and goals for traveling, and also communicating who they are as a person. It is important to get a sense of the person behind the persona, to be able to understand the attitude and the actions that persona could carry out. The persona therefore contains three personality traits that describe them, a visualization of personality dimensions, life goal and a biography. To easily know what to consider, three accessibility considerations are presented as well as frustrations for each persona. In a design project, these personas should be used as a complement to one or more personas without disabilities, since these people should also be included in the solutions. This is what Inclusive Design advocate, that solutions should be accommodating for as many people as possible. Thereby, the personas created in this project should be seen as contributions to projects working with personas that try to include a wide range of people.

Persona 1: Adriana Matthew

Adriana is a young girl with visual impairment. It is important to incorporate people with visual impairment since even though information can be distributed through audio, it can be problematic to hear when it is crowded and a lot of surrounding noises. Also, audio outcalls today do not help people navigate, which could be a big problem for people who cannot see. From a safety perspective, it is important to work with other means to communicate to Adriana for example when a vehicle is closing in without her knowing.

Image 8. *The persona Adriana Matthew.*

Persona 2: Chrissy Andersen

Chrissy is a timid woman with hearing impairment. It is important to incorporate this disability since a lot of information, especially when unforeseen events occur is only (or at least a lot faster) mediated through audio. Not being able to hear this information creates problem for people like Chrissy. It is also very important from a safety perspective if people for example need to evacuate a vehicle quickly.

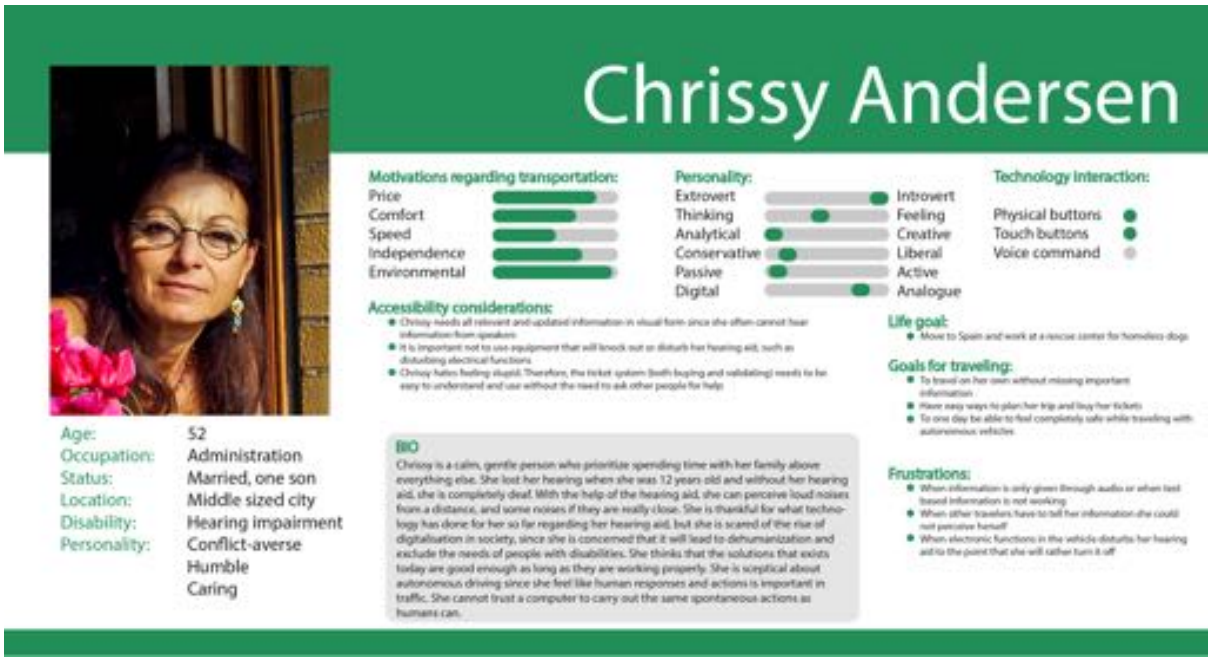

Image 9. *The persona Chrissy Andersen.*

Persona 3: Harry Smith

Harry is suffering from deaf-blindness. He is important to consider since solutions that are facilitating people with hearing impairment or visual impairment is necessarily not the most functional for him. This means that solutions could benefit from having other modalities than only audio and visual ways of receiving information and interact. It would sometimes be easier for him if information were available on an individual level.

Image 10. *The persona Harry Smith.*

Persona 4: Charles Clarkson

Charles is suffering from Aphasia. This persona is important to include since he addresses the communication issues that people can have while traveling. This as well as having the problem with quickly having to interpret information and respond by action, which is sometime challenging for people like Charles.

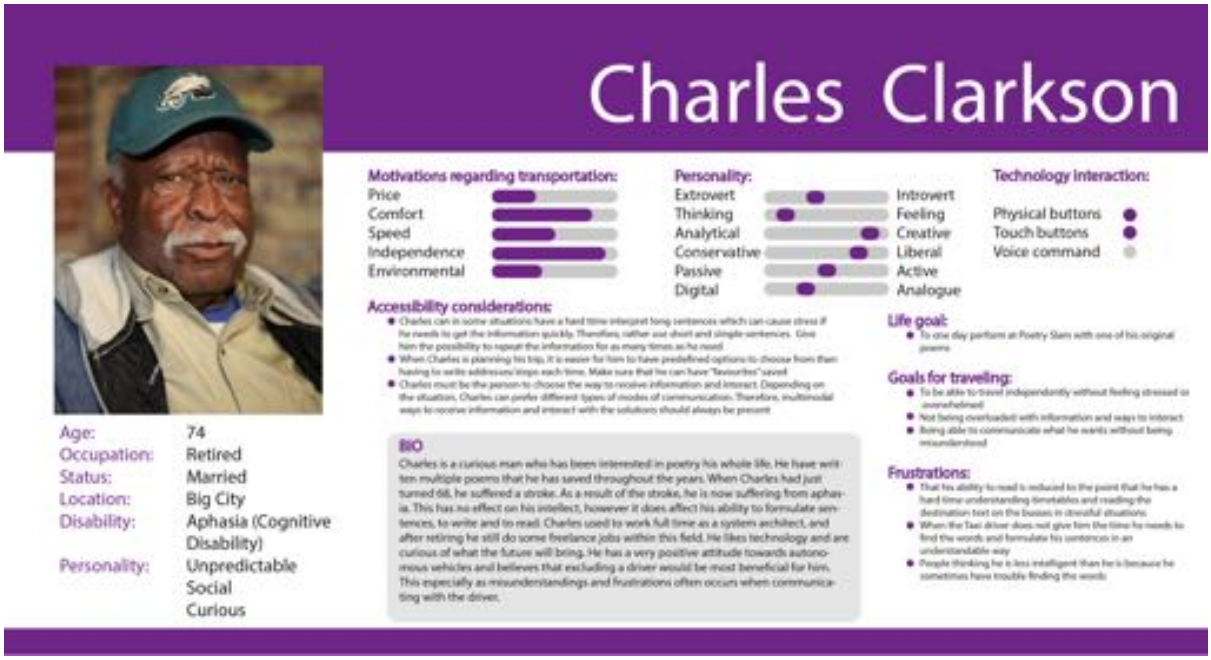

Image 11. *The persona Charles Clarkson.*

Persona 5: Sebastian Harrold

Sebastian is an active young guy with mobility impairment. He likes technology and is open to new solutions. He is important to consider since he represents people in wheelchairs who want to travel by the same conditions and just as fast as people who can walk. He does not want to take detours and be late to meet his friends or to a basketball game.

Image 12. *The persona Sebastian Harrold.*

Persona 6: Henrietta Adams

Henrietta has, just like Sebastian, mobility impairment and uses a wheelchair. But there is where their similarities end. Henrietta is critical towards new solutions and do not enjoy the digitalisation. Therefore, she is an important persona to have in mind when it comes to creating solutions that would make her feel safe enough to want to try and use them, and easy to use so that she does not give up on the first try.

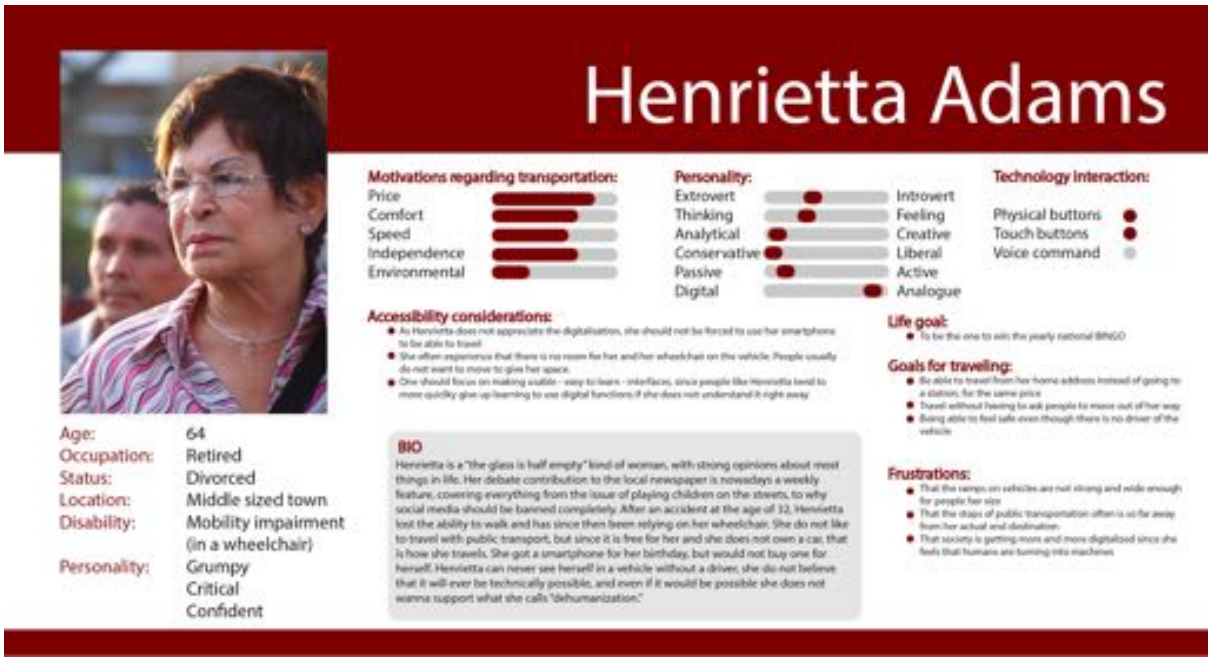

Image 13. *The persona Henrietta Adams.*

6.2 Scenarios

Eight scenarios have been created. Six of them contain one persona each, and two of them contain multiple personas. The scenarios are created to place the personas in situations and contexts to more clearly communicate their needs and reactions. Each scenario presents the included persona(s) and what the contextual goal is for that scenario.

Scenario 1: Traveling home from work with tram

Persona: (2) Chrissy Andersen

Contextual goal: Chrissy wants to be able to travel independently without relying on other people giving her information that she missed because of her hearing impairment, since it is only mediated through audio. She also wants to be able to buy her own ticket and plan her trip by herself. In this scenario, she wants to get home to her family after work.

Chrissy has been working late, as the majority of the days the last month. It is almost 8 pm and she just finished at the office. It is raining outside and because of the construction going on next to her office she has to take a detour to get to the tram station. She arrives at the station and sees on the timetable that it is thirteen minutes left to the next tram. She looks at her monthly ticket, realising it expired yesterday. She remembers her son telling her it is possible to buy monthly tickets in the app on her smartphone, and that she should just as well learn how to do it since they will stop using physical tickets any day now. She starts the app and navigates to the buy ticket section. She sees that there are three options for monthly tickets. She clearly sees that one option is for students, one is for adults and the last one is for elderly. She clicks the buy button on the adult option and now the application is asking her how she wants to pay. Chrissy do not want to give them her credit card information, but sees that there is a possibility to get the amount added to her next phone bill. She accepts that and now she can see the ticket in her app. She feels proud that she actually managed to do this by herself.

She looks up from her phone and can see the tram in front of her. Since she was busy looking at her phone she did not notice the tram arriving. She hurries, and enters the tram just before the doors close. She starts to think that it would never happen if there was a driver in the vehicle, that he would not close the doors if he saw her hurry to enter, only to realise it happened to her a few times even before the vehicles became autonomous. Before taking a seat, she always makes sure the display with the different stops is working and visible from where she sits. Since she has to change to a bus to get home, she wants to see this particular tram's route to know where it will be most convenient for her to change, since this can differ depending on what tram she got on.

She looks at the monitor and recognizes that she can change to a bus at the next stop. She presses the stop button and the display gives visual feedback that the vehicle will stop, and she walks up to the door. She leaves the tram and walks to the bus stop. She can hear noise from the speakers but cannot hear what the voice is saying.

She turns to the big information display at the stop and there she can read that because of an accident, some of the bus lines are delayed. Thankfully, her bus is not on the list.

Scenario 2: Traveling to Bingo with train and tram

Persona: (6) Henrietta Adams

Contextual goal: Henrietta wants to be able to feel safe even though there is no driver of the vehicle. As Henrietta does not appreciate the digitalisation, she does not want to feel forced to use her smartphone to be able to travel. In this scenario, Henrietta wants to go to the Bingo hall in her town and she hope she will be able to do so without any detours because of her mobility impairment.

On Wednesday evenings, Henrietta goes to the weekly BINGO at the local gaming hall and she knows exactly which trains and trams she needs to take to get there in time. Henrietta always leaves at least 10 minutes earlier than she has to, in case she needs to wait for the elevator to get up to the train platform. There are often a lot of people with bags or strollers that uses the elevators, which causes her to have to wait for it to be unoccupied. When she arrives to the train station the elevator is free and she enters it to get up to the platform. She is now a bit early and needs to wait seven minutes for the train to arrive.

Henrietta does not need to buy tickets when she travels with public transportation. This as it, because of her mobility impairment, is free for her. Instead of a ticket she has a travel document that states her condition and validates that she can travel for free. Henrietta does not really like to travel with public transportation, especially with the autonomous once. However, as she does not own a car, her retirement fund is not that big and the public transportation is free for her, she still travels with it, but not without scepticism.

When she is waiting for the train, she takes up her smartphone. She is not really a big fan of smartphones, but she uses it for one thing. There is an application where she can search and see if the elevators at the stations are working or not, or if there is other activities that can affect the journey [see *Image 14*]. This time it is a good thing that she did, as it turns out that the elevator at her usual stop is broken, and she therefore have to get off at one stop earlier than she normally gets off. The route that Henrietta has to take to the BINGO only has one change, which is good, but it is not the fastest way to get there. There is an easier and faster way, however at that stop where she needs to change to the tram, there is no elevator. She therefore needs to take a longer route. Something that frustrates her, as long periods in her wheelchair makes her back hurt.

Image 14. *This picture shows a blocked entrance to the subway. For people like Henrietta this might have been the only way to reach the platform with her wheelchair, so she needs to know about these activities in advance.*

The train arrives and Henrietta enters. There are not a lot of people this time so she has a lot of space around her. Once the train has arrived and she has taken the elevator from the platform, she arrives at the tram stop just in time for the tram to arrive. Is it easy for her to get on the tram, as the tram and platform are on the same level. She appreciates this as it before was hard, a ramp was needed and the ramps do not feel strong and wide enough. While on the tram there is a separate space for wheelchairs, but people are standing there. As soon as they see her entering the tram they move to give her space.

Before the tram starts moving from the stop, they meet another tram. She sees the front of the tram and that it is without a driver. This reminds her that she is also on a vehicle without a driver. This makes her annoyed even though she never really used to talk to the driver anyways. Henrietta does not like that the public transportations only uses autonomous vehicles as she feels they are part of the de-humanisation of the society. But as this is her only way of transportation, she tries to ignore it. She is now arriving at her stop, but there are a lot of people standing by the doors and she has to speak up to make them hear her, telling them to please step aside so she can exit the vehicle. Once again it is easy for her to exit the tram, as the platform and the floor of the tram is in the same level. Now Henrietta can go to her weekly BINGO just around the corner.

Scenario 3: Traveling to shopping mall with taxi, shuttle and subway

Persona: (3) Harry Smith

Contextual goal: Harry's goal for the day is to get to the shopping mall and buy new shoes. Harry wants to be able to travel independently without having to rely on other people for information because of his deaf-blindness. He wants his travel to go by fast and without unnecessary interruptions and he prefers speed over comfort.

Harry is going to the big shopping mall to buy a new pair of shoes. He is going there by the autonomous taxi service. Harry is booking his trip through the taxi service app. Harry has been to the mall before, so he got the address saved in his booking history. He uses voice command to book his trip since it is easier for him than having

to magnify the text to a size that allows him to see. Feedback is given to him both through audio and text. Harry already saved all his information in the app, including a picture of his face.

The taxi arrives and Harry walks up to the facial recognition by the door of the vehicle to scan his face and open the door. Inside there is an interactive screen with his booking information that is also read out loud through audio. Since Harry cannot see what is on the screen, he leans forward to magnify the text before pressing the confirm button. The car starts to drive. After driving for ten minutes, the car receives information regarding an accident on the highway. This is the only way to get to the mall by car from his place. Harry now gets the option to either go to the highway and wait for the road to clear up, to choose a new destination, or get of at the closest public transportation station. Harry makes the choice to get of at the closest station and continue his journey by public transportation. He makes the choice by magnifying the text on the screen and then presses the button for his choice.

The station the taxi dropped him off at is a stop for the cities autonomous shuttles. Each shuttle drives back and forth between two stops in different parts of the city. Harry opens the public transportation app to search from his current location to the shopping mall. He pays the ticket through the application and gets a digital ticket to scan. Harry sees that he is supposed to take a shuttle and later switch to the subway. Harry starts locating the right platform through the GPS-function in the public transportation app.

The shuttle arrives, Harry enters and once on the shuttle he scans his ticket by the entrance to the shuttle where he sees a bright red light shining. Displayed on the screen inside the shuttle, is the number and destination of the shuttle to confirm the passengers they are on the right vehicle. This information is also presented through audio. In the shuttle, there is a GPS based map on the screen that in real time shows the shuttle's location and how far away they are from the destination, this same view is also available in the mobile application. The shuttle arrives to the stop that is right next to the subway station and Harry gets out.

This subway station is trafficked by two different subway lines. At the stop, there are big and clear signs that shows the direction on how to get to the different lines, as opposed to how the stations could look before [see *Image 15*] and it is also possible to use visual and auditory navigation through the public transportation app. Harry uses the application's map to guide him to the right platform. The train arrives and Harry follows the route in real time through the mobile application. After a short ride on the subway Harry gets off at the mall.

Image 15. *A bad example on how unclear signs showing the directions to the different platforms can be. The sign pointing towards the direction of the S-bahn are surrounded by a lot of other signs.*

Scenario 4: Traveling to lunch appointment with taxi

Persona: (4) Charles Clarkson

Contextual goal: Charles wants to travel to a restaurant to meet his granddaughter for lunch by himself. This, because of his Aphasia, is easiest done by presenting him only with short, clear and relevant information and interaction, which does not cause him to be overwhelmed and stressed. Also, that allows him to repeat the information if needed. He wants to be able to communicate what he wants without being misunderstood.

It is Saturday forenoon and Charles is meeting his granddaughter Audrey for lunch at this new vegan place she has been talking so much about. Charles has never been there before, and is not very familiar with the area where the restaurant is located. He decides to travel there by the taxi service for people with disabilities since he cannot travel with public transportation. This is because it makes him feel stressed and he cannot comprehend all the information at once. The taxi service for people with disabilities is exactly like an ordinary taxi service, but cheaper. Since Audrey texted him the whole address yesterday, he copies the address from her text, and paste it into the taxi booking service application. His home address is already saved as one of his favourites, so he can choose the pick-up destination very easily. He selects that he wants to be at the location of the restaurant at 11.50, and the application informs him that the taxi will pick him up at 11.35 at his home address.

At 11.30, Charles walks downstairs to wait for the taxi. When the autonomous taxi arrives, he scans the QR-code he received in the application after booking and the doors open up for him. He sits down and the information about his destination and the time he will arrive is presented both in text on a screen and audio. Since the address of the location is new to him, and quite long and complex, he now gets a little bit stressed and unsure if he really typed in the right address for the restaurant. He decides to call his granddaughter, and request an auditory repetition of the

destination address through the car's interface, and she reassures him that it is the correct one. He now confirms the route by clicking "Confirm" on the screen, and the taxi starts to drive. He can follow the route on a map displayed on the screen.

He arrives at the restaurant and pays his trip through the app since he already has saved his credit card information, he only needs to press "Pay" and when he sees that his payment has gone through, he gets out of the vehicle. Charles has chosen this method of payment as he has problems paying invoices, since it includes interpreting many different types of information and numbers.

Charles enjoys a pleasant lunch with Audrey and when it is time to leave he orders a new taxi from the app. Now Charles chose to press "Current location" as the pick-up address and his already saved home address as his end destination.

Scenario 5: Traveling to basketball game with shuttle

Persona: (5) Sebastian Harrold

Contextual goal: Sebastian wishes to be able to travel without feeling that he is in the way of other travellers. He wishes for a separate space for people in wheelchairs on the vehicle so that he does not have to have people's bags and similar things in his face while traveling, and also to be able to enter and exit the vehicles in an easy way. In this scenario, Sebastian wants to quickly travel to his basketball-game.

Sebastian's basketball team have an important game tonight at seven pm. Since he has promised himself only to take the car to and from work and nothing else, he will go there by using the Autonomous Shuttle in his city. For Sebastian, the important thing is to get there on time, since he needs time to change clothes and give the guys a pep talk as it is expected from the team captain. Luckily for Sebastian, there is a stop for the Shuttle close to his place. He grabs his bag and takes the elevator down to the house entrance floor. He goes to the stop for the Shuttle and he is three minutes early, enough time to buy the ticket he needs to scan before getting on the Shuttle. He picks up his smartphone and opens the app. It remembers what type of ticket he usually buys and his credit card information is already saved so he only need to press buy and the ticket is now in his phone, valid for 90 minutes. The Shuttle arrives, and since all stops for the Shuttle is built to be on the same ground level he can easily get on after scanning his ticket. This was not the case for him when he travelled with public transportation before, as the levels could differ a lot [see *Image 16*].

Image 16. *An example of a bad solution where the floor of the tram and the platform where travellers enter the vehicle are not on the same level.*

Today there are already a lot of passengers on the Shuttle when he enters. He goes to the separate space for wheelchairs and locks the brakes for the wheels. There are straps he can use to secure the wheelchair but Sebastian usually does not use them since he has great brakes on the chair already. The Shuttle stop to pick up some more travellers and now the Shuttle is getting even more full. People are standing up and Sebastian are happy that today's passengers are respecting the separate space for the wheelchair, so that he does not have to have their bags in his face. People are standing in the way of the monitor that shows the upcoming stops so he is glad that there is also clear and loud enough audio reading out the next stop and the stop following that. Sebastian is starting to get nervous about the game and suddenly the Shuttle do a rapid break and the passengers are immediately informed through text and audio that the Shuttle had to stop because of a cyclist. The Shuttle is starting to drive again and Sebastian decides that he might use the straps after all.

The voice in the speakers lets him know that the next stop is his stop and he press the stop button closest to him, which also lets the Shuttle know that it is a person in a wheelchair getting off. Sebastian thinks for himself that it must be an old function from before when ramps was needed on the Shuttle, before they built all the platforms and stops in the same ground level as the vehicle.

He gets off the vehicle and sees that he is actually a few minutes early. The nervousness changes into excitement and he hopes that when he takes the Shuttle the same way back it will be as a winner.

Scenario 6: Traveling to school with taxi-shuttle

Persona: (1) Adriana Matthew

Contextual goals: Today Adriana needs to get to school in time for her test. Since she is very time optimistic, she needs to get to her destination just as fast and smooth as people who do not have visual impairment. She wants to travel independently, without feeling like a burden for other people, as well as easily being able to navigate herself at new locations.

This morning at 9 AM, Adriana will have a very important test in musical theory at school. Unfortunately, she overslept this morning and now she is running the risk of

being late to the test. As soon as Adriana realizes she does not have time to get ready before the bus leaves, she decides to order an autonomous taxi-shuttle. She takes up her smartphone and opens the taxi-shuttle app. With the use of an additional helping application, that makes it possible for her to magnify the interface directly to her preferred size, she chooses her current location as a starting position and the schools address as the destination. Once the order is done, the application notifies her that the taxi-shuttle will arrive in 15 minutes and the journey to the end destination will take around 20 minutes.

After 10 minutes an alarm goes off on Adriana's smartphone, notifying her that the taxi-shuttle is close. She starts putting on her shoes and jacket to go outside. Since Adriana has impaired vision, she has a hard time identifying objects on the street, so she decides to wait outside the entrance of her building. The taxi-shuttle arrives at the sidewalk just outside her building. Because of her visual impairment, she does not see this. However, the taxi-shuttle application has been tracking the route of the taxi-shuttle and is now notifying Adriana through a message, that the taxi-shuttle has arrived. As Adriana is feeling stressed and don't feel she has the time to start the additional magnifying application, she selects the choice to listen to the notification message through audio. Now Adriana knows the taxi-shuttle is there and starts to walk closer to the sidewalk. As Adriana gets closer, the taxi-shuttle presents itself in form of audio to let her know she is close. This is done by the connection of the taxi-shuttle and Adriana's smartphone. Adriana enters the taxi-shuttle and gets seated.

Adriana can through the taxi-shuttle application on her smartphone, track the taxi-shuttles movement on a map in real-time. Adriana appreciates this, as she becomes unsure in situations when the taxi-shuttle stops, as she does not know if it has stopped because she has arrived at her school or if it only stopped at red traffic lights.

After 20 minutes, she has arrived at the address of her school. This is notified to her in form of audio inside the taxi-shuttle, telling her that she has arrived at her destination. However, Adriana does not hear this information clearly, as she had her headphones on, listening to music. She therefore uses the voice command function in the taxi-shuttle and asks if she can get the information repeated to her. The system of the taxi-shuttle recognises Adriana's request and repeats the information once more.

As Adriana has used the taxi-shuttle before, she has a personal account in the application, which make paying easy. Now Adriana exits the taxi-shuttle outside her school, in good time for her to do the test.

Scenario 7: Two people traveling to work with bus

Persona: (3) Harry Smith & (5) Sebastian Harrold

Contextual goals: Harry wants to be able to be able to travel independently without having to rely on other people for information as a result of his deaf-blindness. He wants his travel to go by fast and without unnecessary interruptions and he prefers speed over comfort. Sebastian wants to be able to travel without feeling that he is in the way of other travellers because of his wheelchair. He also wants to be able to access information even when other travellers are standing in the way of information screens. In this scenario, they are both on their way to work.

Harry works as an assistant pastry chef and starts his working hours early in the morning. Harry gets to his work by taking the bus. He buys his ticket in the app on his smartphone. His smartphone has software and applications that help him magnitude the text to a size where he can read it. The app for the bus service has now also added functions to magnitude the text, but the text is not big enough for him.

The bus stop where Harry is catching his bus also have six other bus lines passing. Before, it was really frustrating for him to not know which bus is his bus, since he can't really hear the audio calls the buses use, or see the number of the line on the front and side of the bus [see *Image 17*]. Therefore, he is very happy that they have integrated the function where he gets updated via text message. Today, he gets a text message saying that his bus is eight minutes late at the same time as they call it out in the speakers. Attached is also the link so he can follow the bus through GPS on the map if he wants to. While he sits down on a bench, a young man in a wheelchair enters the waiting area. The young man, named Sebastian, is on his way to work as well. He stops by the screen with the arrival times and sees there is 7 minutes until his bus arrives. Both Sebastian and Harry are now waiting for the same bus.

Image 17. *This image gives an idea of how hard it can be to see the number of the line and the destination of the vehicle even without visual impairment. For people like Harry, this is close to impossible.*

After seven minutes Harry get a text message saying that his bus is now at the stop, which is good since he could not hear the speakers. Sebastian had already seen the bus from afar, so he approached the platform before the bus arrives. As Harry approaches the platform, Sebastian notices his white cane. Therefore, when the doors open, Sebastian waits for Harry to enter the bus first so he does not get in the way of him. This is no problem for Sebastian, as it now a day is quick and easy for him to enter the vehicle, as the platform and the floor of the vehicle is on the same level. Harry enters the bus and since there are no driver to ask, and just to be sure, he scans the code at the entrance of the bus with the app in his phone, and he get direct feedback with a green light and the bus line and destination written on his screen, so

he knows that he is on the right line. He sits down in the bus, knowing he have roughly fifteen minutes to travel.

When Sebastian enters the bus, he moves directly to the separate space in the bus designated for people in wheelchair. The bus starts driving. After ten minutes on the bus Harry can hear that there is a callout in the speakers of the bus, even though he cannot really hear what they are saying. In the same moment, he gets a new text message with information that the bus is now only three minutes behind schedule, instead of eight. Harry can follow the route through GPS in real time and thereby know when they are getting close to his stop. Since he has saved that information in the app, and turned on the notifications, he also gets a text message saying that the next stop is where he needs to get off. At every bus stop the vehicle also uses a blinking light that Harry can see, so he knows that they are in fact at a stop.

There are now so many people on the bus, that some of them have to stand up. Nevertheless, Sebastian can from his separate space see that Harry is getting of the bus. As there are many people on the morning bus, it sometimes happens that people are standing in the way of the screen displaying the next stop. Sebastian always listens to music when he is on the bus, so there are times when he cannot hear the outcalls either. Sebastian have therefore, just as Harry, selected the notification function in the transportation application as well as following the route through GPS in real time. Then, he does not need to worry about people standing in the way of the screen, or not being able to listen to music. Before Sebastian's stop he gets a message that his stop is next. He therefore presses the indication button, that notifies other passengers that someone with a stroller, walking frame or wheelchair is getting off and therefore needs to move away from the doors. Sebastian likes this function, as he then does not need to feel stressed when exiting the vehicle. He also likes that many people use the function, not only people with disabilities, as he does not like to stand out too much in a crowd.

Scenario 8: Traveling home after a thunderstorm

Persona: (1) Adriana Matthew (Visual impairment), (2) Chrissie Andersen (Hearing impairment), (3) Harry Smith (Deaf-Blindness) & (4) Charles Clarkson (Cognitive disability - Aphasia)

Contextual goal: All four personas are trying to get home from the central station with the extra buses that replaces the trains and trams after extensive delays. They want to get the general information about the delays so they know what is going on, and also information on how they can navigate themselves to the right platform, in ways that suits each of their needs.

It is afternoon on a crowded central station that has departures by autonomous buses, trains and trams. Harry, Adriana, Chrissie and Charles are all on their way home. Because of a big thunderstorm that knocked out a big part of the city's electricity, there are multiple delays in the public transportation. To inform travellers of this, the public transportation company are presenting the information of the delays and where people can go to find the extra buses, which replaces the trains and trams in a multimodal way. Adriana needs auditory information, Chrissy needs visual information, Harry would prefer both, as well as for example tangible notifications in form of blinking lights, and Charles always needs the possibility to request the information repeatedly. Adriana listens to the outcalls from the speakers and then uses her smartphone to guide herself to the right position for her bus, and Chrissy walks up to the large digital screen to see which platform she should walk to

and then follow the signs. Harry can hear some of the information about the delays through the speakers, but uses the application on his phone to listen to the information once again and assure himself about the new position. He then uses the map application showing the central station in detail to navigate himself there by audio. Charles, who have become stressed about the situation walk off to a quiet area and uses his smartphone and the public transportation application to calmly listen and read the information about the delays and can see that the application automatically has, as a suggestion, presented information about the new platform for his bus without him having to search for it manually, since his home address is saved in the application.

6.3 Guidelines

These guidelines have been created based on literature studies, additional online research, the interviews, observations, surveys and the personas and scenarios. Each guideline has references to the literature and is also exemplified with personas and scenarios. They also contain examples from and references to the interviews and surveys. Since the authors do not have multiple years of working experience within this field, the guidelines are formulated as suggestions and recommendations based on what other researchers have done in the past, presented in the literature study, and the experience gained from this project. These guidelines are not technical guidelines, and the assumption is made that the technology used in the solutions are in fact working.

1. PROVIDE INDEPENDENCE

All solutions should strive towards helping people become more independent and socially included

References to Persona: (3) Harry (Deaf-blindness), (2) Chrissy (Hearing impairment) & (5) Sebastian (Mobility impairment)

References to Scenario: (3) Traveling to shopping mall with taxi, shuttle and subway

Assistive IoT technology tools are effective in increasing independence and making people participate socially. People with disabilities can be overly dependent on their families or other assistants because of the lack of support services such as building access, transportation, communication and information. This can prevent them from being working, being active and socially included (Domingo, 2011). The Internet of Things can help with support and assistance that people with diverse disabilities need in order to gain a good quality of life and be better included in the economic and social life. The Senate Department for Urban Development and The Environment (2015) writes that for social participation, mobility is essential. IoT constructs enabling environments by giving people with disabilities assistance in transportation, building access, information and communication (Domingo, 2011) *(read more under 3.6.2 Ambient Intelligence and IoT for people with disabilities)*. Sweden has a law against discriminating people with disabilities (Act of Lag 1999:132 ”Prohibiting employment discrimination based on disability”, 2 §). One way of working against discrimination of people with disabilities can be to include them in transportation solutions, allowing them to be more independent and socially included. Being able to travel on your own is a sign of independence, which was pointed out in the interviews and surveys. While there are many issues related to creating design solutions that address this, one example is that users need to be able to identify a vehicle as their intended vehicle on their own, without having to ask for help from other travellers. Activity theorists believe that people are not just accepting and being satisfied with existing institutional relations, instead they are equipped with the power to act - the human agency - which enables critique and revision (Roth & Lee, 2007). The liberty of choosing one’s actions could be seen as a big part of being independent. Solutions, therefore, need to enable users’ possibility to choose their actions accordingly.

Both the survey and the interviews showed that independence is truly important for all participants in the study. It also showed the lacking possibility of independence as current solutions sometimes prohibits them to make spontaneous travels on their own. The scenarios connected to these guidelines exemplify situations where the personas can travel independently. This means that they can act on their own and not being restricted in their travels because of their disabilities. The scenarios show examples where the users can do things on their own, things that they normally (or in today's solutions) needs assistance with, for example asking the driver or other travellers if they are on the right bus. In *Scenario 3*, Harry does not need to ask anyone for information regarding location and identifying his taxi. Instead he can use his phone to access information and the facial scanning unlocks the car and thereby confirming that it is the right vehicle. This leads him to becoming and feeling more independent. Chrissy, as a persona, feels frustrated when other travellers have to tell her information she could not perceive herself because of her hearing impairment, which makes her feel reliant on others. Sebastian is the persona with the strongest need of feeling total independence, it is extremely important to him.

2. PROVIDE ACCOMMODATING ENVIRONMENTS

Make sure that the interior of the vehicle, platform and waiting areas are accommodating to the different needs of the users

References to Personas: (5) Sebastian (Mobility impairment), (6) Henrietta (Mobility impairment), (1) Adriana (Visual impairment) & (2) Chrissy (Hearing impairment)
References to Scenarios: (1) Traveling home from work with tram, (5) Traveling to basketball game with shuttle

This can for example be to provide vehicles and waiting areas with hearing loops, or make sure that the locations of displays with information (both outside and inside vehicles) are adapted to also be able to be seen by short people and people in wheelchairs (Partnersamverkan för en förbättrad kollektivtrafik, 2012). Another important thing is to make it easy for people to locate the right vehicle at stations. Synskadades Riksförbund (2015) (Visually impaired federal federations in Sweden) writes that more clear and evident signs with better contrast between text and background are actions that can be crucial for people with visual impairment. They also say that there is a need for a formation and design of vehicles, terminals, stations and platforms that facilitates self-orientation and guarantees security.

In the survey, people with movement-, visual- and hearing impairments, all expressed that catching connecting vehicles in an easy way is difficult. People with movement impairment also wished for entries and exits to be designed properly for wheelchairs, as well as functional elevators at all stations. In the interviews, both people with movement impairments and visual impairments had problems with the fact that the floor of the vehicle and the platform was on different ground levels. As seen in *scenario 5*, the floor of the vehicle and the platform are always on the same level. The personas of Sebastian and Henrietta both wishes for a space for the wheelchairs from where they still clearly can see the information display. When the persona Adriana, who has impaired vision, is changing from one vehicle to another there should be accessible tools for her to quick and easy find the location of the new

vehicle. In *Scenario 1*, all relevant information is updated in visual form since Chrissy cannot hear the information from the speakers. Before taking a seat, she has to make sure that she can see the display from where she sits. Future solutions should make sure there are no "blind spots" where travellers cannot see the visual information.

3. PROVIDE INFORMATION OF CHANGES AND UNFORESEEN EVENTS

Provide alternatives for traveling routes and information about surrounding events such as traffic jams, delays and accidents

References to Persona: (1) Adriana (Visual impairment), (5) Sebastian (Mobility impairment), (2) Chrissy (Hearing impairment), (3) Harry (Deaf-Blindness)

References to Scenarios: (1) Traveling home from work with tram, (3) Traveling to shopping mall with taxi, shuttle and subway

If delays or other problems occur, provide multimodal information about alternative routes and where people can find them. The Senate Department for Urban Development And The Environment (2015) writes that giving the public information about for example traffic jams and different public transportation alternatives increases the traffic flow. It is important to remember that this information needs to be mediated in different ways so that people with diverse disabilities can access the information. This can be done when the users are planning their trip in the application, when they are at the station, and when they are already on board a vehicle. The vehicle can retrieve information about accidents along the way and can calculate a different route. To provide travellers of the vehicle of this information before actually arriving to the site of the accident, will be beneficial and effective for all. For people with cognitive disabilities such as aphasia, it is important to get unforeseen information as early as possible since improvisation can be hard, if not impossible, for some people with this condition, which was learnt from the interviews.

In the survey, people expressed that when users with visual impairments ends up at a place that is new for them because of unforeseen events, they need to know this as early as possible so they that can on their own terms, and based on their own needs better navigate the new area. This is exemplified in the persona of Adriana and is therefore a part of her accessibility considerations. This also goes for the persona Sebastian. He too needs information mediated directly if situations such as an elevator should break, as he therefore needs to alter his traveling route. In *Scenario 1*, Chrissy can hear a sound from the speakers but cannot identify what the voice is saying. She turns to the big information display at the stop and there she can read that because of an accident, some of the bus lines are delayed. In *Scenario 3*, the car receives information regarding an accident on the highway and mediates this to Harry, which can then re-plan his route. These kinds of multimodal ways of presenting changes and unforeseen events should be considered.

4. PROVIDE REAL TIME AWARENESS

The solution should have real time situational awareness of what is going on in the real world in order to make travellers feel safe

References to Persona: (2) Chrissy (Hearing impairment), (4) Charles (Cognitive disability - aphasia)
References to Scenario: (5) Traveling to basketball game with shuttle, (1) Traveling home from work with tram

Smart Computing signifies the new generation of integrated software, hardware and network technologies that can provide IT systems with real-time awareness of what is going on in the real world and use advanced analytics that help people make smarter decisions and optimizes business processes (Chourabi et al, 2012). Everyday objects, the "things", becomes smart and are able to sense, interpret and react to the environment. This is made possible by the Internet and rising technologies such as Radio-frequency Identification (RFID), embedded sensors and real-time localization (Domingo, 2011). Solutions with real time situational awareness must grab the attention when it is needed, and have the means to understand what is happening and respond to that situation without delay (Inova Solutions, n.d.). This is connected to making the travellers feel safe while traveling with the autonomous vehicle. The vehicle needs to have the ability to recognise objects. Generally, two steps in the process of recognition are applied: detection and classification. There are two classes of objects that are relevant for autonomous vehicles. The first being elements of the infrastructure, such as road marks, road boundaries, traffic lights and traffic signs. The other class is traffic participants, such as pedestrians, bicycles and vehicles (Franke et al, 1999).

As learned from the interviews, people are mostly sceptical towards autonomous vehicles because of the presumed unsafe aspect. According to some of the interviewees, the driver's role is to make the travellers feel safe and calm. This is especially important for travellers that have visual- or hearing impairment. These people should be able to feel just as prepared and safe as people without impairments in case of emergency. In *Scenario 5*, the Shuttle makes a sudden break. The passengers are then immediately informed through text and audio that the Shuttle had to stop because of a cyclist. The scenario shows one way of communicating the situation, which will help the passengers feel safe. In *Scenario 1*, the persona Chrissy reflects on that she almost did not make it to the vehicle, and that a nice driver would have waited for her. One way of solving this could be to create solutions that make travellers feel "seen" by the vehicles, so that people notice that the vehicle recognizes objects. The persona Charles is very positive towards autonomous vehicles and believes that excluding a driver would be most beneficial for him. This especially since misunderstandings and frustrations often occurs when communicating with the driver since it is sometimes hard for Charles to express himself because of his cognitive impairment.

5. CONNECT SMART OBJECTS

Connecting smart objects/things and sensors to vehicles and traffic situations (IoT) will ease the travels of the users, but consider already existing solutions

References to Personas: (1) Adriana (Visual impairment), (3) Harry (Deaf-blindness), (5) Sebastian (Mobility impairment)

References to Scenario: (6) Traveling to school with taxi-shuttle, (7) Two people traveling to work with bus

Combining mobile communications, sensors and RFID seems to be very promising to enable more applications to contribute in building the IoT. One example of the development of RFID-based systems is helping people with visual impairment to be guided on buses with handheld devices and RFID (Biader Ceipidor et al., 2009). It is important to think about optimising security, performance and privacy performance in these solutions (Chaouchi, 2013). Solutions need to accommodate other already existing solutions. If not, it could cause problems. Therefore, it is important to research what could be done to ease and facilitate already existing solutions. This could make it possible for people to access information on an individual level that suit their needs, for example reading on their own screen with the text size optimal for that specific user, or listening to a callout from the speakers again in their own device in their own volume and pace.

In the surveys, people with visual impairments answered that they are already relying on different digital solutions to facilitate their everyday life. They think that the ongoing digitalisation is a positive thing *"as long as the new systems works well with my assisting tools"*. In the interviews, people with hearing impairments expressed that the digitalisation have helped them a lot and they are positive towards future development. This also as many tools are used for communication, both in work and social context, so consider these already existing IT-solutions when designing new ones. In *Scenario 6*, Adriana uses an additional helping application to magnify the interface according to her preferences. This is one example of how additional tools are used. Smart City solutions should not exclude the use of additional helping aids, but rather complement, enhance or include them. Providing the possibility to connect smart objects can also be beneficial in other contexts with people with diverse disabilities. As shown in *Scenario 7*, both Harry (Acquired deaf-blindness) and Sebastian (Mobility impairment) use a function that allows them to follow the route of the bus in real time, to retrieve information. Harry uses this function because he has a hard time hearing and seeing auditory and visual information and Sebastian uses it as he, when there are people standing in the way on the vehicle, have a hard time seeing the visual information. The reason for their use is different, but the need is the same.

6. PRESENT MULTIMODAL INFORMATION

All information, inside and outside the vehicle, should be presented in a multimodal way

References to Personas: (1) Adriana (Visual impairment), (2) Chrissy (Hearing impairment), (3) Harry (Deaf-blindness), (4) Charles (Cognitive disability - Aphasia)
References to Scenarios: (8) Traveling home after a thunderstorm

G3ict & World Enabled (2016) writes that smart city digital services can be made more accessible by for example making content available in multiple formats. SRF (Visually impaired federal federations in Sweden) writes that there is a need for audio-visual outcalls regarding both the different stops and the destination (Synskadades Riksförbund, 2015a). In the interviews and surveys, it was requested that information should be presented at least both auditory and visually, and that the visual information should be given just as fast as the auditory information. Around every third participant asked in a study presented by SRF believes that there is a need for more or better outcalls on the vehicles. Almost every fourth person asked, wants more and better outcalls at stations and platforms (Synskadades Riksförbund, 2015a). Working with multi-modal ways to communicate danger, changes and unexpected events are very important. In addition to audio and text information, a way to catch travellers' attention at for example an emergency situation can be with lights and vibrations. Feedback should also be given to the user in multimodal ways, for example knowing that the stop button reacted to the touch by showing is visually, with audio and also vibration.

Gilakjani et al., (2011) writes that multimodal learning is most effective if it only includes relevant content in relation to the learning objectives, because of the brain's limited information processing resources. Also, if the persons who are learning from the information are able to control it, they will learn more. Information presented in multimodal formats are more effective when the learner has the ability to interact with it, for example by starting and stopping it or slowing it down (Gilakjani et al., 2011). When presenting information to travellers, the information should not become hidden before the user is finished with it, which was expressed as a problem in the interviews and surveys, and is also one of the guidelines given by Developer.gnome.org (2014). For people who suffer from deaf-blindness for example, the ability to retrieve multi-modal information on an individual level would be beneficial. Since public transportation should be for the public, which includes people with diverse disabilities, there is a need for multimodal information to be presented from different types of media at the same time, for people not to be excluded. Something that should be considered when designing solutions for autonomous transportation is that in current transportation solutions that include a driver, the travellers have the possibility to ask the driver for information. In other words, the possibility to request information, not only receive it, should be considered when designing the new solutions.

If given the situation where Adriana, Chrissy, Charles and Harry are on the same station or vehicle, the same information should to be mediated to all of them,

preferably at the same time, as seen in *Scenario 8*. Adriana needs auditory information, Chrissy needs visual information, Harry would prefer both but on an individual level, as well as for example tangible notifications in form of blinking lights, and Charles always needs the possibility to request the information repeatedly. Given this situation, one should reflect on and accommodate the different needs when designing new solutions. These types of situations show the importance of multimodal distribution of information.

7. PROVIDE MULTIMODAL INTERACTION

It should be possible to interact with the vehicle's interface(s) and surrounding or connected interfaces in multiple different ways

References to Personas: (3) Harry (Deaf-blindness), (4) Charles (Cognitive disability - Aphasia)
References to Scenarios: (3) Traveling to shopping mall with taxi, shuttle and subway, (4) Traveling to lunch appointment with taxi

Kleinberger et al. (2007) writes that *"Multi-modal interaction paradigms that combine several modes (e.g., gesture, sound) are a good approach to enhance usability and accessibility."* (Kleinberger et al., 2007, p 107). Different users prefer different ways of interacting with interfaces, this especially when it comes to people with disabilities. Some ways of interaction that is natural for one group of people could be impossible for others. Therefore, it is important to provide easy and multiple different (multimodal) ways to interact with the vehicle both from the outside and the inside. The vehicle should clearly signal to the user where interactive functions are located. With autonomous vehicles, there should be ways for the traveller to request information if needed, if possible equivalent to asking a driver for information. Feedback from the interactions should also be given in multimodal ways.

It is a challenge for a robot or system to understand a user's natural interaction. But it is necessary for enabling new users to use the robot or system smoothly and intuitively. It is easier to implement a set of hard-coded commands to control the system, but it is troublesome for the user because it does not allow the users to use their natural interaction style. Therefore, it would be beneficial to enable the system to learn to understand the user's natural way of giving commands and feedback by instinctive interaction through for example speech or touch (Austermann, 2010).

All personas include information regarding preferred interaction, whether it is physical buttons, touch buttons and/or voice command. The different needs of ways to interact depend on their preferences in regard to their disability. In *Scenario 3*, Harry interacts with the vehicle by facial scanning to unlock the car and this also is a way for him to get feedback that it is in fact the right vehicle. In *Scenario 4*, Charles unlocks the vehicle by scanning a QR-code. These are only two ways of showing how two different interactions can achieve the same goal for two people with different disabilities. This being said, it is still possible for one solution to be accommodating for other disabilities as well. What is important to think about is to not use interactive functions that will exclude groups of people. For example, Charles with his aphasia would have problems if the only option were to use voice

command. There is a need for further research of ways to interact with smart city solutions, not only through buttons or voice command, but also for example gestures, facial- or eye movements. However, keep in mind that there should be multiple different ways to interact since people have different levels of capabilities on how they can physically interact.

8. PROVIDE USABLE SCREEN INTERFACES FOR PEOPLE WITH DISABILITIES

Design screen interfaces to be accommodating for people with diverse disabilities

References to Persona: (6) Henrietta (Mobility impairment), (3) Harry (Deaf-blindness), (1) Adriana (Visual impairment)

References to Scenario: (6) Traveling to school with taxi-shuttle, (3) Traveling to shopping mall with taxi, shuttle and subway

There are already multiple different guidelines existing on how to design usable screen interfaces (for example Nielsen, 1995; Warsi, 2011), which should always be considered. However, this particular guideline aims to point out some important considerations to think about when designing screen interfaces that should be able to be used by the user groups in this study, in particular people with sight impairments. These guidelines should be applied both on phone applications but also on interactive screens such as payment systems or on interactive screens on board vehicles. According to SRF (Visually impaired federal federations in Sweden), every system for planning the trip, traffic information and also purchase of tickets needs to be fully usable for travellers with impaired sight (Synskadades Riksförbund, 2015a).

- Synskadades Riksförbund, (2015a) writes that one concrete example for improved accessibility for people with visual impairments is that color contrasts needs to be improved. Color contrast between background and text needs to be stronger for it to be easier to read. The screen resolutions also need to be improved, and people request less moving graphics and more text (Synskadades Riksförbund, 2015b). In the interviews and surveys people with visual impairment and deaf-blindness expressed that screens often suffer from poor contrast between background and text, and that the text size is too small. This causes stress for the travellers since they cannot assimilate the information properly.
- Interaction with interfaces should be available both through buttons and voice command. People who suffer from deaf-blindness are in majority not entirely blind or deaf (In Sweden, only 12% of people who suffer from deaf-blindness is estimated to have a total loss of vision and hearing (Rönnberg and Borg, 2001)), often with one of the impairments more severe than the other. Therefore, a combination of ways to interact with the interface was wished for in the survey.
- Interfaces should use for example screen readers (Partnersamverkan för en förbättrad kollektivtrafik, 2012), which according to the surveys also is a tool that is used by participants with visual impairment. The interface should also

allow users to choose the size of the text themselves, by providing the possibility to magnify the text (Developer.gnome.org, 2014).

- Don't use labels that are spelled differently but sound the same, this because it can be confusing for users that are using screen readers (Developer.gnome.org, 2014).
- Create large clickable areas and make it possible to control the interface with only one finger, and minimize text input in the interface - offer lists with choices instead (Developer.gnome.org, 2014).

To follow universal usability guidelines for designing usable, easy to learn interfaces will benefit everyone and especially people like the persona Henrietta, who is not very digital. If the interface is too complex for her to figure out, she will abandon it and stop trying. This specific guideline is particularly produced to accommodate people like the personas Harry and Adriana, who both suffer from impaired sight. In *Scenario 6*, Adriana is having use of an additional helping application that makes it possible for her to magnify the interface so that she can use it. In *Scenario 3*, Inside Harry's vehicle there is an interactive screen displaying his booking information that is also read out loud through audio.

7. Discussion

This chapter will discuss the project's result, the methods used, the process, the generalisation of the results, ethical reflections and lastly future work.

Interaction design is an emerging field, though not yet established worldwide or in some especially big corporations. Therefore, the lack of knowledge regarding the field of interaction design, could limit the possibility for access within connected businesses. This is an issue that the authors were worried about in the beginning of the project. Even though the majority of the connected parties had knowledge about the area, some did not, which resulted in the lack of common understanding regarding this project. This was a factor that affected the process. However, this did not prohibit the project to move forward and reach a conclusion.

7.1 Result

This chapter discusses the result of the study, by reflecting on descriptive versus prescriptive guidelines, the changes of main stakeholder and how this affected the end result, whether a multimodal approach is the obvious choice, the exclusion of some possible users and the assumption that the technology in the mobility solutions is working. The contributing uniqueness this study brings lays in the combination of working from an inclusive design approach, looking at public transportation and taxi services with a special focus on autonomous vehicles. The different parts of the package solution complement each other and are according to the authors a good tool to use to know how these types of mobility solutions can be designed with these user groups in mind.

Some parts of this project withhold aspects that might not necessarily be directly connected to the fields of interaction design. One of these aspects is shown in guideline 2. Provide Accommodating Environments that suggests to "*make sure that the interior of the vehicle, platform and waiting areas are accommodating to the different needs of the users"* [*see Chapter 6.3*]. The guideline focuses on the environments both inside the vehicles and outside at platforms and waiting areas. It also provides examples such as entries and exits to be designed properly for wheelchairs, as well as the importance of functional elevators at all stations. These environmental aspects are not necessarily connected to the fields of interaction design but it is however connected to answering the research question. Additionally, as this aspect also was shown to be of most importance and was a common issue amongst the participants of the study, to exclude this would to be suppressing the findings and results gathered in the study.

Descriptive vs. prescriptive guidelines (should or must)

Guidelines should be based on research, experience, and good examples. A prerequisite for this is many years of experience within the subject, something neither of the authors have. Even though an effort was made to gather as much experiences as possible during the project, the authors cannot argue with the same

authority. The result of this is that the guidelines are more suggestive. This can also be reflected in the way the guidelines are phrased. As presented in the theoretical chapter in this thesis [*see Chapter 4.4.7*], guidelines can be formulated in two different ways, prescriptive or descriptive. Prescriptive guidelines are strict and regulatory and descriptive guidelines provide input into the design process and tend to be more flexible. The resulted Guidelines within this project [*see Chapter 6.3*], are phrased based on a descriptive way, as is emphasizes the result as suggestions and not as rules. Although the decision was made to formulate descriptive guidelines, a discussion arose whether it would be possible to formulate some guidelines as prescriptive and some as descriptive, to highlight the compiled requirements from analysing the data [*see Chapter 5.4.1*]. Some requirements, especially those gathered from the additional online resources were formulated in way as "one needs to" instead of "one should". The conclusion of the discussion however was, that in additional to previous acknowledgement of lacking experiences, when using both prescriptive and descriptive guidelines, there is a risk that when using the guidelines, one might only use the prescriptive guidelines and ignore the descriptive ones.

Stakeholder changes: How this affects our end product

In the introduction of this thesis, stakeholder companies are introduced. These companies have in different phases and aspects influenced the result of this project. This has affected the results of the personas and scenarios in terms of structure and degree of detail. Personas and scenarios are used as helpful tools when designing in projects. However, within this thesis there were no specific projects in focus for which they were intended to be used. Therefore, the personas and scenarios was not as extensively iterated or detailed to fit a specific project. Furthermore, both the scenarios and personas worked very well as an aiding tool within this project to be able to create clear examples, which further on made it possible to answer the research question. The personas and scenarios, could however be adjusted and further detailed and in that way adapting them to a specific project. Additional factors that may change the structure of the result are the various processes used for different companies and within their projects. Cisco's innovation Center Open Berlin for example [*see Chapter 1.4*], is completely digitalised and does not use any type of paper and therefore, based on their work process, the end product should also be digital. This however contradicts the preferred work process of others such as the authors, as well as the Technical University in Berlin (introduced in *Chapter 5.2.1*), where it is preferred to use physical cards.

Potential cons with multimodality?

The resulting guidelines suggests that when designing a smart digital mobility solution in a smart city project, one should present multimodal information, as well as provide multimodal interaction, which is supported by the literature. The authors tried to find potential cons with using multimodal interaction by using search words and phrases such as *"why not to use multimodality"*, *"cons with multimodality"*, *"disadvantages with multimodality*" *"when not to use multimodal information"*, but there seems to be a lack of research regarding this. Kahn (2006) writes that the

disadvantages of multimodality includes that there are no universal standards for having all biometrics technologies seamlessly work together, that it can drive up the price of the solution and that if a stronger biometric is used in conjunction with a weaker biometric, the result is not necessarily a stronger combined system. This source is however over a decade old, but it was also the only source the authors could find. Therefore, the choice was made to include this argument in the background of this thesis [see *Chapter 2.6]*. These arguments are recognised as valid points; however, the authors still deem that multimodality is the most beneficial solution for this target group. This as within the context of public transportation and taxi services, where a lot of people that requires access to the same information at the same time, something that also was shown in the result of the interviews and survey. This could also be used as argument whether to give the possibility to use multimodality simultaneously or giving the choice of one at a time. The point of view within this thesis is to use multiple modals at the same time.

The exclusion of some possible users

One part of the goal of this project is to discover the users' needs regarding public transportation and taxi services. Even though personas are used as a tool to mediate this, there are some groups that also uses public transportation, that are not included in the personas or even a part of this project. People under 24 years of age, as well as people over 74 years of age are excluded. This reason for this is simply because of the lack of a wider range of ages of the participants in this project. This might affect the result of the product when designing for a wide range of users. One could argue that these types of user groups would then run the risk of being forgotten or simply excluded in a design process. However, as these users was not part of the study and no information about them was gathered, the creation of such a persona would have been entirely fabricated without any foundation in research.

How representative are the personas

While acknowledging that the personas cannot be trusted to a 100% since not enough data overall was collected, some of the personas could however be seen as more reliable since more information about them was assembled. Some of the personas are based on a very small amount of data or based on a few numbers of participants. For example, the persona Charles, who suffers from Aphasia, are only based on one participant and literature research. However, this persona has still been included in the end result, for the reason that these people should not be forgotten or excluded in the solutions. Based on the answers from the interviews, the participants with visual impairments said that there was usually no problem traveling alone if they were familiar with the start and end destination, while in the observations, people with white canes were never seen traveling alone. This could be a coincidence, meaning that those people were maybe traveling from or to an unfamiliar place, but it is also important to be open to the fact that people with visual impairments might have trouble traveling alone even though they are familiar with the area, and the particular people that was interviewed does not represent the general opinion.

The assumption that technology works

Something that was frequently brought up in the surveys and interviews from different users was the fact that existing solutions today does not work properly. Experiences were shared where they have been on a vehicle or platform without working displays or outcalls. This is something that the authors decided to exclude from the further development of the design, since the purpose of the guidelines are for them to be considered when designing smart city mobility solutions. Therefore, considering fixing broken already existing technology was not part of the project and all the guidelines are developed with the assumption that the technology used in fact works. Without a working interface, there is no interface to use.

7.2 Methods

The methods used during this master thesis have been over all sufficient and resulted in the possibility to answer the research question, however some aspects should still be discussed.

The motivation for choosing to work with personas is that it is widely used by interaction designers for user modelling. Since one hope for this project is that the package solution can be of help for other interaction designers in smart city projects, the decision was made to use personas as part of it. This is something many interaction designers, including the authors, are familiar with.

The motivation for using scenarios as part of the package solution is that it works well for placing the personas into action and try to break down the tasks they carry out, to provide ways to support them. Other methods that could have been used are for example storyboards (van der Lelie, 2005) or user journey maps (Howard, 2014). However, the authors felt like storyboards could not provide as much details as they wished for, and there was a limitation in experience regarding working with user journey mapping. Scenarios however, was a method the authors had more experience in working with, which could also provide enough details and it is a great way to add a third dimension to the personas.

During the process, there was a discussion whether it was more important to try and have equal interviews or if it was more worth it to have them adjusted based on the user's needs. The decision was made to adjust the different methods to fit the specific user's needs and wishes. Although the differences were shown to be both functional and complaisant for the interviewees, the decision can further be discussed and questioned, as the differences in how the interviews were executed, also came to be reflected in the process of creating the personas. When creating the personas, it was easier to start the first iteration based on the user group where the interviews had been conducted face-to-face. This is something that can have affected the outcome of the personas. It is therefore worth mentioning and to question whether the outcome would have been different and the different types of interviews more consistent if all the participants had put on video during the

interviews that were carried out online. Even though the option of using video was presented to the participants of the interviews, which would have been preferred since body language and gestures can be of most importance, many preferred to have the question sent to them through text only. The interviews that were conducted in form of written chats online (messenger) worked over all well as it gave the possibility to in a quick and easy way ask additional question, compared to the interviews conducted through only text. This method was the most time-consuming interview technique, since it was long time periods in between the questions waiting, while the interviewee wrote the answer to the question. However, it did result in more profound answers than the mail based text interviews.

During the process of gathering data, it was not without difficulty to find participants, especially in regard to the number of participants of the survey. The intention of the survey was to gather both quantitative and qualitative data and for it to work as a gateway to get connected to possible participants for the interviews. However, the amount of answers gathered from the survey was limited. It might be so, that one reason to why there was so few replies on the survey, could have been based on that the survey did not reach the potential users, and that they therefore did not know about the survey. Since the authors sent the survey to organisations and asked them to distribute the survey to members, it is impossible to know how many people that were actually reached.

Personas and scenarios are often used as an aiding design tool to evaluate a specific product, system or solution. Within this project, the end result or product is the personas, scenarios and guidelines themselves. It was therefore desired to apply an already existing method to evaluate these. However, these kinds of evaluation methods or research regarding evaluating them were shown to be lacking and therefore no specific evaluation method was used to evaluate the final version of personas, scenarios or guidelines. The evaluation of these happened when working with them simultaneously, placing one in the other to see how they worked together and what effect changes in one had in the other.

7.3 Process

This section discusses the process of the project, reflecting on what worked well and what could have worked better. The planning, the research phase and the prototyping phase are discussed in more detail.

The planning of this project was altered during the process. The initial plan presented in *Chapter 5.1 Initial planning* was changed and became more detailed after conducting the literature study, and the new plan (presented in *Chapter 5.2.3*) had the goal of finishing the result of the study in the middle of April. This plan was too optimistic and was not followed in the end. This had much to do with the authors not planning for unexpected obstructions, such as not getting replies from stakeholders and long wait in the data gathering phase. What was noticed after sending out the survey was that half of the answers were received very fast directly

after sending it out, followed by almost two weeks without replies, and then suddenly the rest of the answers arrived. This was also something that was not planned for and something that need to be taken into consideration when making the time plan for a project. One cannot assume that answers will come in a steady pace and have a natural end to them. The time plan also did not have enough time to develop the personas, scenarios and guidelines that demanded plenty of iterations each and was worked on simultaneously and affected each other, and therefore took a lot more time than expected.

The literature study was extensive since it needed to cover so many different areas and subjects, everything from what defines a smart city in general, autonomous vehicles, different disabilities to what we are talking about when we discuss Internet of Things. The literature study could have been more extensive in ways of looking at more sources for the same subjects, and also try to find more recent sources regarding some areas. Since technology is rapidly developing and this particular area of smart cities and autonomous vehicles is a very hot topic, a lot can happen in a couple of years. Because of this, a source claiming something that was written six years ago may not at all be accurate or up-to-date now. However, the authors feel like the background and theory of the report is covering the relevant topics and areas in a good way and is presented so that the reader can get good knowledge of the subject dealt with in this paper.

Regarding the data gathering from interviews, surveys and observations, there was a discussion to think about when to actually stop and move forward. The decision beforehand was to stop gathering data from participants when the information felt saturated, meaning that the same answers keep coming back and there might be a risk of not getting more new information. However, this did not turn out to be the case. Instead, the data gathering phase had to stop and move on to analysis since it was very hard to recruit more participants for the study. The authors would have wished for more participants, but because of time constraints it was impossible to continue trying to find more people to interview or trying to conduct more observations. There is a strong possibility that the results could have been different if there were more participants to gather information from, since the authors feel like much more information regarding this topic can be retrieved from users.

One can think about the reasons of the lack of answers to the survey. There is always the risk when contacting organisations and asking them to distribute the survey, that it will be forgotten, or that it does not reach as many people as hoped for. The authors have no insight in how many people got the information about the survey, in relation to how many people actually answered it. It would be beneficial to have more control and knowledge about the distribution of surveys in the future, to know roughly how many people know about it, to know if it is worth to put extra time and effort into contacting even more people about the survey. The user groups with Aphasia did not reply at all, and the authors got information beforehand that this was a strong possible outcome, since many people suffering from this disability can have trouble responding to surveys. In hindsight, more effort should have been put

into trying to find more participants from this user group for the interviews to balance it out.

When moving on to the prototyping phase, designing the personas, scenarios and guidelines followed a good iteration cycle as they were worked on at the same time and the changes and decisions affected each other. It was natural to start working with the personas and scenarios a little bit before starting to formulate the guidelines because it would be easier to communicate around the guidelines having personas and scenarios to refer to. It was a productive way to have a long lasting lo-fi prototyping phase since when one new idea surfaced, for example to try and put all the personas in the same scenario, then seeing how this did not contribute to the guidelines after testing only a couple of personas out, the idea could be discarded. It was a more time-consuming phase than expected, but worked very well to in the end feel more secure about the results knowing that they were thoroughly iterated and tested.

7.4 Generalisation

Regarding generalisation and how established some of the results are, it depends on the different user groups. For example, regarding the cognitive disabilities, there was no answer to the survey and only one person interviewed. Therefore, the results regarding this are based on literature research and additional online research but only one participant in the study. Therefore, the authors are well aware of the lack of validity in this particular persona and this user group's needs and wants, and are aware that there are much more information to gather from this user group. However, the choice to still include this persona was made since it is better to have one weaker persona then forgetting about this user group all together. This way, this user group are at least remembered and included in the design process in the projects. In general, the authors feel like there is more information to gather from all user groups and would have wished for more data gathered through the surveys and interviews, and also that there would have been time to observe more patterns and habits that did not transpire in the interviews. With more gathered information from the users, the result would have been stronger.

This project has been studying the needs and wishes for people with diverse disabilities regarding public transportation and taxi services and especially in relation to autonomous vehicles. The created personas could still be usable as a foundation in other types of design projects where the project group want to consider people with diverse disabilities. However, they contain specific traveling goals and accessibility considerations that are connected to the topic of this project. The scenarios are also very close connected to the topic since they all contain autonomous vehicle in public transportation settings. In that sense, the adaptability of these for other domains is limited.

The design guidelines that have been developed for this project are more general and can be adapted for other types of solutions as well. The guidelines are

formulated in a more general sense and are recommendations of what to think about when designing mobility solutions with this target group in mind. For example, the first guideline that recommends that solutions should strive towards helping people become more independent, the sixth and seventh guidelines that advocates multimodal information and interaction is also of more general use that can be adapted to other solutions. The last guideline about usable screen interfaces can also work on most screen interfaces, no matter the type of solution.

7.5 Ethical reflections

The ethical considerations mentioned in *Chapter 1.4* have been considered throughout the study. However, something that was noticed when working with people from two countries with similar but still different cultures is that depending on where the person is from, the denominations and terms are use differently. For example, in Germany, the people tend to use the term "handicapped" to describe a person suffering from a disability. In Sweden, that term can be seen as offensive and people would rather say "a person with a disability" or "disabled". Therefore, different terminology was used both by stakeholders and the participants (depending on where that person was from) throughout the project. The authors however, were consistent in the use of the terminology established in the beginning of the project.

The terminology is changing and evolving all the time and new terms to describe people with disabilities originates. It is important to listen to the people with preferential right of interpretation, the people actually affected by the different disabilities. In Sweden, people do not use the term handicapped as frequently as people in Germany, but Swedish people still use dated Swedish words to describe a person with a disability. It is common in Sweden to use a term that describe that the person has reduced function. Following discussions online, it is now however more preferred to talk about a variation of functions, or a person with a function variant. The authors have also made a conscious choice to in the report always write "a person with an impairment" or "people with disabilities" instead of objectifying by writing "impaired people" or "disabled person" etc. The most important thing to consider, according to the authors, is that people should not refer to someone by their disability if it is not absolutely relevant in that specific context. For example, someone should be referred to by their name if this is known, otherwise by the colour of their shirt or their haircut rather than being referred to as "the blind person" or "the person in the wheelchair."

Important to think of in these kinds of studies in regard to ethical considerations, is the attitudes of the participants. A quite sensitive social subject, such as disabilities and by default the categorisation and objectification of being disabled, might have been an interfering factor regarding the answer rate for the survey that was sent out in this project. This as people might not want to categorise themselves as someone with a disability, as it to others might be seen as someone that can't be independent and needs additional help or them simply not wanting to be objectified by

superficial differences. Therefore, one might even consider that to some, even the title/research question could be considered as offensive and could in itself be a reason to the low answer rate.

Within the area of autonomous vehicles, there have been many discussions regarding responsibility, or rather the lacking definition of who is to be responsible in situations, when a vehicle has no driver. According to Swedish law, the driver of a vehicle is responsible for passengers under the age of 15. An example of these kinds of responsibilities is to make sure that the passengers under the age of 15 are wearing their seatbelts, and this also includes securing the wheelchair properly according to the rules. The question to be asked is who is responsible for this when driverless cars come into the picture? This is a subject that must be discussed and must be resolved before autonomous vehicles can truly be included in the everyday traffic, as well as public transportation.

7.6 Future work

The next step for this project would be to further evaluate the personas, scenarios and guidelines. This could be done by implementing the personas and guidelines and furthermore distribute them to design teams working with smart city projects in regard to mobility solutions. Initially however, additional interviews of some of the user groups should be conducted, as complementary work to the personas. This example in regard to people with cognitive disabilities, as the persona created based on the small amount of information gathered during this project cannot be seen as representative for this specific user group. It would also be beneficial to further evaluate the guidelines in the future and update them to match the current solutions at that time. One example of this is the last guideline *8. Provide usable screen interfaces for people with disabilities*. The guideline is focusing on screen interfaces, however there are currently discussions whether screen interfaces even will be used as a common way of interacting with technology, in the future. Therefore, this guideline would then have to be updated and adapted to the new solutions.

Additional research could be beneficial for these kinds of projects, by further looking into the subject of how autonomous cars should behave. If an autonomous car's behaviour is pre-programmed to act in a specific way in a specific situation - this would be optimal in a traffic situation including only autonomous cars, as the vehicles would analyse situations the same way. However, in the change and introduction of autonomous vehicles in traffic, there are other factors that need to be considered. This, in terms of pedestrians and travellers perceived assurance of safety. Factors that should be further researched is how different cultural aspects of behaviour of pedestrians or other cars with drivers (if both are in the traffic) will change the way the autonomous vehicle will act or react to another's behaviour. If in the future both cars with drivers and autonomous cars will exist in traffic, also some potential cultural differences might exist in regard to the way one drives. This example regarding the different situations a driver would honk the horn, where some cultures use it as a warning, some as an indication of switching traffic lane and

some simply as a way of saying hello. Therefore, when designing autonomous vehicles, especially in cases of international markets, one should analyse these cultural differences of behaviours and attitudes to minimize security risks.

In the interview with people with visual impairment, they expressed some concern and disappointment in that they would probably never be able to own an autonomous car by themselves because of their impairment. This because of the situation where technical problems occurs with the car, they would not be able to repair it themselves. It should in the future be discussed that the fact that people with disabilities should be able to own an autonomous car, since IoT solutions should be self-diagnosing and self-healing as described in previous chapter [*see Chapter 3.5.2*].

Another interesting aspect of the subject of users with diverse disabilities and smart devices is the extension of smart devices capacity to become self-analysing. What if devices could become so much smarter that they would be able to in a seamless way be connected to its surrounding and thereby letting the users change devices without having to learn the new interaction for each device? For example, in regard to the scenario where a user is approaching a taxi-shuttle, the user's preferences for how to interact with the technology would then be directly registered by the vehicle. Thereby there would be no need for the user to choose what multimodal way of interacting, but would simply be presented the specific predetermined way based on the user. This would be most beneficial for people with diverse disabilities. If a user with visual impairment would approach the vehicle, its system would recognize that the interaction and feedback could be presented in form of voice command and audio outputs.

8. Conclusion

This project aims to answer the research question:

"Which factors should be considered in a Smart City project, when designing a smart digital mobility solution, for it to be more adequate for people with disabilities?"

To be able to answers this research question, personas, scenarios and design guidelines have been created.

The study investigated user's needs, attitude, experiences and wishes in relation to public transportation and taxi services through interviews, observations and survey. This data together with information gathered from a literature study and additional online research are the foundation for the presented factors. To be able to develop these guidelines, personas and scenarios were created. The personas can be used to build empathy for the users, understanding their goals, to define whom the software is being created for, to easier communicate about the users amongst the design team and help with prioritizing and determine what to design. The created personas were:

- **Sebastian Harrold**, Mobility impairment
- **Henrietta Adams**, Mobility impairment
- **Charles Clarkson**, Cognitive disability (Aphasia)
- **Adriana Matthew**, Visual impairment
- **Harry Smith**, Deaf-blindness
- **Chrissy Andersen**, Hearing impairment

These personas are meant to be used as a complement to other personas without disabilities. The scenarios were created to place the personas in context and different situations, to get a clearer picture of their reactions, their needs and where problems can occur. The created scenarios were:

- **Scenario 1: Traveling home from work with tram**
- **Scenario 2: Traveling to Bingo with train and tram**
- **Scenario 3: Traveling to shopping mall with taxi, shuttle and subway**
- **Scenario 4: Traveling to lunch appointment with taxi**
- **Scenario 5: Traveling to basketball game with shuttle**
- **Scenario 6: Traveling to school with taxi-shuttle**
- **Scenario 7: Two people traveling to work with bus**
- **Scenario 8: Traveling home after a thunderstorm**

The factors to be considered when designing Smart City mobility solutions are partly based on the created personas and scenarios. They are therefore also used to exemplify why and in what contexts the factors could be considered [*see Chapter 6.3*]. The factors to consider when designing Smart City mobility solutions to be more

adequate for people with diverse disabilities are presented in the form of these design guidelines:

1. PROVIDE INDEPENDENCE
All solutions should strive towards helping people become more independent and socially included.

2. PROVIDE ACCOMMODATING ENVIRONMENTS
Make sure that the interior of the vehicle, platform and waiting areas are accommodating to the different needs of the users.

3. PROVIDE INFORMATION OF CHANGES AND UNFORESEEN EVENTS
Provide alternatives for traveling routes and information about surrounding events such as traffic jams, delays and accidents.

4. PROVIDE REAL TIME AWARENESS
The solution should have real time awareness of what is going on in the real world in order to make travellers feel safe.

5. CONNECT SMART OBJECTS
Connecting smart objects/things and sensors to vehicles and traffic situations (IoT) will ease the travels of the users, but consider already existing solutions.

6. PRESENT MULTIMODAL INFORMATION
All information, inside and outside the vehicle, should be presented in a multimodal way.

7. PROVIDE MULTIMODAL INTERACTION
It should be possible to interact with the vehicle's interface(s) and surrounding or connected interfaces in multiple different ways.

8. PROVIDE USABLE SCREEN INTERFACES FOR PEOPLE WITH DISABILITIES
Design screen interfaces to be accommodating for people with diverse disabilities.

The next step for further work with this package solution can be to implement the personas and guidelines in different design projects, and distribute them to design teams working with smart city projects with a focus on mobility solutions. However, additional data gathering from some of the user groups should be conducted, to further develop the personas and maybe add to the guidelines and scenarios. The guidelines could also need to be updated in the future based on the technological progress and development, to better match future solutions.

References

Adlin, T., Pruitt, J. (2006). *Why is it so Hard to Make Products that People Love?*. http://www.aiga.org/why-is-it-so-hard-to-make-products-that-people-love/

Alben, L. (1996). *Defining the criteria for effective interaction design*. Quality of Experience

Allwinkle, S. Cruickhank, P. (2011) *Creating Smarter Cities: An Overview*. Journal of Urban Technology. Published online: 10 Aug 2011.

Andersson, M.L. (2007). How to study the mind: *An introduction to embodied cognition. I: F.Santoianni and C. Sabatano* (Red:er.). Brain Development in Learning Environments: Embodied and Perceptual Advancements. Cambridge: Cambridge Scholars Press (s. 65-82)

Austermann, A. (2010). *Learning to Understand Multimodal Commands and Feedback for Human-Robot Interaction*. A dissertation submitted to the Department of Informatics, School of Multidisciplinary Sciences, The Graduate University for Advanced Studies (SOKENDAI).

Asha.org. (n.d.). *Different Styles of Hearing Aids*. [online] Available at: http://www.asha.org/public/hearing/Different-Styles-of-Hearing-Aids/ [Accessed 21 May 2017].

Benyon, D. (2010) Designing Interactive Systems. *A comprehensive guide to HCI and interaction design*. Pearson Inc.

Biader Ceipidor, U., Medaglia, C., Serbanati, A., Azzalin, G., Barboni, M., Rizzo, F. and Sironi, M. (2009). SeSaMoNet: *an RFID-based economically viable navigation system for the visually impaired*. International Journal of RF Technologies: Research and Applications, 1(3), pp.214-224.

Blomberg J., Giacomi J., Mosher A., Swenton-Wall P.Ethnographic (1993) *Field Methods and Their Relation to Design. Participatory design Principles and practices*. Lawrence Erlbaum Associates, 1993. 123-155.

Bringolf, J. (2008) *Universal design is it accessible?* Vol 1(2), Multi

Buxton, W. (2007) Sketching User Experiences: *Getting the Design Right and the Right Design*. Amsterdam: Elsevier/Morgan Kaufmann. Print.

Caragliu, A., Del Bo, C., Nijkamp, P. (2009) *"Smart Cities in Europe."* 3rd Central European Conference in Regional Science. n. pag. Web.

Carroll, J, M. (1999) *Five Reasons for Scenario-Based design*. Proceedings of the 32nd Hawaii International Conference on System Sciences

Cdc.gov. (n.d.). Blindness and Vision Impairment. *Gateway to Health Communication*. CDC. [online] Available at: https://www.cdc.gov/healthcommunication/ToolsTemplates/EntertainmentEd/Tips/Blindness.html [Accessed 21 May 2017].

Center for Universal Design NCSU. About the Center - Ronald L. Mace." *Center for Universal Design NCSU* N.p., n.d. Web. 06 Feb. 2017. https://www.ncsu.edu/ncsu/design/cud/about_us/usronmace.htm

Centre for Excellence in Universal Design. (2017) *"Designing a More Inclusive World."* N.p., n.d. Web. 10 Feb. 2017.

Chaouchi, H. (2013). *The Internet of things: Connecting objects.* 1st ed. Somerset: Wiley.

Chourabi, H., Nam, T., Walker, S, J., Gil-Garcia, R., Mellouli, S., Nahon, K., Pardo, T, A., Scholl, H, J. (2012) "Understanding Smart Cities: *An Integrative Framework*." 2012 45th Hawaii International Conference on System Sciences. n. pag. Web.

Cisco. (2017). *Cisco openBerlin Innovation Center.* [online] Available at: http://www.cisco.com/c/m/de_de/innovationcenter/berlin.html [Accessed 9 Feb. 2017].

Cooper, A., Reimann, R., Cronin, D., Noessel, C., Csizmadi, J., LeMoine, D. (2014) About Face: *The Essentials of Interaction Design*. 4th ed. INpolis, IN: Wiley, Print.

Coyette, A., Kieffer, S., & Vanderdonckt, J. (2007). *Multi-fidelity prototyping of user interfaces*. In IFIP Conference on Human-Computer Interaction (pp. 150-164). Springer Berlin Heidelberg.

Crabtree A., Rouncefield M., Tolmie P. (2012) *Doing Design Ethnography*. Springer-Verlag London

Dalby, D., Hirdes, J., Stolee, P., Strong, J., Poss, J., Tjam, E., Bowman, L. and Ashworth, M. (2009). Characteristics of Individuals with Congenital and Acquired Deaf-Blindness. Journal of Visual Impairment & Blindness.

Deakin, M., Al Waer, H. (2011) From intelligent to smart cities, Intelligent Buildings International, 3:3, 133-139

Developer.gnome.org. (2014). *User Interface Guidelines for Supporting Accessibility*. [online] Available at: https://developer.gnome.org/accessibility-devel-guide/stable/gad-ui-guidelines.html.en [Accessed 9 May 2017].

Djajadiningrat, J. P., Gaver, W. W. and Fres, J. W. (2000): Interaction Relabelling and Extreme Characters: *Methods for Exploring Aesthetic Interactions*. In: Proceedings of DIS00: Designing Interactive Systems: *Processes, Practices, Methods, & Techniques* 2000. pp. 66-71

Domingo, M. C. (2011) "*An Overview of the Internet of Things for People with Disabilities*." Journal of Network and Computer Applications 35.2: 584-96. Web.

Elmansy, R,. (2016); "Design Thinking Tools: *Reverse Brainstorming*." Designorate. Designorate, 07 Apr. 2016. Web. 15 Feb. 2017.

Embrey, D. (2000) "TASK ANALYSIS TECHNIQUES." *Task Analysis Techniques*: n. pag. Web. 9 Feb. 2017.

Emiliani, P. L., Stephanidis, C. (2005) "Universal Access to Ambient Intelligence Environments: *Opportunities and Challenges for People with Disabilities*." IBM SYSTEMS JOURNAL, VOL 44, NO 3, Web. 2017.

Follette Story, M. (1998) Maximizing Usability: *The Principles of Universal Design, Assistive Technology*, 10:1, 4-12, DOI: 10.1080/10400435.1998.10131955

Fonteyn, M-E,. Kuipers, B., Grobe, S-J (1993) *A description of think aloud method and protocol analysis*. Qualitative Health Research, Vol 3. No 4, November 1993. 430-441.

Franke, U., Gavrila, D., Görzig, S., Lindner, F., Paetzold, F., Wöhler, C. (1999) *Autonomous Driving approaches Downtown*. IEEE Intelligent Systems, vol .13, nr. 6

Frayling, C. (1993/4) "Research in Art and Design." Royal College of Art Research Papers 1.1. n. pag. Web.

Friedenberg, J. D., Silverman, G. W. (2006) Cognitive Science: *An Introduction to the Study of Mind*. Sage Publications, Inc.

Gable, G. G (1994) *Integrating case study and survey research methods: an example in information systems*. European Journal of Information Systems 3(2):pp. 112-126.

Gajjar B. N., (2013) *"Ethical Consideration in Research"*. International Journal for Research in Education. Vol. 2, Issue:7, July,. Web.

Gaver, W. (2012) *What Should We Expect From Research Through Design?*. New York (NY): A.C.M., Web.

Gilakjani, A., Ismail, H. and Ahmadi, S. (2011). *The Effect of Multimodal Learning Models on Language Teaching and Learning*. Theory and Practice in Language Studies, 1(10).

Degener, T. (2004) *"Definition of Disability."* E.U. NETWORK OF EXPERTS ON DISABILITY DISCRIMINATION. European Community Action Programme., Web.

Graziano, A. and Raulin, M. (2013). Research methods: *A Process of Inquiry*. 8th ed. Boston, Mass. [u.a.]: Pearson.

Grudin J., Pruitt, J., (2002): *Personas, Participatory Design and Product Development*: An Infrastructure for Engagement. In Design, 2002

G3ict, and World ENABLED. (2016) *"Infusing Accessibility into Smart Cities Programs to Improve Human Rights, Civic Engagement, and Business Outcomes.*" Smart Cities & Digital Inclusion. n. pag. Web.

Hall, R. E. (2000). *The vision of a smart city*. In Proceedings of the 2nd International Life Extension Technology Workshop, Paris, France, September 28, Available from http://www.osti.gov/bridge/servlets/purl/773961- oyxp82/webviewable/773961.pdf.

Hartmann, B. (2009) *Gaining design insight through interaction prototyping tools*. Department of Computer Science, Stanford University

Howard, T. (2014). Journey mapping: *A Brief Overview*. Communication Design Quarterly Review, 2(3), pp.10-13.

Inclusivedesigntoolkit.com. (n.d.). *What is inclusive design?*. [online] Available at: http://www.inclusivedesigntoolkit.com/whatis/whatis.html [Accessed 5 Jun. 2017].

Inova Solutions (n.d.). Dashboard Design for Real-Time Situation Awareness. Inova Solutions, pp.2-3.

The Interaction Design Foundation., (2017), *"Design Scenarios - Communicating the Small Steps in the User Experience."* ,. Web. 10 Feb. 2017.

Jonsson, F., Lundmark S. (2014) *An interaction approach for norm-critical design analysis of interface design*. (p 65-75)

Kahn, I. (2006). *Multimodal Biometrics– Is Two Better Than One?*. Frost & Sullivan Market Insight. [online] Available at: http://www.frost.com/prod/servlet/market-insight-print.pag?docid=80082644 [Accessed 31 May 2017].

Keates, S., Clarkson, J. (2003) *Countering design exclusion*. In J Clarkson et al (eds.) Inclusive design. Springer-Verlag London, 2003.p. 438-453.

Kelly, T. (2000). *The perfect Brainstorm.* In Kelly, T. & Littman, J. The Art of Innovation, chapter 4, Doubleday.

Kleinberger, T., Becker, M., Ras, E., Holzinger, A. and Müller, P. (2007). Ambient Intelligence in Assisted Living: *Enable Elderly People to Handle Future Interfaces*. Universal Access in HCI, Part II, HCII 2007, LNCS 4555, pp. 103–112, 2007.

Kvale, S. (2007) *Doing Interviews*. London: SAGE Publications. Print.

Langemar, P. (2008) *Kvalitativ forskningsmetod I psykologi. Att låta en värld öppna sig*. Liber AB

Lawton, H., Abou-Zahra, S., Brewer, J. (2014) "The Role of Accessibility in a Universal Web." *Proceedings of the 11th Web for All Conference on - W4A '14*: n. pag. Web.

Levinson, J., Askeland, J., Becker, J., Dolson, J., Held, D., Kammel, S., Kolter, J. Z., Langer, D., Pink, O., Pratt, V., Sokolsky, M., Stanek, G., Stavens, D., Teichman, A., Werling, M., Thrun, S. (2011) *Towards Fully Autonomous Driving: Systems and Algorithms*. 2011 IEEE Intelligent Vehicles Symposium (IV) Baden-Baden, Germany, June 5-9

Lin, G. (2009) *"Higher Education Research Methodology-Literature Method."* CCSE International Education Studies 2.4. n. pag. Web. 9 Feb. 2017.

Localmotors.com. (2017) *Labs - Local Motors.* [online] Available at: https://localmotors.com/labs/ [Accessed 9 Feb. 2017].

Long, F (2009) 'Real or Imaginary; *The effectiveness of using personas in product design'*, Proceedings of the Irish Ergonomics Society Annual Conference, May 2009, pp1-10 Dublin.

Mackay, W. E. (1988) Video Prototyping: *a technique for developing hypermedia systems*. In CHI'88 Conference Companion Human Factors in Computing Systems (Vol. 5).

Martin, B., Hanington, B. (2012) *Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions*. Beverly, MA: Rockport, Print.

Mellis, D. A., (2009) Making Prototypes Work: *Reflections from a Course in Tangible User Interfaces*. Copenhagen Institute on Interaction Design

Moggridge, B. (2006) *Designing Interactions*. MIT Press.

Morton, N.E. (1991) *Genetic epidemiology of hearing impairment*. Annals of the New York Academy of Sciences, 630, 16-31.

"Multimodal". 2017. In https://en.oxforddictionaries.com/
Retrieved May 21, 2017, from https://en.oxforddictionaries.com/definition/us/multimodal

Myin, E. & O'Regan, K. (2009). *Situated Perception and Sensation in Vision and Other Modalities: A Sensimotor Approach*. I: Robbins, P. & Aydede, M. (Red:er). The Cambridge Handbook of Situated Cognition. Cambridge: Cambridge University Press. 520.

Nam, T., Pardo, T. A. (2011) "Smart City as Urban Innovation." *Proceedings of the 5th International Conference on Theory and Practice of Electronic Governance - ICEGOV '11*: n. pag. Web.

National Institute for Health and Care Excellence (2014). Developing NICE guidelines: *the manual*. National Institute for Health and Care Excellence, pp.4-6.

National Disability Authority (2009). *Ethical Guidance for Research with People with Disabilities.* Disability Research Series 13. October 2009.

Neads.ca. (n.d.). *NEADS.* [online] Available at:
http://www.neads.ca/en/about/projects/inclusion/guide/pwd_01.php [Accessed 31 May 2017].

Newell, A., Sablé, S., Latif, A., Tyler, S., Jones, C., Rabin, A., Buchanan, J. (2009) *Identity meets ability. In Graham Pullin. Design meets disability*. MIT press, 2009.

Nielsen, J. (1995). *10 Heuristics for User Interface Design*: Article by Jakob Nielsen. [online] Nngroup.com. Available at: https://www.nngroup.com/articles/ten-usability-heuristics/ [Accessed 9 May 2017].

Nielsen, L., (2013). *Personas*. I Mads, S., & Friis Dam, R., (Red.), *Encyclopedia of Human-Computer Interaction* (2nd edition). Aarhus, Denmark: Interaction Design Foundation

Norman, Donald A. (2004). *Ad–Hoc personas & Empathic Focus*. Retrieved 1 January 2004 from JND.org: http://www.jnd.org/dn.mss/personas_empath.html

Partnersamverkan för en förbättrad kollektivtrafik (2012). *Tillgänglig kollektivtrafik för personer med funktionsnedsättning*. Tillgänglighet. Svensk Kollektivtrafik.

Patton, M. Q. (2002) *Qualitative Research & Evaluation Methods*. 3rd Edition. Sage Publications, Inc.

Petrovskaya, A., Thrun, S. (2009) Model Based Vehicle Detection and Tracking for Autonomous Urban Driving: *Autonomous Robots* (2009) 26: 123-139

Pirkl, J, J. (1994) *Transgenerational Design: Products for an Aging Population*. 1st ed. New York: Van Nostrand Reinhold, 1994. Print.

Preece, J., Rogers, Y., Sharp, H. (2002) *Interaction Design: Beyond Human-computer Interaction*. 3th ed. New York, NY: J. Wiley & Sons, 2002.

Resnikoff, S., Pascolini, D., Etya'ale, D., Kocur, I., Pararajasegaram, R., Pokharel, G. and Mariotti, S. (2004). *Policy and Practice: Global data on visual impairment in the year 2002*. Programme for the Prevention of Blindness and Deafness, World Health Organization.

Rittel, H. W. J., Webber, M. M. (1973) *"Dilemmas in a General Theory of Planning."* Policy Sciences 4.2. 155-69. Web. 8 Feb. 2017.

Rohrbach, B. (1969); "Kreativ nach Regeln – *Methode 635, eine neue Technik zum Lösen von Problemen*". Creative by rules - *Method 635, a new technique for solving problems first published in the German sales magazine "Absatzwirtschaft"*, Volume 12, 1969. p73-75 and Volume 19, 1 October 1969.

Roth, W. -M., & Lee, Y. -J. (2007). "Vygotsky's neglected legacy": *Cultural-historical activity theory*. *Review of Educational Research, 77*(2), 186-232. http://dx.doi.org/10.3102/0034654306298273

Rubin, J. Chisnell, D. (2008) Handbook of Usability Testing, Second Edition: *How to Plan, Design, and Conduct Effective Tests*. Wiley Publishing, Inc.

Rönnberg, J. and Borg, E. (2001). A review and evaluation of research on the deaf-blind from perceptual, communicative, social and rehabilitative perspectives. Scandinavian Audiology, 30(2), pp.67-77.

Saariluoma, P, and Hannakaisa, I. (2009) *Future Interaction Design II*. London: Springer, Print.

Salber, D., & Coutaz, J. (1993). *Applying the wizard of oz technique to the study of multimodal systems*. In International Conference on Human-Computer Interaction (pp. 219-230). Springer Berlin Heidelberg.

Senate Department For Urban Development And The Environment. (2015) "Smart City Strategy Berlin." Smart City Strategy Berlin. n. pag. Web. 9 Feb. 2017.

SFS 1999:132 Prohibition of Discrimination in Working Life of People with Disability

SFS 2001:526 Government authorities under the government shall design and conduct their activities in consideration of the disability policy objectives

Shaughnessy, M. F., and Kennedy, C. K. (2008) "Q & A with Ed Tech Leaders Interview with Allan Collins." *Educational Technology (JournalSeek)* XLVIII.3: 49-53.*Educational Technology (JournalSeek)*. Web. 08 Feb. 2017.

Sheller, M. (2011). *Mobility*. Editorial Arrangement of Sociopedia.isa.

Sheller, M., Urry, J. (2006). The New Mobilities Paradigm. Environment and Planning A, 38(2), pp.207-226.

Schunn, C. D., Crowley, K., & Okada, T. (1998). The growth of multidisciplinarity in the Cognitive Science Society. *Cognitive Science,* 22(1), 107-130.

Smart City Research. (n.d.). Retrieved January 13, 2017, from http://www.smartcityresearch.com/

Special Collections Research Center. *James J. Pirkl Papers: An Inventory of His Papers at Syracuse University*. Syracuse University Libraries, n.d. Web. 06 Feb. 2017

Synskadades Riksförbund (2015a). *Åsikter om kollektivt resande*. Resande och Internet. Synskadades Riksförbund.

Synskadades Riksförbund (2015b). *Dålig digital delaktighet*. Resande och Internet. Synskadades Riksförbund.

National Disability Authority (2009) "*Ethical Guidance for Research with People with Disabilities*." The National Disability Authority. Web. 10 Feb. 2017.

Urmson, C., Anhalt, J., Bagnell, D., Baker, C., Bittner, R., Clark, M. N.., Dolan, J., Duggins, D., Galatali, T., Geyer, C., Gittleman, M., Harbaugh, S., Hebert, M., Howard, T. M., Kolski, S., Kelly, A., Likhachev, M., McNaughton, M., Miller, N., Peterson, K., Pilnick, B., Rajkumar, R., Rybski, P., Salesky, B., Seo, Y-W., Singh, S., Snider, J., Stentz, A., Whittaker, W., Wolkowicki, Z., Ziglar, J. Bae, H., Brown, T., Demitrish, D., Likouhi, B., Nickolaou, J., Sadekar, V., Zhang, W., Struble, J., Taylor, M., Darms, M., Ferguson, D. (2008) Autonomous Driving in Urban Environments: *Boss and the Urban Challenge*. Journal of Field Robotics 25(8), 425–466

U.S. Department of Transportation, (2016). Smart City Challenge: *Lessons for Building Cities of the Future*. U.S. Government of Transportation.

van der Lelie, C. (2005). *The value of storyboards in the product design process*. Personal and Ubiquitous Computing, 10(2-3), pp.159-162.

Warsi, A. (2011). *7 usability guidelines for websites on mobile devices*. [online] Webcredible.com. Available at: https://www.webcredible.com/blog/7-usability-guidelines-websites-mobile-devices/ [Accessed 9 May 2017].

Washburn, D., Sindhu, U., Balaouras, S., Dines, R. A., Hayes, N. M., & Nelson, L. E. (2010). Helping CIOs Understand "Smart City" Initiatives: *Defining the Smart City, Its Drivers, and the Role of the CIO*. Cambridge, MA: Forrester Research, Inc.

Washington.edu. (n.d.). *Mobility Impairments | DO-IT*. [online] Available at: http://www.washington.edu/doit/mobility-impairments [Accessed 21 May 2017].

Watson, I. (2001). *An Introduction to Design Guidelines*. PLANNING COMMISSIONERS JOURNAL, 41.

Wilson, M. (2002). S*ix views of embodied cognition*. Psychonomic Bulletin and Review, 9 (4), 625-636

Woodhead, H. E. (2010). *Anchor Management: A Roadmap for Innovative Problem-solving*. New York: IUniverse,. Print.

World Health Organization. (2011) "World Report on Disability." *World Health Organization*. Web. 10 Feb. 2017.

Appendix 1: Survey, English version

Investigation regarding transport solutions

The survey is sent to serve as the basis for a Master's dissertation at the Chalmers University of Technology, which deals with automated transport solutions for people with different types of disabilities. We appreciate your participation, and your answers will help us in this important work.

*Required

1. **I got this questionnaire from the following organisation:** *

2. **How old are you?** *
   Mark only one oval.
   - 15 - 25
   - 26 - 40
   - 41 - 65
   - 65 +

3. **Which of these means of transport do you use in everyday life?** *
   Tick all that apply.
   - Bus
   - Train
   - Tram
   - Subway
   - Taxi
   - Transportation service

4. **What possible advantages do you see in traveling with these means of transportation?** *

5. **What possible disadvantages do you see in traveling with these means of transportation?** *

6. **If you use public transportation, which kind of ticket system do you use?** *
   Tick all that apply.

   - [ ] Payment in the app
   - [ ] Payment on the vehicle
   - [ ] Season ticket
   - [ ] Other: _____

7. **How do you think the ticket system works for you? Please motivate your answer** *

8. **How important is the driver of the vehicle for you? and what role does the driver have for you? Please motivate your answer** *

9. **What are your views on that society is becoming more automated with new technologies?** *

10. **What / which way is most natural for you to interact with technology on?** *
    Tick all that apply.

    - [ ] Touch-buttons
    - [ ] Physical buttons
    - [ ] Talk function / voice command
    - [ ] Other: _____

11. **Is there any new technology that you rely on to help you in your everyday life?** *

12. **Are there any solutions you know of that could help you regarding means of transportation?** *

13. **With regard to your disability, what problems, if any, may you encounter while traveling with previously mentioned vehicles?**

14. **In this paragraph, you can write more opinions, problems or additions that have not been answered by the form's previous questions.**

15. **If you are willing to set up an interview and help us further with this project, please write your email address here and we will contact you. Otherwise, leave the field empty.**

Appendix 2: Interview questions, English version

1. Facts:

1.1 - How old are you?

1.2 - What is your occupation?

2. Transportation:

2.1 - Do you travel with public transportation (if so, which vehicles), or taxi services?

2.2 - Can you describe one scenario of how it is when you travel with public transport or taxi services? (From door to door)

2.3 - Can you tell us about any negative experience(s) you have had when traveling with public transportation or taxi services?

2.4 - Can you tell us about any positive experience(s) you have had when traveling with public transportation?

2.5 - How important is the driver of the vehicle for you? Why?

2.6 - Is there any situations where you have to to ask other travelers for help? Can you give any examples?

2.7 - What kind of features exists today in vehicles that you need to be able to travel with public transportation or other vehicles?

2.8 - Can you think of some feature or tool that you would like to have inside or outside a vehicle that is currently missing?

3. Technology:

3.1 - Is there any kind of technology that you rely on in your everyday life to assist you? In what way?

3.2 - What are your thoughts regarding that our society is getting more and more digitalized?

3.3 - Do you experience that the digitalization has either helped or restrained you in any way(s)?

3.4 - Today there are a lot of discussions about driverless vehicles, namely autonomous driving vehicles without a human driver. Have you heard about this? What are your thoughts about this? What positive and negative aspects is there with this concept?

Appendix 3: Requirements Result First iteration

Visual impairment

- They need to be able to catch connecting vehicles in public transportation as fast as anyone else
- They need the possibility to request audible information

These requirements have been gathered from Synskadades Riksförbund (2015a):

- Well thought of design of vehicles, stations, platforms, terminals which facilitates accessibility, usability and assure safety is needed
- Better automatic outcalls for lines, destinations, and stations is needed
- They need an easy to use ticket system with no price discrimination
- Ticket machines should "speak"
- Tickets should be available through phone and internet
- They need more clear and evident signs
- Every system for planning the trip, traffic information and also purchase of tickets needs to be fully usable for travelers with impaired sight.

These requirements have been gathered from Synskadades Riksförbund (2015b):

- They need better color contrast between text and background on screens and signs
- The screen resolutions needs to be improved
- They want less moving graphics and more text

These requirements have been gathered from Partnersamverkan för en förbättrad kollektivtrafik (2012):

- Websites need to follow rules for visual impairments, for example use speech synthesis
- Information need to be accessible in different ways that works for different visual impairments
- All information that is shown for people who can see, must also be available for people who suffer from visual impairment in other ways
- Buttons and levers bust be easy to use without seeing them, for example on doors and in elevators
- Clear colors that are easy to see need to show where stairs, thresholds and windows are located

Hearing impairment

- They need information about canceled or late vehicles visually just as fast as it is informed through audio
- If delays or other problems occur, they need visual information about alternative routes and where people can find them
- Provide travelers with audiovisual information
- They need multimodal feedback when validating the ticket
- If the user needs to contact customer service, they need to have the possibility to do so in text format
- Make sure not to use electrical functions that somehow disturb user's hearing aids
- There should be hearing loops in all vehicles and waiting areas
- When the stop button is pressed, they want both clear audio and visual feedback

- Provide blinking lights and some sort of movement/shaking indication in emergency situations
- They want blinking lights and/or some sort of movement/shaking indication when important information is presented to the travelers to catch their attention

These requirements have been gathered from Partnersamverkan för en förbättrad kollektivtrafik (2012):

- Solutions need to work well with technical hearing aids (no disturbance so that they have to turn them of)
- There must be ways to notice if an alarm goes of without hearing sound

Deaf-blindness

- Smart city solutions need to contribute to increased independence
- Solutions need to communicate its location in different ways to the user
- They need multimodal information on the actual vehicle about delays, change of route and other unforeseen events
- People with impaired hearing need to access audible information on their terms
- The screen for ticket/payment systems need to contain clear contrast between text and background and have the possibility the adjust the size of the text.
- Interaction with interfaces must be available both through buttons and voice command
- It should be easy for the user to identify where there is a free seat on the vehicle
- Avoid a gap between the vehicle and the platform since it can be hard for people with impaired sight to calculate the distance

Mobility impairment

- They need all necessary information about vehicles and platforms beforehand when the users are planning their trip
- The floor of the vehicle and the platform need to be on the same ground level
- They want a separate space for people in wheelchairs in the vehicle
- People in wheelchairs do not want to take detours or other inconvenient ways to get to vehicles
- If platform and the floor of the vehicle is not on the same ground level, there must be an easy and fast way to unfold a ramp for people in wheelchairs
- Design entries and exits to make them well functional and easy to use for people in wheelchairs

These requirements have been gathered from Partnersamverkan för en förbättrad kollektivtrafik (2012):

- They need enough space to rotate wheelchairs
- People in wheelchairs should not have to take detours
- They need handrails to hold on to
- There should not be any thresholds, stairs or narrow and heavy doors
- Handles, buttons and levers must be easy to reach and use
- Floor and ground should be even and hard
- Display of information should be adapted to short people and people in wheelchair

Cognitive disability

- They need to be able to communicate in own pace

- They need saved addresses in booking system to be able to book on their own

These requirements have been gathered from Partnersamverkan för en förbättrad kollektivtrafik (2012):

- Information should be short, simple and easy to read
- Information about how to use devices need to be easy to understand
- It has to be easy to find all the different locations
- Signs should contain easy illustrations or pictures

Graphical User Interface Requirements

These requirements was gathered since the initial plan was to be part of designing the GUI of OLLI. *These requirements have been gathered from Developer.gnome.org (2014).*

- Don't use labels that are spelled differently but sounds the same for people who use screen readers
- There should be the possibility for the user to choose the size of the text themselves
- Don't show GUI elements that don't actually do anything
- Make interactive GUI elements easily identifiable
- Make sure information do not disappear or become hidden before the user are finished with it (for example on digital screens that changes with time)
- Don't hardcode timeouts or other time based features. Some users may read, type or react more slowly than others
- Make sure animations can be turned off. Information should be available in at least one other non-animated way
- Don't assume that users will hear audio information
- Provide an undo function for every action that changes the user's data or the application's functions
- Don't place frequently used functions deep in a menu structure
- Minimize the user's memory load
- Provide commands to restore default settings, such as font size
- Use colors that works for people with color blindness
- Provide high contrast between text and backgroud
- Provide the ability for the user to magnify the display

Appendix 4: Personas, result second iteration

Name: Sebastian Harrold
Age: 31
Occupation: Office worker
Status: Single
Location:
Disability: Movement impaired (in a wheelchair)
Archetype: The Friend

Personality categories: Sweet, Dedicated, Trustworthy

Motivations regarding transportation:

Price	
Comfort	------
Speed	----------
Independence	----------
Environmental	----

Goles:

- His basketball team will win all games of the season
- To sign up for online dating and dare to go out on more dates
- To own a sports car

Frustrations:

- When people who does not have to use the elevator at stops still use it which sometime causes him to have to wait and thereby miss his train
- When there is a lot of people on the vehicle and he gets all their bags in his face
- When the entrance to the vehicle and the platform are not at the same ground level
- When he comes to a stop and the elevator is broken so he have to go to another stop

Bio: Sebastian is a guy everyone likes. He is kind and positive and do not hesitate to help people he knows and do not know. He loves basketball, and practice with his team as team captain three times a week. He normally drives his own car to work, but for other purposes he likes to travel with public transportation. He often uses an app where he can see if lifts are broken at stops beforehand, so he knows if he have to go by another route, but sometimes this has not been updated in time. He is positive towards digitalization and is eager to see what the future will bring. Sebastian is very positive towards autonomous driving, since a human driver can be tired and thereby make mistakes, while a computer can just keep going. However, he heard about an accident with that kind of car, which scares him a little.

Personality:

Extrovert	x			Introvert
Thinking		x		Feeling
Analytical	x			Creative
Conservative			x	Liberal
Passive			x	Active
Digital	x			Analogue

Technology interaction:

Physical buttons	x
Touch buttons	x
Voice command	x

Accessibility considerations:

- Sebastian needs to receive fast information regarding the condition of the elevators at the different stops
- He wishes for a separate space for people in wheelchairs so he does not have to have people's stuff in his face while traveling
- To be able to easier enter the vehicles, Sebastian needs the entrance to be on the same ground level as the platform

Name: Henrietta Adams
Age: 64
Occupation: Retired
Status: Divorced
Location:
Disability: Movement impaired (in a wheelchair)
Archetype: The Critic

Personality categories: Grumpy, Critical, Confident

Motivations regarding transportation:

Price	----------
Comfort	----------
Speed	----------
Independence	----------
Environmental	----

Goals:

- To be the one to win the neighborhood's weekly BINGO the most times
- To get back with her ex-husband who divorced her 35 years ago
- To lose at least 20 kg

Frustrations:

- That the ramps on vehicles are not strong and wide enough for people her size
- That the stops of public transportation often is so far away from her actual end destination
- That society is getting more and more digitalized since she feels that humans are turning into machines
- Long travels sitting in the wheelchair makes her back hurt

Bio: Henrietta is a "the glass is half empty" kind of woman, with strong opinions about most things in life. Her debate contribution to the local newspaper is nowadays a weekly feature, covering everything from the issue of playing children on the streets, to why social media should be banned completely. After an accident at the age of 32, Henrietta lost the ability to walk and has since then been relying on her wheelchair. She do not like to travel with public transport, but since it is free for her and she does not own a car, that is how she travels. She got a smartphone for her birthday, but would not buy one for herself. Henrietta can never see herself in a vehicle without a driver, she do not believe that it will ever be technically possible, and even if it would be possible she does not wanna support what she calls "dehumanization."

Personality:

Extrovert		x		Introvert
Thinking			x	Feeling
Analytical	x			Creative
Conservative	x			Liberal
Passive		x		Active
Digital			x	Analogue

Technology interaction:

Physical buttons	x
Touch buttons	x
Voice command	

Accessibility considerations:

- When lifts to platforms are not working Henrietta have no way to get to the vehicle the is supposed to travel with. She needs a way to know in advance which stops that works for her.
- She often experience that there is no room for her and her wheelchair on the vehicle. People usually do not want to move to give her space.
- Some platforms and stops are not in the same ground level as the vehicle, which makes it hard to get on with the wheelchair without a ramp.

Name: Charles Clarkson
Age: 74
Occupation: Retired but freelancing as a consulting system architect
Status: Married
Location: Big city
Disability: Cognitive disability (Aphasia)
Archetype: The Unforeseeable

Personality categories: Unpredictable, Social, Curious
Motivations regarding transportation:

Price	-----
Comfort	----------
Speed	--------
Independence	----------
Environmental	----

Goals:

- To be able to travel independently without help from others
- To one day perform at Poetry Slam with one of his original poems
- To bring his granddaughter to Natural History Museum in London

Frustrations:

- When the Taxi service for people with disabilities do not arrive on the appointed time
- That his ability to read is reduced to the point that he have a hard time understanding timetables and reading the destination text on the busses in stressful situations which causes him to not be able to travel with public transportation.
- When the Taxi driver does not give him the time he needs to find the words and formulate his sentences in an understandable way
- People thinking he is less intelligent than he is because he sometimes have trouble finding the words

Bio: Charles is a curious man who has been interested in poetry his whole life. He have written multiple poems that he has saved throughout the years. When Charles had just turned 68, he suffered a stroke. As a result of the stroke, he is now suffering from aphasia. This has no effect on his intellect, but he have trouble speaking, writing, reading and sometimes listening. Charles used to work full time as a system architect, and after retiring he still do some freelance jobs within this field. He likes technology and are curious of what the future will bring. He has a very positive attitude towards autonomous vehicles and believes that excluding a driver would be most beneficial for him. This especially as misunderstandings and frustrations often occurs when communicating with the driver.

Personality:

Extrovert	x		Introvert
Thinking	x		Feeling
Analytical		x	Creative
Conservative		x	Liberal
Passive	x		Active
Digital	x		Analogue

Technology interaction:

Physical buttons	x
Touch buttons	x
Voice command	

Accessibility considerations:

- Charles can in some situations have a hard time interpret long sentences which can cause stress if he needs to get the information quickly
    - Therefore, rather use shorter and simple sentences that can be interpreted faster
    - When displaying longer information, make it possible to receive the information through audio and give him the possibility to repeat the information for as many times as he wants
- When Charles is planning his trip, it is easier for him to have predefined options to choose from than having to write addresses/stops each time. Make sure that he can have "favourites" saved to choose from
- Charles must be the person to choose the way to receive information and interact. Depending on the situation, Charles can prefer different types of modes of communication. Therefore, multimodal ways to receive information and interact with the solutions must always be present.

Name: Adriana Matthew
Age: 24
Occupation: University studies: Classical guitar and Music theory
Status: Partner
Location: Middle sized town
Disability: Visually impaired
Archetype: The daredevil

Personality categories: Music enthusiast, fearless, intelligent

Motivations regarding transportation:

Price	--------
Comfort	-----
Speed	----------
Independence	----------
Environmental	------

Life goals:

- Play guitar on stage with Ed Sheeran
- Bungee jump from the Royal Gorge Bridge, Colorado, United States
- Be successful enough in music so that she can buy a house for her mother

Frustrations:

- Running out of battery on her smartphone
- Being on hold for too long when ordering the Taxi
- Not being able to make the change between vehicles because the time is too short
- When she has to ask people for help, which makes her feel like a burden

Bio: Adriana is a music nerd who spend most of her time practicing her guitar. She has been visually impaired since birth, and the older she gets the worse her vision becomes. Now at 24, she can only see displayed text if it is in 900% magnitude. She travels by Taxi the most, but she occasionally also takes the bus or train. She is not afraid to try new things, both in life and new technology. She is thankful for the help she has gotten thanks to the development of new technologies, which makes her more independent. Adriana is very positive towards autonomous vehicles, since that might help her being even more independent, however, she worries that it would still require a driver's license which she probably won't be allowed to get.

Personality:

Extrovert	x			Introvert
Thinking			x	Feeling
Analytical			x	Creative
Conservative			x	Liberal
Passive			x	Active
Digital	x			Analogue

Technology interaction:

Physical buttons	
Touch buttons	x
Voice command	x

Accessibility considerations:

- If Adriana is traveling to a new unexplored area, she needs to know in good advance when she is supposed to get of, and be certain that she is getting of at the right stop.
- Adriana needs the information to be mediated through audio and given the possibility to have the information repeated.
- When Adriana is changing from one vehicle to another on her route, there should be accessible tools for her to quick and easy find the location of the new vehicle, without her having to ask people for the information.

Name: Harry Smith
Age: 39
Occupation: Working part time as assistant pastry cook.
Status: Partner
Location:
Disability: Deaf-Blind (Acquired deafblindness)
Archetype: The Epicurean

Personality categories: Opinionated, enthusiastic, gourmand

Motivations regarding transportation:

Price	---
Comfort	-------
Speed	----------
Independence	----------
Environmental	----------

Goals:

- To get a full time job as a food critic
- To one day be able to drive a car by himself
- To buy a house in the maldives and have an early retirement

Frustrations:

- Not knowing if the driver of the vehicle have seen him or not, especially Taxi drivers.
- When information is not avaliable for him to read on his smartphone, and he has to rely on information on the vehicle, at the stations or at the platforms, which is often mediated only through audio.
- That he is often late even if he ordered a taxi in time, since he have to identify the vehicle as a taxi, and then find his actual taxi.

Bio: Harry is a happy guy that always look on the bright side of life. He acquired deaf-blindness when he was around 18 years old, but his hearing impairment is more severe than his sight impairment. He can still hear some, but only with the help of his hearing aid. His sight is good enough so that he can make his way around without a lot of trouble, but in later years he has started to use the white cane to help him out more. Harry mostly use the Taxi service for people with disabilities, but he wants to travel more with public transportation, since he enjoys being around people and randomly socialize. Harry's opinions about autonomous driving is divided, since he is used to be able to ask the driver for information, for example if he is on the right bus, which is important to him.

Personality:

Extrovert	x			Introvert
Thinking		x		Feeling
Analytical	x			Creative
Conservative			x	Liberal
Passive			x	Active
Digital	x			Analogue

Technology interaction:

Physical buttons	x
Touch buttons	x
Voice commandx	

Accessibility considerations:

- Since Harry have trouble both seeing and hearing, information displayed or given by audio might not be enough. If the bus is late or the route changes, Harry would for example appreciate a text message he can read on his smartphone where he have the tools to read the information.
- Since Harry do most of the communication through tools in his smartphone, he wishes for ways to communicate with drivers in public transportation through text, for example if he needs help with something.
- Because of Harry's deaf-blindness, he has a hard time knowing if he is on the right bus or train. Therefore he needs to be able to, in some way, ask for such confirming information when he wants, in a way that suits his disability.

Name: Chrissy Andersen
Age: 52
Occupation: Administration
Status: Married. 1 son
Location:
Disability: Hearing impaired
Archetype: Wallflower
Personality categories: Humble, caring, afraid of conflicts

Motivations regarding transportation:

Price	----------
Comfort	----------
Speed	-------
Independence	----------
Environmental	----------

--

Goals:

- To have the courage to stand up for herself more often
- Move to Spain and work at a rescue center for homeless dogs
- To start using public transportation and recycle more

Frustrations:

- When information is only given in audio and text based information is not working
- When other travelers have to tell her information she could not perceive herself
- When electronic functions in the vehicle disturbs the hearing aid to the point that she will rather turn it off.
- That she always have to ask her son for help when buying a new ticket, since she cannot figure the machine out

Bio: Chrissy is a calm, gentle person who prioritize spending time with her family above everything else. She lost her hearing when she was 12 years old and without her hearing aid, she is completely deaf. With the help of the hearing aid, she can perceive loud noises from a distance, and some noises if they are really close. She is thankful for what technology has done for her so far regarding her hearing aid, but she is scared of the rise of digitalisation in society, since she is concerned that it will lead to dehumanization and exclude the needs of people with disabilities. She thinks that the solutions that exists today are good enough as long as they are working properly. She is sceptical about autonomous driving since she feel like human responses and actions is important in traffic. She cannot trust a computer to carry out the same spontaneous actions as humans can.

Personality:

Extrovert			x	Introvert
Thinking		x		Feeling
Analytical	x			Creative
Conservative	x			Liberal
Passive	x			Active
Digital			x	Analogue

Technology interaction:

Physical buttons	x
Touch buttons	x
Voice command	

Accessibility considerations:

- Chrissy needs all relevant and updated information in visual form since she cannot hear information from speakers
- It is important not to use equipment that will knock out or disturb her hearing aid, such as disturbing electrical functions.
- Chrissy hates feeling stupid, therefore, the ticket system (buying and validate) needs to be easy to understand and use without the need to ask someone for help.

Appendix 5: Personas, result third iteration

Name: Sebastian Harrold
Age: 31
Occupation: Office worker
Status: Single
Location:
Disability: Movement impaired (in a wheelchair)
Archetype: The Friend

Personality categories: Sweet, Dedicated, Trustworthy
Motivations regarding transportation:

Price	
Comfort	------
Speed	----------
Independence	----------
Environmental	----

Life Goal:

- To play basketball professionally on a national level

Goals for traveling:

- Reaching end destination without having to take detours because of broken elevators
- Access information even when other travelers are standing in the way of information screens
- Being able to travel without feeling that he is in the way of other travelers

Frustrations:

- When people who does not have to use the elevator at stops still use it which sometime causes him to have to wait and thereby miss his train
- When there is a lot of people on the vehicle and he gets all their bags in his face
- When the entrance to the vehicle and the platform are not at the same ground level
- When he comes to a stop and the elevator is broken so he have to go to another stop

Bio: Sebastian is a guy everyone likes. He is kind and positive and do not hesitate to help people he knows and do not know. He loves basketball, and practice with his team as team captain three times a week. He normally drives his own car to work, but for other purposes he likes to travel with public transportation. He often uses an app where he can see if lifts are broken at stops beforehand, so he knows if he have to go by another route, but sometimes this has not been updated in time. He is positive towards digitalization and is eager to see what the future will bring. Sebastian is very positive towards autonomous driving, since a human driver can be tired and thereby make mistakes, while a computer can just keep going. However, he heard about an accident with that kind of car, which scares him a little.

Personality:

Extrovert	x			Introvert
Thinking			x	Feeling
Analytical		x		Creative
Conservative			x	Liberal
Passive			x	Active
Digital		x		Analogue

Technology interaction:

Physical buttons	x
Touch buttons	x
Voice command	x

Accessibility considerations:

- Sebastian needs to receive fast information regarding the condition of the elevators at the different stops
- He wishes for a separate space for people in wheelchairs so he does not have to have people's stuff in his face while traveling
- To be able to easier enter the vehicles, Sebastian needs the entrance to be on the same ground level as the platform

---

Name: Henrietta Adams
Age: 64
Occupation: Retired
Status: Divorced
Location:
Disability: Movement impaired (in a wheelchair)
Archetype: The Critic

Personality categories: Grumpy, Critical, Confident

Motivations regarding transportation:

Price	----------
Comfort	----------
Speed	----------
Independence	----------
Environmental	----

Life goal:

- To be the one to win the yearly national BINGO

Goals for traveling:

- Be able to travel from her home address instead of going to a station, for the same price
- Travel without having to ask people to move out of her way
- Being able to feel safe even though there is no driver of the vehicle

Frustrations:

- That the ramps on vehicles are not strong and wide enough for people her size
- That the stops of public transportation often is so far away from her actual end destination
- That society is getting more and more digitalized since she feels that humans are turning into machines
- Long travels sitting in the wheelchair makes her back hurt

Bio: Henrietta is a "the glass is half empty" kind of woman, with strong opinions about most things in life. Her debate contribution to the local newspaper is nowadays a weekly feature, covering everything from the issue of playing children on the streets, to why social media should be banned completely. After an accident at the age of 32, Henrietta lost the ability to walk and has since then been relying on her wheelchair. She do not like to travel with public transport, but since it is free for her and she does not own a car, that is how she travels. She got a smartphone for her birthday, but would not buy one for herself. Henrietta can never see herself in a vehicle without a driver, she do not believe that it will ever be technically possible, and even if it would be possible she does not wanna support what she calls "dehumanization."

Personality:

Extrovert	x		Introvert
Thinking		x	Feeling
Analytical	x		Creative
Conservative	x		Liberal
Passive	x		Active
Digital		x	Analogue

Technology interaction:

Physical buttons	x
Touch buttons	x
Voice command	

Accessibility considerations:

- When lifts to platforms are not working Henrietta have no way to get to the vehicle the is supposed to travel with. She needs a way to know in advance which stops that works for her.
- She often experience that there is no room for her and her wheelchair on the vehicle. People usually do not want to move to give her space.
- Some platforms and stops are not in the same ground level as the vehicle, which makes it hard to get on with the wheelchair without a ramp.

Name: Charles Clarkson
Age: 74
Occupation: Retired
Status: Married
Location: Big city
Disability: Cognitive disability (Aphasia)
Archetype: The Unforeseeable

Personality categories: Unpredictable, Social, Curious

Motivations regarding transportation:

Price	-----
Comfort	----------
Speed	--------
Independence	----------
Environmental	----

Life goal:

- To one day perform at Poetry Slam with one of his original poems

Goals for traveling:

- To be able to travel independently without feeling stressed or overwhelmed
- Not being overloaded with information and ways to interact
- Being able to communicate what he wants without being misunderstood

Frustrations:

- When the Taxi service for people with disabilities do not arrive on the appointed time
- That his ability to read is reduced to the point that he have a hard time understanding timetables and reading the destination text on the busses in stressful situations which causes him to not be able to travel with public transportation.
- When the Taxi driver does not give him the time he needs to find the words and formulate his sentences in an understandable way
- People thinking he is less intelligent than he is because he sometimes have trouble finding the words

Bio: Charles is a curious man who has been interested in poetry his whole life. He have written multiple poems that he has saved throughout the years. When Charles had just turned 68, he suffered a stroke. As a result of the stroke, he is now suffering from aphasia. This has no effect on his intellect, but he have trouble speaking, writing, reading and sometimes listening. Charles used to work full time as a system architect, and after retiring he still do some freelance jobs within this field. He likes technology and are curious of what the future will bring. He has a very positive attitude towards autonomous vehicles and believes that excluding a driver would be most beneficial for him. This especially as misunderstandings and frustrations often occurs when communicating with the driver.

Personality:

Extrovert		x		Introvert
Thinking	x			Feeling
Analytical			x	Creative
Conservative			x	Liberal
Passive		x		Active
Digital		x		Analogue

Technology interaction:

Physical buttons	x
Touch buttons	x
Voice command	

Accessibility considerations:

- Charles can in some situations have a hard time interpret long sentences which can cause stress if he needs to get the information quickly
    - Therefore, rather use shorter and simple sentences that can be interpreted faster
    - When displaying longer information, make it possible to receive the information through audio and give him the possibility to repeat the information for as many times as he wants
- When Charles is planning his trip, it is easier for him to have predefined options to choose from than having to write addresses/stops each time. Make sure that he can have "favourites" saved to choose from
- Charles must be the person to choose the way to receive information and interact. Depending on the situation, Charles can prefer different types of modes of communication. Therefore, multimodal ways to receive information and interact with the solutions must always be present.

Name: Adriana Matthew
Age: 24
Occupation: University studies: Classical guitar and Music theory
Status: Partner
Location: Small sized town
Disability: Visually impaired
Archetype: The daredevil

Personality categories: Music enthusiast, fearless, time optimistic

Motivations regarding transportation:

Price	--------
Comfort	-----
Speed	----------
Independence	----------
Environmental	------

Life goals:

- Play and sing a duet on stage with Ed Sheeran

Goals for Traveling:

- She wants to travel independently, without feeling like a burden for other people
- To easily be able to navigate herself at new locations
- Since she is very time optimistic, she needs to get to her destination just as fast and smooth as people who can see well

Frustrations:

- Running out of battery on her smartphone
- Being on hold for too long when ordering the Taxi
- Not being able to make the change between vehicles because the time is too short
- When she has to ask people for help, which makes her feel like a burden

Bio: Adriana is a music nerd who spend most of her time practicing her guitar. She has been visually impaired since birth, and the older she gets the worse her vision becomes. Now at 24, she can only see displayed text if it is in 900% magnitude. She travels by Taxi the most, but she occasionally also takes the bus or train. She is not afraid to try new things, both in life and new technology. She is thankful for the help she has gotten thanks to the development of new technologies, which makes her more independent. Adriana is very positive towards autonomous vehicles, since that might help her being even more independent, however, she worries that it would still require a driver's license which she probably won't be allowed to get.

Personality:

Extrovert	x			Introvert
Thinking		x		Feeling
Analytical			x	Creative
Conservative		x		Liberal
Passive		x		Active
Digital	x			Analogue

Technology interaction:

Physical buttons	
Touch buttons	x
Voice command	x

Accessibility considerations:

- If Adriana is traveling to a new unexplored area, she needs to know in good advance when she is supposed to get of, and be certain that she is getting of at the right stop.
- Adriana needs the information to be mediated through audio and given the possibility to have the information repeated.
- When Adriana is changing from one vehicle to another on her route, there should be accessible tools for her to quick and easy find the location of the new vehicle, without her having to ask people for the information.

Name: Harry Smith
Age: 39
Occupation: Working part time as assistant pastry cook.
Status: Partner
Location: Mid-size city
Disability: Deaf-Blind (Acquired deafblindness)
Archetype: The Epicurean

Personality categories: Opinionated, enthusiastic, gourmand

Motivations regarding transportation:

Price	---
Comfort	-------
Speed	----------
Independence	----------
Environmental	----------

Life Goal:

- To get a full time job as a food critic

Goals for traveling:

- Travel independently without having to ask other people for information
- To get to his destination just as fast as he thinks he would have driven there himself
- To fast and easy be able to locate his ordered vehicle

Frustrations:

- Not knowing if the driver of the vehicle have seen him or not, especially Taxi drivers.
- When information is not avaliable for him to read on his smartphone, and he has to rely on information on the vehicle, at the stations or at the platforms, which is often mediated only through audio.
- That he is often late even if he ordered a taxi in time, since he have to identify the vehicle as a taxi, and then find his actual taxi.

Bio: Harry is a happy guy that always look on the bright side of life. He acquired deaf-blindness when he was around 18 years old, but his hearing impairment is more severe than his sight impairment. He can still hear some, but only with the help of his hearing aid. His sight is good enough so that he can make his way around without a lot of trouble, but in later years he has started to use the white cane to help him out more. Harry mostly use the Taxi service for people with disabilities, but he wants to travel more with public transportation, since he enjoys being around people and randomly socialize. Harry's opinions about autonomous driving is divided, since he is used to be able to ask the driver for information, for example if he is on the right bus, which is important to him.

Personality:

Extrovert	x			Introvert
Thinking		x		Feeling
Analytical	x			Creative
Conservative			x	Liberal
Passive			x	Active
Digital	x			Analogue

Technology interaction:

Physical buttons	x
Touch buttons	x
Voice command	x

Accessibility considerations:

- Since Harry have trouble both seeing and hearing, information displayed or given by audio might not be enough. If the bus is late or the route changes, Harry would for example appreciate a text message he can read on his smartphone where he have the tools to read the information.
- Since Harry do most of the communication through tools in his smartphone, he wishes for ways to communicate with drivers in public transportation through text, for example if he needs help with something.
- Because of Harry's deaf-blindness, he has a hard time knowing if he is on the right bus or train. Therefore he needs to be able to, in some way, ask for such confirming information when he wants, in a way that suits his disability.

Name: Chrissy Andersen
Age: 52
Occupation: Administration
Status: Married. 1 son
Location: Mid-size city
Disability: Hearing impaired
Archetype: Wallflower

Personality categories: Humble, caring, afraid of conflicts
Motivations regarding transportation:
Price ----------
Comfort ----------
Speed -------
Independence ----------
Environmental ----------

Life goals:
- Move to Spain and work at a rescue center for homeless dogs

Goals for Traveling:
- To travel on her own without missing important information
- Have easy ways to plan her trip and buy her tickets
- To one day be able to feel completely safe while traveling with autonomous vehicles

Frustrations:
- When information is only given through audio, and when text based information is not working
- When other travelers have to tell her information she could not perceive herself
- When electronic functions in the vehicle disturbs the hearing aid to the point that she will rather turn it off.
- That she always have to ask her son for help when buying a new ticket, since she cannot figure the machine out

Bio: Chrissy is a calm, gentle person who prioritize spending time with her family above everything else. She lost her hearing when she was 12 years old and without her hearing aid, she is completely deaf. With the help of the hearing aid, she can perceive loud noises from a distance, and some noises if they are really close. She is thankful for what technology has done for her so far regarding her hearing aid, but she is scared of the rise of digitalisation in society, since she is concerned that it will lead to dehumanization and exclude the needs of people with disabilities. She thinks that the solutions that exists today are good enough as long as they are working properly. She is sceptical about autonomous driving since she feel like human responses and actions is important in traffic. She cannot trust a computer to carry out the same spontaneous actions as humans can.

Personality:

Extrovert		x	Introvert
Thinking		x	Feeling
Analytical	x		Creative
Conservative	x		Liberal
Passive		x	Active
Digital		x	Analogue

Technology interaction:

Physical buttons	x
Touch buttons	x
Voice command	

Accessibility considerations:
- Chrissy needs all relevant and updated information in visual form since she cannot hear information from speakers
- It is important not to use equipment that will knock out or disturb her hearing aid, such as disturbing electrical functions.
- Chrissy hates feeling stupid, therefore, the ticket system (buying and validate) needs to be easy to understand and use without the need to ask someone for help.

Appendix 6: Result - Guidelines, first iteration

Guidelines

Survey: Smart city solutions should contribute to increased independence

- People need to feel that new solutions enable them to carry out tasks etc on their own

INSIDE the Vehicle

Presentation of multimodal information

Survey: There should be multi modal information on the actual vehicle about delays, change of route and other unforeseen events

- Not through speakers only, or text only. All information should be available in different formats at the same time.

Survey: Provide travelers with audiovisual information. Don't only inform passengers through audio on speakers, make sure the same information is given visually

Lit: All information displayed to anyone who can see must also be available to anyone who is visually impaired**(Svensk Kollektiv)**

Survey: When the "stop button" is pressed, provide both clear audio and visual feedback for all travelers

- All travelers should be notified when someone has pressed the stop button. If a hearing impaired person do not get visual feedback after pressing stop, he/she do not know if the driver has received the information that he/she wants to get off at the next stop

Survey: Make sure that people with impaired hearing can access audible information on their terms

- Since people are dependent on different volume levels, individual access to information is a possible solution. This could for example be access to audible information through their own smart devices or the possibility to access the information from their particular seat through headphones or similar. The loud volume that is needed for one user to hear can disturb other travelers, therefore individual ways to access the information is prefered.

Survey: Provide information visually just as fast as the audible information is given

- People with hearing impairments should not have to wait for visual information that people who can hear has already been given.

Lit: Information should be short, simple and easy to read (cognitive) **(Svensk Kollektiv)**

Lit: Make sure information do not disappear or become hidden before the user are finished with it (for example on digital screens that changes) (Dev Gnome)

Survey: Try to make it easy for the user to identify where there is a free seat on the vehicle

- Especially for visually impaired travelers, there is a problem to see where there is a free seat for them.

Survey: Given an emergency situation, provide blinking lights and some sort of movement/shaking indication

- Make sure that all travelers are aware of the situation. To only give information through audio and displayed in text might not be enough. Lights and/or vibrations also catches the attention of people with hearing impairment that otherwise might not pay attention to the screen at that moment

Lit: Must be able to notice if an alarm is triggered **(Svensk Kollektiv)**

Survey: Provide blinking lights and/or some sort of movement/shaking indication when important information is presented to the travelers

Survey: Make sure not to use electrical functions that somehow disturb user's hearing aid

- Devices that people with hearing impairments use to enhance their hearing can be disturbed by some electrical functions. Make sure not to use these types of functions so that the users do not have to turn their hearing aids off.

Lit.: Work well with technical devices like teleslinga (no malfunction so they need to turn them off) **(Hörsellinjen)**

Survey: Provide hearing loops in all vehicles and waiting areas

    - To enable people with impaired hearing to enhance their ability to hear, provide them with hearing loops in public areas so that they easier can hear the information given through audio

Interaction with vehicles system/Interface

Survey: Create the opportunity to request audible information if needed
- The solution should be equivalent to the possibility to ask a driver for information.

Lit: Make sure information do not disappear or become hidden before the user are finished with it (for example on digital screens that changes) (Dev Gnome)
- Don't hardcode timeouts or other time based features. Some users may read, type or react more slowly than others (Dev Gnome)

Survey: When the "stop button" is pressed, provide both clear audio and visual feedback for all travelers
- All travelers should be notified when someone has pressed the stop button. If a hearing impaired person do not get visual feedback after pressing stop, he/she do not know if the driver has received the information that he/she wants to get off at the next stop

Lit: Give feedback to the user both with for example sound, vibration, visual (Dev Gnome)

For vehicles that will have use of a screen based interactive interface:
Survey: Interaction with interfaces must be available both through buttons and voice command
- People who suffer from deaf-blindness are in majority not entirely blind or deaf, often with one of the impairments more severe than the other. Therefore, a combination of ways to interact with the interface is needed.

Lit: Websites should follow rules for visual impairments, such as speech synthesis **(Svensk Kollektiv)**
Lit: Don't use labels that are spelled differently but sounds the same (screen readers) (Dev Gnome)
Lit: Possibility for the user to choose the size of the text themselves (Dev Gnome)
Lit: Make sure information do not disappear or become hidden before the user are finished with it (for example on digital screens that changes) (Dev Gnome)
- Don't hardcode timeouts or other time based features. Some users may read, type or react more slowly than others (Dev Gnome)

Lit: Make interactive GUI elements easily identifiable(Dev Gnome)
Lit: Create large clickable areas (Dev Gnome)
Lit: Make it possible to control the interface with only one finger (Dev Gnome)
Lit: Minimize text input in the interface, offer lists with choices instead (Dev Gnome)

Ticketsystem

Lit: The whole machine should be multimodal
- Talande biljettautomater (SRF)

Survey: Make sure that the feedback when validating/stamping the ticket is multimodal
- For example, provide the user with both a blinking light and a sound as feedback that their ticket is validated

Lit: Give the user clear status information (to know what is happening all the time) (Dev Gnome)
Survey: The screen for ticket/Payment systems should contain clear contrast between text and background and have the possibility the adjust the size of the text.
- The User Interface of the system should follow universally known usability standards for User Interfaces. Particularly important for this user group is the contrast and brightness levels and the importance of being able to magnify the text.

Lit: Use colors that works for people with color blindness (Dev Gnome)
Lit: Provide high contrast between text and backgroud (Dev Gnome)
Lit: Provide the ability for the user to magnify the display (Dev Gnome)
Lit: Make it possible to control the interface with only one finger (Dev Gnome)

Lit: Lit.: Don't use labels that are spelled differently but sounds the same (screen readers) (Dev Gnome)
Lit: Possibility for the user to choose the size of the text themselves (Dev Gnome)
Lit: Make sure information do not disappear or become hidden before the user are finished with it (for example on digital screens that changes) (Dev Gnome)
Lit: Don't hardcode timeouts or other time based features. Some users may read, type or react more slowly than others (Dev Gnome)
Lit: Don't show GUI elements that don't actually do anything (Dev Gnome)
Lit: Make interactive GUI elements easily identifiable (Dev Gnome)
Lit: Give the user clear status information (to know what is happening all the time) (Dev Gnome)

Specifically for wheelchairs

Interview: Create a separate place for people in wheelchairs in the vehicle

- Think about the space and differences in height for sitting and standing passengers. People in wheelchairs should not have to have people's backpacks in their face because they are standing so close. Try to find a solution to that.

Lit: Enough room for rotating wheelchair and rollator **(Svensk Kollektiv)**
Lit: Adequate range of rollator and wheelchair **(Svensk Kollektiv)**
Lit: Rails and handrails to hold in**(Svensk Kollektiv)**
Lit: No thresholds, stairs or narrow and heavy doors **(Svensk Kollektiv)**
Lit: Display of information adapted to short people and people in wheelchair **(Svensk Kollektiv)**

OUTSIDE the vehicle

Presentation of multimodal information

Multimodal;
Survey: Provide travelers with audiovisual information

- Don't only inform passengers through audio on speakers, make sure the same information is given visually

Survey: Provide information visually just as fast as the audible information is given

- People with hearing impairments should not have to wait for visual information that people who can hear has already been given.

Survey: If the user needs to contact customer service, make sure that he/she have the possibility to do this in the form of text

    - People with hearing impairment may not have the possibility to call and talk to customer service directly. Provide solutions as for example chat functions. The solution should get the user connected to customer service just as fast as calling.

Interview: If delays or other problems occur, provide visual information about alternative routes and where people can find them.

- Present information fast about other ways people can travel to their destination and how they should find the new vehicles. This need to be informed by multimodal means.

Survey: Given an emergency situation, provide blinking lights and some sort of movement/shaking indication

- Make sure that all travelers are aware of the situation. To only give information through audio and displayed in text might not be enough. Lights and/or vibrations also catches the attention of people with hearing impairment that otherwise might not pay attention to the screen at that moment

Survey: Provide blinking lights and/or some sort of movement/shaking indication when important information is presented to the travelers

- Make sure that all travelers are aware of the situation. To only give information through audio and displayed in text might not be enough. Lights and/or vibrations also catches the attention of people with hearing impairment that otherwise might not pay attention to the screen at that moment

Interview: Provide information about canceled or late vehicles must be updated visually just as fast as it is informed through audio
Lit: All information displayed to anyone who can see must also be available to anyone who is visually impaired **(Svensk Kollektiv)**

- This minimizes stress for people with impaired hearing when they see that people who can hear get information that they do not, and they do not want to have to ask other stressed travelers to get the same information.

Lit: Make sure information do not disappear or become hidden before the user are finished with it (for example on digital screens that changes) (Dev Gnome)
Lit: Information should be short, simple and easy to read (cognitive) **(Svensk Kollektiv)**
Lit.: Signs can have simple pictures, difficult to understand numbers and information (cognitive) **(Svensk Kollektiv**
Survey: Provide hearing loops in all vehicles and waiting areas

- To enable people with impaired hearing to enhance their ability to hear, provide them with hearing loops in public areas so that they easier can hear the information given through audio

Survey: Make sure not to use electrical functions that somehow disturb user's hearing aid

- Devices that people with hearing impairments use to enhance their hearing can be disturbed by some electrical functions. Make sure not to use these types of functions so that the users do not have to turn their hearing aids off.

Lit.: Work well with technical devices like teleslinga (no malfunction so they need to turn them off) **(Svensk Kollektiv)/(egen)**
Survey: If the user needs to contact customer service, make sure that he/she have the possibility to do this in the form of text

- People with hearing impairment may not have the possibility to call and talk to customer service directly. Provide solutions as for example chat functions. The solution should get the user connected to customer service just as fast as calling.

Interaction with vehicles system/Interface

Survey: Solutions need to communicate its location in different ways to the user

- Users need to be able to identify a vehicle as their intended vehicle. In other words being able to identify where the vehicle is and what vehicle it is before boarding. The user should not have to be hesitant that he/she is boarding the wrong vehicle or need to ask someone to be sure.

Lit.: Make sure information do not disappear or become hidden before the user are finished with it (for example on digital screens that changes) (Dev Gnome)
Survey: Interaction with interfaces must be available both through buttons and voice command

- People who suffer from deaf-blindness are in majority not entirely blind or deaf, often with one of the impairments more severe than the other. Therefore, a combination of ways to interact with the interface is needed.

Lit.: Keys and levers must be easy to use without looking (example on doors and elevators) **(Svensk Kollektiv)**

Navigation

Survey: People who are visually impaired should be able to catch connecting vehicles in public transportation just as fast as travelers that are not visually impaired

- Create solutions that allow people that have impaired sight finding their connecting vehicles fast, so that they don't have to get used to waiting for a new one because they had trouble finding the vehicle at the connecting stop. This could be done for example by navigating audible information

Survey: Do not force people in wheelchairs to take detours or other inconvenient ways to get to vehicles

- If a person in a wheelchair is trying to catch a connecting vehicle, they should not have to go another way that takes longer for them than the way people that can walk takes

Interview: If delays or other problems occur, provide visual information about alternative routes and where people can find them.

- Present information fast about other ways people can travel to their destination and how they should find the new vehicles. This need to be informed by multimodal means.

Lit.: Colors that appear good should show where stairs, thresholds and windows are somewhere**(Svensk Kollektiv)**
Lit: Ledges that can be followed by white cane **(Svensk Kollektiv)**
Interview: Provide travelers with the possibility to follow the route the vehicle travels in real time.

- People with visual impairment may feel stressed when not knowing exactly where they are on their rout. Having the possibility to follow the route in real time through their smartphone, could result in a more calm and stress free experience.
- Hearing impaired people can follow the route visually through a map in their smartphone or on the information display on the vehicle (visually show how far they are from the next stop).

Lit: Colors that look good should show where stairs, thresholds and windows are somewhere **(Svensk Kollektiv)**

Entry and Exit

Survey: Ideally, make platform and vehicle ground level the same height

- This will make the use of ramps unnecessary, and will therefore make it easier and faster for people in wheelchairs to enter and exit the vehicle (especially as they then do not require additional help).

Survey: Design entries and exits to make them well functional and easy to use for people in wheelchairs

- This should be considered both for entries and exits in vehicles but also in waiting areas. This includes for example broad enough doorways and excluding thresholds

Survey: Avoid a gap between the vehicle and the platform

- Visually impaired travelers then don't have to worry about not being able to estimate the distance properly

Survey: If platform and the floor of the vehicle is not on the same ground level, there must be an easy and fast way to unfold a ramp for people in wheelchairs

- This must be done without leaving the person in need of the ramp feeling stressed, or feeling that they interrupt the flow of boarding or exiting

Interview: Make sure that the vehicle and the platform is on the same ground level

- This eliminates the use of ramps and is an easy way for the people in wheelchairs to enter and exit. Also make sure that the ground and the floor of the lift is on the same level.

Planning

Interview: Provide all necessary information about vehicles and platforms beforehand when the user is planning his/her trip

- For example, for people in wheelchairs, they need to know if there is a lift at the platform they are going to if it is not on ground level (this goes for all platforms, the starting one, the end station and also at connecting platforms). Information about if the lift is actually working is also needed.

Appendix 7: Result - Guidelines, second iteration

The main goal of these guidelines is to make Smart city solutions contribute to increased independence. People need to feel that new solutions enable them to carry out tasks etc on their own.

INSIDE the Vehicle

Presentation of multimodal information

1. All information should be presented in a multimodal way

a. Information presented should be both auditory and visual

Example: When unforeseen events occur, for example delays or changes of routes, travelers must be informed both through speakers and screens. As Svensk Kollektivtrafik writes; all information that is shown for someone who can see, must also be available for someone who cannot see. In the survey, users also pointed out that they need multimodal feedback when the stop button is pressed (for example visual, auditory, vibrations). If a person with hearing impairment do not get visual feedback, he or she will not know if the driver has received the information that they want to get of at the next stop. Svensk kollektivtrafik writes that the information should be short, simple and easy to interpret. This was also requested by people with cognitive disabilities in the interviews.

b. Provide information visually just as fast as the audible information is given

Example: People with hearing impairment should not have to wait for visual information that people who can hear will access directly. In the interviews and survey, people with hearing impairments gave multiple examples of how they have been on the train and other travelers have left the train because they got information about occured errors through speakers, that the people with hearing impairment could not receive.

c. Make sure that information do not disappear or become hidden before the user are finished with it

Example: Dev Gnome writes that information presented to users should not disappear before the user is finished with the information. It is not a good idea to hardcode timeouts or other time based features, instead let the user themself decide when they are finished with the information. Work with confirmations or let the user access the information again if they want. In the interviews, people with cognitive disabilities expressed concern about not being given the time to properly comprehend the information before it disappears. In the surveys, people with deaf-blindness disliked the fact that people without disabilities receive information that they missed, and they could not access again, which causes a lot of stress for them, especially since they sometimes have problems with the communication with other travelers and can't just ask them what is going on.

d. In case of emergency situations, work a lot with multimodal ways to communicate the danger

Example: Make sure that all travelers are aware of the situation. For example, catch the attention of people with hearing impairment who might not pay attention to screens, by providing blinking lights or some sort of movement/shaking indication. This was requested from users in the survey. Svensk kollektivtrafik writes that everyone must notice if there is an ongoing alarm.

Interaction with vehicles system / Interface

2. It should be possible to interact with the vehicle's interface(s) in multiple different ways.

a. It should be possible for the user to request information if needed

Example: People in the survey expressed that they want to be able to ask for information in case they happened to miss information already provided, or if they need other information. If the vehicle is autonomous without a driver, there should be a way for the user to ask for such information a driver would usually provide. This information needs to be reached when the users themselves needs it, and present for the amount of time they need it. Some users might read, type, process or react to information slower than others (Dev Gnome).

b. Feedback should be given in a multimodal way.

Example: Dev Gnome writes that users can be given visual and auditory feedback, as well as through vibration. For the example with the stop button, users can receive feedback through vibration when pressing, as well as through audio and visually.

c. If there is use of an interactive screen based interface on the vehicle, think about this:

- Interaction with interfaces should be available both through buttons and voice command
    - *Example: People who suffer from deaf-blindness are in majority not entirely blind or deaf, often with one of the impairments more severe than the other. Therefore, a combination of ways to interact with the interface was wished for in the survey.*
- The interface should follow rules for visual impairments, for example use speech synthesis (Svensk kollektivtrafik)
- Don't use labels that are spelled differently but sounds the same, this because it can be confusing for users that are using screen readers (Dev Gnome)
- Allow users to choose the size of the text themselves, by providing the possibility to magnify the text size (Dev Gnome)
- The screen should contain clear contrast between text and background
    - *Example: People in the survey with visual impairments expressed concern about the contrast and brightness levels not being clear enough. It is particularly important for this user group.*

- Use colors that works for people with color blindness
- Make interactive Graphical User Interfaces easily identifiable.
    - *Example: Make sure to provide affordances to show the user if something is clickable or not.*
- Create large clickable areas and make it possible to control the interface with only one finger (Dev Gnome)
- Minimize text input in the interface, offer lists with choices instead (Dev Gnome)

Environment stuff

3. Make sure that the interior of the vehicle, platform and waiting areas are accommodating to the different needs of the users

a. Create a separate place for people in wheelchairs in the vehicle

Example: People in the interviews was bothered that there is no thought put into today's solutions regarding the space and differences in height for sitting and standing passengers. People in wheelchairs should not have to have people's backpacks in their face because other travelers are standing so close to them. There should also be enough space for people in wheelchairs to rotate their wheelchair and the possibility to hold on to a rail (Svensk kollektivtrafik).

b. Displayed information should be reachable to the users regardless of their position in the vehicle

Example: Information displayed on a screen, can be hard for people who are sitting down to reach, especially if people are standing in the way. A person with hearing impairment would rely on the screen for information and if other travelers are standing in the way, the person might miss valuable information. In the interviews, people in wheelchairs explained concern to miss information shown on screens, when other travelers are standing up. Svensk kollektivtrafik also writes that display of information should be adapted to short people and people in wheelchairs.

c. Provide hearing loops in all vehicles and waiting areas

Example: To enable people with impaired hearing to enhance their ability to hear, provide them with hearing loops in the vehicles and waiting areas so that they easier can hear the information given through audio. Make sure not to use electrical functions that somehow disturb user's hearing aid. Many people with hearing impairments emphasized both in the survey and interviews the importance of not using electrical functions that can disturb their hearing aids. This problem often caused them to rather turn of their hearing aid than using is because of the hissing sound it causes. Hörsellinjen also writes that solutions should work well with technical devices such as hearing loops.

d. Necessary information should be provided beforehand when the user is planning the trip.

Example: Information about working elevators or the lack of elevators going up or down to platforms, need to be provided to the user before traveling. In surveys and interviews, people in wheelchairs expressed frustration over the fact that they sometimes have arrived to stops only to see that the elevator is not working or there are no elevator. Make sure that this information is regularly updated in case a elevator breaks. For a person with deaf-blindness or visual impairment, they would gain from getting as detailed information about how they are going to navigate themselves at potential connecting stops and also for unexpected situations like reconstruction. This especially since information gathered through the surveys showed that people with visual impairments prefer to take routs they already know, as it is easier for them to navigate at places they have been before.

OUTSIDE the vehicle

Presentation of multimodal information

4. All information should be presented in a multimodal way

a. Information presented should be both auditory and visual

Example: When unforeseen events occur, for example delays or changes of routes, travelers must be informed both through speakers and screens. As Svensk Kollektivtrafik writes; all information that is shown for someone who can see, must also be available for someone who cannot see. In the interviews, people wished for fast information about how they can travel to their destination and how they can find the connecting vehicles. This information needs to be presented by multimodal means since the user with visually impairment might need to be directed through audio in an app or by lanes, and a person with cognitive impairment might need very short, simple and easy to interpret information to do so (Svensk kollektivtrafik). For a person in a wheelchair, they need a way to know which is the fastest way for them to go to their connecting vehicle without stairs or other obstacles.

b. Provide information visually just as fast as the audible information is given

Example: People with hearing impairment should not have to wait for visual information that people who can hear will access directly. This is also the case if the user needs to contact customer service, where people with hearing impairment should be able to get their answers through text in the same

speed as people can get through calling. Chat functions is one solution to do so that was requested in the interviews.

c. Displayed information should be possible to retrieve individually

Example: Since people have different prerequisites to receive information and does so in different paces it would be beneficial to allow users to retrieve displayed or called out information on an individual level. For example, if someone with cognitive disabilities can not comprehend the information right away, they can take their time to read or listen to the information through their smartphone instead in their own pace. Same goes for people with deaf-blindness. In the interviews, people with cognitive disabilities expressed concern about not being given the time to properly comprehend the information before it disappears.

d. Work with multimodal ways to communicate vehicle presence for people on sidewalks and surrounding area of the vehicle

Example: Make sure that all travelers are aware of the vehicle closing in. People on sidewalks and people who are crossing the road wants to get indications that the vehicle have "seen" them. This was requested in the interviews. The way of communicating this must be shown in multimodal ways, with for example lights and sound.

e. Users need to be able to identify a vehicle as their intended vehicle.

Example: The user need to be able to identify what vehicle is in front of them before boarding. The users should not have to be hesitant that they are boarding the wrong vehicle or feel the need to ask someone to be sure. This must be done in a multimodal way with both visual means and audio. For example, people with visual impairment explained in the surveys and interviews that when traveling by taxi, they had to ask multiple drivers which car is their intended taxi. Same goes for traveling by bus or train when they cannot see the number and end destination presented on the vehicle's display on the outside of the vehicle. This causes them to always have to ask for confirmation from other people to be sure they are boarding the right vehicle.

Interaction with vehicles system/Interface

5. Provide easy and multiple different ways to interact with the vehicle from the outside

a. The vehicle should clearly signal to the user where interactive functions are located

Example: If a user with visual impairment need to manually open the door somehow, they need to know where the function of doing so is located. This was sometimes shown to be a problem for people answering the survey. If the vehicle would for example have a scanning function for scanning the ticket from the user's smartphone, the users need to know where the scanner is located on the vehicle.

b. Interaction with functions outside the vehicle should be multimodal

Example: People who suffer from deaf-blindness are in majority not entirely blind or deaf, often with one of the impairments more severe than the other. Therefore, a combination of ways to interact with the interface is needed and was requested in the surveys and interviews. Transport services like taxis, could for example make use of voice command as one way to control the interaction. Gestures is another way people can use to interact with the vehicle's interface. Remember that the feedback from the interaction also needs to be multimodal with for example lights, sound and vibrations. Svensk kollektivtrafik writes that buttons and handles must be easy to use without the ability to see.

Navigation

6. **People with diverse disabilities should be able to catch connecting vehicles just as fast as travelers without disabilities**

a. Make it easy to locate the right vehicle at stations

Example: Solutions should allow people that have impaired sight finding their connecting vehicles fast. People in the interviews said that they now have become used to waiting for the next departure after their intended departure because they had trouble finding the vehicle at the connecting stop. This could be managed by for example navigating audible information. Also, people in wheelchairs expressed in the interviews that they are used to taking detours or other inconvenient ways to get to vehicles. If a person in a wheelchair is trying to catch a connecting vehicle, they should not have to take another longer way than the way people that can walk.

b. If delays or other problems occur, provide multimodal information about alternative routes and where people can find them

Example: In the surveys and interviews, people with impaired sight, impaired hearing, deaf-blindness and cognitive impairments all expressed the difficulties with locating and navigating themselves when unforeseen changes occurs. Finding the replacement bus for a broken train can be a struggle for everyone, but especially for people with disabilities. Therefore, make sure to provide fast and clear multi modal information about alternative routes to reach the user's destination and how they can find the new vehicle.

c. Provide travelers with the possibility to follow the route the vehicle travels in real time.

Example: During the interviews with people with visual impairment, they expressed feeling stressed when not knowing exactly where they are on their rout. Having the possibility to follow the route in real time through their smartphone, could result in a more calm and stress free experience. People with hearing impairment can follow the route visually through a map in their smartphone or on the information display on the vehicle that visually show how far they are from the next stop.

Appendix 8: Result, guidelines - third iteration

1. PROVIDE INDEPENDENCE

All solutions should strive towards helping people become more independent and socially included

Assistive IoT technology tools are effective in increasing independence and making people participate socially. The Senate Department For Urban Development and The Environment (2015) writes that for social participation, mobility is essential. The participation and inclusion of people with disability in social, political, cultural and economic life can be supported by the environment. IoT constructs enabling environments by giving people with disabilities assistance in transportation, building access, information and communication (Domingo, 2011). Being able to travel on your own is a sign of independence, which was pointed out in the interviews and surveys. To be able to do this, users need for example to be able to identify a vehicle as their intended vehicle on their own, without having to ask for help from other travelers.

Survey + interviews ; *independence is truly important.*
Scenarios shows; *examples were the users can do thing on their own , things that they normally (or in today's solutions) needs to ask for help. example "im i on the right bus?"*

- ***Harry*** *normally needs to ask the taxi driver if he is . In the scenario, Harry does not need to ask around, he can use his phone to access information and the facial scanning does the job for him. aka he becomes and feels more independent.*
- ***Sebastian*** *feels "happy" that there are no raps anymore, as it implyes that he needs additional help. if floor of the vehicle and the platforms are the same high / level he needs no additional solution, resulting in him feeling more independent.*

Personas ; *independence can be shown to be important in the majority of the personas.*

- ***Harry*** *wants to be able to "drive" his own car. and he feels frustrated when needing to ask for confirmation if it is his ordered taxi or not.*
- ***Chrissy*** *feels frustrated when information is only given in audio and text based information is not working and when other travelers have to tell her information she could not perceive herself, which makes her feel she´s not independent*
- ***Sebastian*** *needs to feel totally independent, it is important for him.*

3. PROVIDE ACCOMMODATING ENVIRONMENTS

Make sure that the interior of the vehicle, platform and waiting areas are accommodating to the different needs of the users

This can for example be to provide vehicles and waiting areas with hearing loops, or make sure that the locations of displays with information (both outside and inside vehicles) are adapted to also be able to be seen by short people and people in wheelchairs (Svensk kollektivtrafik rapport). Another important thing is to make it easy for people to locate the right vehicle at stations. SRF (Visually impaired federal federations in Sweden) writes that more clear and evident signs with better contrast between text and background are actions that can be crucial for people with visual impairment. They also say that there is a need for a formation and design of vehicles, terminals, stations and platforms that facilitates self-orientation and guarantees security.

4. PROVIDE INFORMATION OF SURROUNDINGS

Provide alternatives for traveling routes and information about surrounding events such as traffic jams, delays and accidents

If delays or other problems occur, provide multimodal information about alternative routes and where people can find them. The Senate Department For Urban Development And The Environment (2015) writes that giving the public information about traffic jams, where there is free parking spaces and different public transportation alternatives, provided this way, increases the traffic flow. It is important to remember that this information needs to be mediated in different ways so that people with diverse disabilities can access the information. This can be done already when the users are planning their trip in the application, when the user is at the station or when the user is already traveling on a vehicle. The vehicle can retrieve information about accidents along the way and can calculate a different route. To provide travelers of the vehicle of this information before actually arriving to the site of the accident, will be beneficial and effective for all. For people with cognitive disabilities such as aphasia, it is important to get unforeseen information as early as possible since improvisation can be hard, if not impossible, for some people with this condition. If users with visual impairments because of unforeseen events ends up at a place that is new for them, they need to know this as early as possible so they that can on their own terms, and based on their own needs better navigate the new area.

5. PROVIDE REAL TIME AWARENESS

The solution should have real time awareness of what is going on in the real world in order to make travelers feel safe.

Smart Computing signifies the new generation of integrated software, hardware and network technologies that can provide IT systems with real-time awareness of what is going on in the real world and use advanced analytics that help people make smarter decisions and optimizes business processes (Chourabi et al., 2012). Solutions with real time situational awareness must grab the attention when it is needed, and have the means to understand what is happening and respond to that situation without delay (Few, p 2). This is connected to making the travelers feel safe while traveling with the autonomous vehicle. The vehicle need to have the ability to recognise objects. Generally, two steps in the process of recognition is applied; detection and classification. There are two classes of objects that are relevant for autonomous vehicles. The first being elements of the infrastructure, such as road marks, road boundaries, traffic lights and traffic signs. The other class is traffic participants, such as pedestrians, bicycles and vehicles (Franke et al., 1999).

Everyday objects, the "things", becomes smart and are able to sense, interpret and react to the environment. This is made possible by the Internet and rising technologies such as Radio-frequency Identification (RFID), embedded sensors and real-time localization (Domingo, 2011).

Interview; *according to interviews, people are sceptic to autonomous vehicles because they do not feel safe. Drivers part is making the traveler feel safe and calm.*
This is also important (as shown in the ***interviews*** *and* ***scenarios****) for travelers that can not see or hear in the same way as others. These people should be able to feel just as prepared and safe as any other in case of emergency.*

Personas; *regardless of attitude against autonomous vehicles, all Personas (based on the interviews and surveys) needs to feel safe when traveling. However in different perspectives.*

- ***Sebastian*** *is positive towards autonomous vehicles,* However, he heard about an accident with that kind of car, which scares him a little.
- ***Chrissy;*** *is sceptical towards autonomous vehicles, as she feels they might not be as reliable as with a driver in spontaneous events.*

- ***Harry;*** *attitude towards autonomous vehicles are divided. If no driver, who is there to ask about things.*
- ***Charles:*** He has a very positive attitude towards autonomous vehicles and believes that excluding a driver would be most beneficial for him. This especially as misunderstandings and frustrations often occurs when communicating with the driver.

Scenarios;

- ***Sebastian;*** *in the scenario a situation occurs where* "suddenly the Shuttle do a rapid break and the passengers are immediately informed through text and audio that the Shuttle had to stop because of a cyclist. The Shuttle are starting to drive again and Sebastian decides that he might use the straps after all."
    - By communication the situation will help the passengers /travelers to feel safe.
- ***Chrissy;*** *she is sceptical towards autonomous vehicles, she feels that a driver could show "more respect and understanding" than a vehicle without. This is shown in the scenario;* "She hurries, and enters the tram just before the doors close. She starts to think that it would never happen if there was a driver in the vehicle, that he would not close the doors if he saw her entering, only to realise it happened to her a few times even before the vehicles became autonomous".
    - *think about adapting functions that are time-based to people that might need more time to react to things, "like a* ***nice*** *driver would have".*
- ***Harry;*** *it is important for Harry to be able to confirm that he is at the right stop or in the right vehicle.* ***These*** *are the things that makes him feel safe. Example in scenario; he can confirm that he is in the right vehicle /taxi and will be driving towards the right address before the vehicle starts to drive. communicate and confirmation is the key to feel safe for Harry.*
- ***Charles;*** *As Charles sometimes has a hard expressing himself and it might take some time to do so, there might be situation where misunderstandings with a driver occurs. Therefore it is important for him to be able to communicate in his own terms, such as where he is going, and using multiple ways of interacting and getting information, for him to be able to feel safe. It is important to not make time-based functions to stressful for the travelers, but rather work with simple commands for them to feel comfortable and safe.*

6. CONNECT SMART DEVICES

Connecting smart devices and sensors to vehicles and traffic situations (IoT) will ease the travels of the users, as it can be more personalized.

Information on a screen should be accessed from own device. Calls can be re-listened on their own initiative on own device.

7. PRESENT MULTIMODAL INFORMATION

All information, inside and outside the vehicle, should be presented in a multimodal way.

G3ict & World Enabled (2016) writes that smart city digital services can be made more accessible by for example making content available in multiple formats. SRF (Visually impaired federal federations in Sweden) writes that there is a need for audiovisual outcalls regarding both the different stops and the destination. In the interviews and surveys, it was requested that information should be presented at least both auditory and visual, and that the visual information should be given just as fast as the auditory information. Around every third participant asked in a study presented by SRF believes that there is a need for more or better outcalls on the vehicles. Almost every fourth person asked wants more and

better outcalls at stations and platforms. When presenting information to travelers, make sure that the information does not become hidden before the user is finished with it, which was expressed as a problem in the interviews and surveys, and is also one of the guidelines given by Dev Gnome. Working with multi-modal ways to communicate danger, changes and unexpected events is very important. In addition to audio and text information, a way to catch travelers attention at for example an emergency situation can be with lights and vibrations. Feedback should also be given to the user in multimodal ways, for example knowing that the stop button reacted to the touch by showing is visually, with audio and also vibration. For people who suffer from deaf-blindness for example, the ability to retrieve multi-modal information on an individual level would be beneficial.

8. PROVIDE MULTIMODAL INTERACTION

It should be possible to interact with the vehicle's interface(s) and surrounding or connected interfaces in multiple different ways.

Kleinberger et al. (2007) writes that "Multi-modal interaction paradigms that combine several modes (e.g., gesture, sound) are a good approach to enhance usability and accessibility." (Kleinberger et al., 2007, p 107). Different users prefer different ways of interacting with interfaces, this especially when it comes to people with disabilities. Some ways of interaction that is natural for one group of people could be impossible for others. Therefore, it is important to provide easy and multiple different (multi-modal) ways to interact with the vehicle both from the outside and the inside. The vehicle should clearly signal to the user where interactive functions are located. With autonomous vehicles, there should be ways for the traveler to request information if needed, if possible equivalent to asking a driver for information. Feedback from the interactions should also be given in multimodal ways.

9. PROVIDE ACCESSIBLE SCREEN INTERFACES

Design screen interfaces to be accommodating for people with diverse disabilities.

There are multiple different guidelines (REF) already existing on how to design usable screen interfaces. This guideline aims to point out some important things to think about when designing for the user groups in this study, in particular people with sight impairments. These points should be applied both on phone applications but also on interactive screens such as payment systems or screens on board vehicles. According to SRF (Visually impaired federal federations in Sweden), every system for planning the trip, traffic information and also purchase of tickets needs to be fully usable for travelers with impaired sight.

- SRF (Visually impaired federal federations in Sweden) writes that one concrete example for improved accessibility for people with visual impairments is that color contrasts needs to be improved. Color contrast between background and text needs to be stronger for it to be easier to read. The screen resolutions also needs to be improved, and people request less moving graphics and more text. People in the survey with visual impairments expressed concern about the contrast and brightness levels not being clear enough.
- Interaction with interfaces should be available both through buttons and voice command. People who suffer from deaf-blindness are in majority not entirely blind or deaf, often with one of the impairments more severe than the other. Therefore, a combination of ways to interact with the interface was wished for in the survey.

- Interfaces should use for example speech synthesis (Svensk Kollektivtrafik rapport) and also allow users to choose the size of the text themselves, by providing the possibility to magnify the text (Dev Gnome).
- Don't use labels that are spelled differently but sounds the same, this because it can be confusing for users that are using screen readers (Dev Gnome)
- Create large clickable areas and make it possible to control the interface with only one finger, and minimize text input in the interface - offer lists with choices instead (Dev Gnome)

Appendix 9: Result, guidelines fourth iteration

1. PROVIDE INDEPENDENCE

All solutions should strive towards helping people become more independent and socially included

Assistive IoT technology tools are effective in increasing independence and making people participate socially. People with disability can be overly dependent on their families or other assistants because of the lack of support services such as building access, transportation, communication and information. This can prevent them from being working, being active and socially included (Domingo, 2011). The Internet of Things can help with support and assistance that people with diverse disabilities need in order to gain a good quality of life and be better included in the economic and social life.The Senate Department For Urban Development and The Environment (2015) writes that for social participation, mobility is essential. IoT constructs enabling environments by giving people with disabilities assistance in transportation, building access, information and communication (Domingo, 2011) ***(read more under 3.6.2 Ambient Intelligence and IoT for people with disabilities)***. Sweden has a law against discriminating people with disabilities (Act of Lag 1999:132 ”Prohibiting employment discrimination based on disability”, 2 §). One way of working against discrimination of people with disabilities can be to include them in transportation solutions, allowing them to be more independent and socially included. Being able to travel on your own is a sign of independence, which was pointed out in the interviews and surveys. While there are many issues related to creating design solutions that address this issue, one example is that users need to be able to identify a vehicle as their intended vehicle on their own, without having to ask for help from other travelers.

Activity theorists believe that people are not just accepting and being satisfied with existing institutional relations, instead they are equipped with the power to act - the human agency - which enables critique and revision (Roth & Lee, 2007). The liberty of choosing one’s actions could be seen as a big part of being independent. Solutions, therefore, need to enable users possibility to choose their actions accordingly.

Both the survey and the interviews showed that independence is truly important for all participants in the study. It also showed the lacking possibility of independence as current solutions sometimes prohibits them to make spontaneous travels on their own. The scenarios connected to these guidelines exemplifies situations where the personas can travel independently. This means that they can act on their own and not being restricted in their travels because of their disabilities. The scenarios shows examples were the users can do things on their own, things that they normally (or in today's solutions) needs assistance with, for example asking the driver or other travelers if they are on the right bus. In **Scenario x**, Harry does not need to ask anyone for information regarding location and identifying his taxi. Instead he can use his phone to access information and the facial scanning unlocks the car and thereby confirming that it is the right vehicle. This leads him to becoming and feeling more independent. Chrissy, as a persona, feels frustrated when other travelers have to tell her information she could not perceive herself because of her hearing impairment, which makes her feel reliant on others. Sebastian is the persona with the strongest need of feeling total independence, it is extremely important to him.

3. PROVIDE ACCOMMODATING ENVIRONMENTS

Make sure that the interior of the vehicle, platform and waiting areas are accommodating to the different needs of the users

This can for example be to provide vehicles and waiting areas with hearing loops, or make sure that the locations of displays with information (both outside and inside vehicles) are adapted to also be able to be seen by short people and people in wheelchairs (Partnersamverkan för en förbättrad kollektivtrafik, 2012). Another important thing is to make it easy for people to locate the right vehicle at stations. Synskadades Riksförbund (2015) (Visually impaired federal federations in Sweden) writes that more clear and evident signs with better contrast between text and background are actions that can be crucial for people with visual impairment. They also say that there is a need for a formation and design of vehicles, terminals, stations and platforms that facilitates self-orientation and guarantees security.

In the survey, people with movement-, visual- and hearing impairments, all expressed that catching connecting vehicles in an easy way is difficult. People with movement impairment also wished for entries and exits to be designed properly for wheelchairs, as well as functional elevators at all stations. In the interviews, both people with movement impairments and visual impairments had problems with the fact that the floor of the vehicle and the platform was on different ground levels. As seen in **scenario x**, the floor of the vehicle and the platform are always on the same level. The personas of Sebastian and Henrietta both wishes for a space for the wheelchairs from where they still clearly can see the information display. When the persona Adriana, who has impaired vision, is changing from one vehicle to another on her route **in scenario x**, there should be accessible tools for her to quick and easy find the location of the new vehicle. In **scenario x**, all relevant information is updated in visual form since Chrissy cannot hear the information from the speakers. Before taking a seat she have to make sure that she can see the display from where she sits. Future solutions should make sure there are no "blind spots" where travelers cannot see the visual information.

4. PROVIDE INFORMATION OF SURROUNDINGS

Provide alternatives for traveling routes and information about surrounding events such as traffic jams, delays and accidents

If delays or other problems occur, provide multimodal information about alternative routes and where people can find them. The Senate Department For Urban Development And The Environment (2015) writes that giving the public information about for example traffic jams and different public transportation alternatives increases the traffic flow. It is important to remember that this information needs to be mediated in different ways so that people with diverse disabilities can access the information. This can be done when the users are planning their trip in the application, when they are at the station, and when they are already onboard a vehicle. The vehicle can retrieve information about accidents along the way and can calculate a different route. To provide travelers of the vehicle of this information before actually arriving to the site of the accident, will be beneficial and effective for all. For people with cognitive disabilities such as aphasia, it is important to get unforeseen information as early as possible since improvisation can be hard, if not impossible, for some people with this condition, which was learnt from the interviews.

In the survey, people expressed that when users with visual impairments ends up at a place that is new for them because of unforeseen events, they need to know this as early as possible so they that can on their own terms, and based on their own needs better navigate the new area. This is exemplified in the persona of Adriana and is therefore a part of her accessibility considerations. This also goes for the persona Sebastian. He too needs information mediated directly if situations such as a an elevator should break, as he

therefore needs to alter his traveling route. In **scenario x**, Chrissy can hear a sound from the speakers but can not identify what the voice is saying. She turns to the big information display at the stop and there she can read that because of an accident, some of the bus lines are delayed. These kinds of multimodal ways of presenting changes and unforeseen events should be considered. Connecting different smart objects might be one way of dealing with this which could be worth investigating.

5. PROVIDE REAL TIME AWARENESS

The solution should have real time awareness of what is going on in the real world in order to make travelers feel safe.

Smart Computing signifies the new generation of integrated software, hardware and network technologies that can provide IT systems with real-time awareness of what is going on in the real world and use advanced analytics that help people make smarter decisions and optimizes business processes (Chourabi et al, 2012). Everyday objects, the "things", becomes smart and are able to sense, interpret and react to the environment. This is made possible by the Internet and rising technologies such as Radio-frequency Identification (RFID), embedded sensors and real-time localization (Domingo, 2011). Solutions with real time situational awareness must grab the attention when it is needed, and have the means to understand what is happening and respond to that situation without delay (Inova Solutions, n.d.). This is connected to making the travelers feel safe while traveling with the autonomous vehicle. The vehicle need to have the ability to recognise objects. Generally, two steps in the process of recognition is applied; detection and classification. There are two classes of objects that are relevant for autonomous vehicles. The first being elements of the infrastructure, such as road marks, road boundaries, traffic lights and traffic signs. The other class is traffic participants, such as pedestrians, bicycles and vehicles (Franke et al, 1999).

As learned from the interviews, people are mostly sceptical towards autonomous vehicles because of the presumed unsafe aspect. According to some of the interviewees, the driver's role is to make the travelers feel safe and calm. This is especially important for travelers with visual- or hearing impairment. These people should be able to feel just as prepared and safe as people without impairments in case of emergency. In **scenario x**, the Shuttle make a sudden break. The passengers are then immediately informed through text and audio that the Shuttle had to stop because of a cyclist. The scenario shows one way of communicating the situation, which will help the passengers feel safe. In **scenario x**, The persona Chrissy reflects on that she almost did not make it to the vehicle, and that a nice driver would have waited for her. One way of solving this could be to create solutions that make travelers feel "seen" by the vehicles, that people notice that the vehicle recognizes objects. The persona Charles is very positive towards autonomous vehicles and believes that excluding a driver would be most beneficial for him. This especially since misunderstandings and frustrations often occurs when communicating with the driver since it is sometimes hard for Charles to express himself because of his cognitive impairment.

6. CONNECT SMART DEVICES

Connecting smart devices and sensors to vehicles and traffic situations (IoT) will ease the travels of the users, as it can be more personalized.

Combining mobile communications, sensors and RFID seems to be very promising to enable more applications to contribute in building the IoT. One example of the development of RFID-based systems is helping people with visual impairment to be guided on buses with handheld devices and RFID (Biader Ceipidor et al., 2009). It is important to think about optimising security, performance and privacy performance in these solutions (Chaouchi,

2013). Solutions need to accommodate other already existing solutions. If not, it could cause problems. Therefore, it is important to research what could be done to ease and facilitate already existing solutions. This could make it possible for people to access information on an individual level that suit their needs, for example reading on their own screen with the text size optimal for that specific user, or listening to a callout from the speakers again in their own device in their own volume and pace.

In the surveys, people with visual impairments are already reliable on different digital solutions to facilitate their everyday life. They think that the ongoing digitalization is a positive thing "as long as the new systems works well with my assisting tools". In the interviews, people with hearing impairments expressed that the digitalization has helped them a lot and they are positive towards future development. This also as many tools are used for communication, both in work and social context, so consider these already existing IT-solutions when designing new ones. In **scenario x**, Adriana uses an additional helping application to magnify the interface according to her preferences. This is one example of how additional tools are used. Smart City solutions should not exclude the use of additional helping aids, but rather complement, enhance or include them.

7. PRESENT MULTIMODAL INFORMATION

All information, inside and outside the vehicle, should be presented in a multimodal way.

G3ict & World Enabled (2016) writes that smart city digital services can be made more accessible by for example making content available in multiple formats. SRF (Visually impaired federal federations in Sweden) writes that there is a need for audiovisual outcalls regarding both the different stops and the destination (Synskadades Riksförbund, 2015). In the interviews and surveys, it was requested that information should be presented at least both auditory and visually, and that the visual information should be given just as fast as the auditory information. Around every third participant asked in a study presented by SRF believes that there is a need for more or better outcalls on the vehicles. Almost every fourth person asked, wants more and better outcalls at stations and platforms (Synskadades Riksförbund, 2015). Working with multi-modal ways to communicate danger, changes and unexpected events is very important. In addition to audio and text information, a way to catch travelers attention at for example an emergency situation can be with lights and vibrations. Feedback should also be given to the user in multimodal ways, for example knowing that the stop button reacted to the touch by showing is visually, with audio and also vibration.

Gilakjani et al., (2011) writes that multimodal learning is most effective if it only includes relevant content in relation to the learning objectives, because of the brain's limited information processing resources. Also, if the persons who are learning from the information are able to control it, they will learn more. Information presented in multimodal formats are more effective when the learner has the ability to interact with it, for example by starting and stopping it or slowing it down (Gilakjani et al., 2011). When presenting information to travelers, the information should not become hidden before the user is finished with it, which was expressed as a problem in the interviews and surveys, and is also one of the guidelines given by Developer.gnome.org (2014). For people who suffer from deaf-blindness for example, the ability to retrieve multi-modal information on an individual level would be beneficial. Since public transportation should be for the public, which includes people with diverse disabilities, there is a need for multimodal information to be presented from different types of media at the same time, for people not to be excluded.

Something that should be considered when designing solutions for autonomous transportation, is that in current transportation solutions which includes a driver, the travelers have the possibility to ask the driver for information. In other words the possibility to request information, not only receive it, which should be considered when designing the new solutions.

If given the situation where Adriana, Chrissy, Charles and Harry are on the same station or vehicle, the same information should to be mediated to all of them, preferably at the same time **(see scenario x)**. Adrana needs auditory information, Chrissy needs visual information, Harry would prefer both but on an individual level, as well as for example tangible notifications in form of blinking lights, and Charles always needs the possibility to request the information repeatedly. Given this situation, one should reflect and accommodate the different needs when designing new solutions. These types of situations also shows the importance of multimodal distribution of information.

8. PROVIDE MULTIMODAL INTERACTION

It should be possible to interact with the vehicle's interface(s) and surrounding or connected interfaces in multiple different ways.

Kleinberger et al. (2007) writes that "Multi-modal interaction paradigms that combine several modes (e.g., gesture, sound) are a good approach to enhance usability and accessibility." (Kleinberger et al., 2007, p 107). Different users prefer different ways of interacting with interfaces, this especially when it comes to people with disabilities. Some ways of interaction that is natural for one group of people could be impossible for others. Therefore, it is important to provide easy and multiple different (multimodal) ways to interact with the vehicle both from the outside and the inside. The vehicle should clearly signal to the user where interactive functions are located. With autonomous vehicles, there should be ways for the traveler to request information if needed, if possible equivalent to asking a driver for information. Feedback from the interactions should also be given in multimodal ways.

It is a challenge for a robot or system to understand a user's natural interaction. But it is necessary for enabling new users to use the robot or system smoothly and intuitively. It is easier to implement a set of hard-coded commands to control the system, but it is troublesome for the user because it does not allow the users to use their natural interaction style. Therefore, it would be beneficial to enable the system to learn to understand the user's natural way of giving commands and feedback by instinctive interaction through for example speech or touch (Austermann, 2010).

All personas includes information regarding prefered interaction, whether it is physical buttons, touch buttons and/or voice command. The different needs of ways to interact depends on their preferences in regards to their disability.

In **scenario x**, Harry interacts with the vehicle by facial scanning to unlock the car and this also is a way for him to get feedback that it is in fact the right vehicle. In **scenario x**, Charles unlocks the vehicle by scanning a QR-code. These are only two ways of showing how two different interactions can achieve the same goal for two people with different disabilities. This being said, it is still possible for one solution to be accommodating for other disabilities as well. What is important to think about is to not use interactive functions that will exclude groups of people. For example, Charles with his aphasia would have problems if the only option was to use voice command.

There is a need for further research of ways to interact with smart city solutions, not only through buttons or voice command, but also for example gestures, facial- or eye movements. However, keep in mind that there should be multiple different ways to interact since people have different levels of capabilities on how they can physically interact.

9. PROVIDE ACCESSIBLE SCREEN INTERFACES

Design screen interfaces to be accommodating for people with diverse disabilities.

There are already multiple different guidelines existing on how to design usable screen interfaces (Nielsen, 1995; Warsi, 2011) which should always be considered. However, this particular guideline aims to point out some important considerations to think about when designing screen interfaces that should be able to be used by the user groups in this study, in particular people with sight impairments. These points should be applied both on phone applications but also on interactive screens such as payment systems or on interactive screens on board vehicles. According to SRF (Visually impaired federal federations in Sweden), every system for planning the trip, traffic information and also purchase of tickets needs to be fully usable for travelers with impaired sight (Synskadades Riksförbund, 2015).

- Synskadades Riksförbund, (2015) writes that one concrete example for improved accessibility for people with visual impairments is that color contrasts needs to be improved. Color contrast between background and text needs to be stronger for it to be easier to read. The screen resolutions also needs to be improved, and people request less moving graphics and more text (Synskadades Riksförbund, 2015). In the interviews and surveys people with visual impairment and deaf-blindness expressed that screens often suffer from poor contrast between background and text, and that the text size is too small. This causes stress for the travelers since they cannot assimilate the information properly.
- Interaction with interfaces should be available both through buttons and voice command. People who suffer from deaf-blindness are in majority not entirely blind or deaf (In Sweden, only 12% of people who suffer from deaf-blindness is estimated to have a total loss of vision and hearing (Rönnberg and Borg, 2001)), often with one of the impairments more severe than the other. Therefore, a combination of ways to interact with the interface was wished for in the survey.
- Interfaces should use for example screen readers (Partnersamverkan för en förbättrad kollektivtrafik, 2012), which according to the surveys also is a tool that is used by participants with visual impairment. The interface should also allow users to choose the size of the text themselves, by providing the possibility to magnify the text (Developer.gnome.org, 2014).
- Don’t use labels that are spelled differently but sounds the same, this because it can be confusing for users that are using screen readers (Developer.gnome.org, 2014).
- Create large clickable areas and make it possible to control the interface with only one finger, and minimize text input in the interface - offer lists with choices instead (Developer.gnome.org, 2014).