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Understanding Information Needs for an Autonomous Bus Service from an Inclusive Design Perspective

Master's thesis in Interaction Design and Technology

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Abstract

The goal of this thesis was to investigate the basic requirements and information needs of people with cognitive impairment who commute in Autonomous Vehicles (AV) buses in order to support an inclusive experience. As a result, four design solutions were developed in this context to investigate and extract key aspects in order to propose inclusive design guidelines.

An iterative design process was applied in this project, which involved researching theory in inclusive design, investigating target users' characteristics, defining users' problems in public transportation, proposing solutions, and assessing the solutions. As a result, seven comprehensive design guidelines were created, complete with references to literature, research, and design solutions. The main goal of creating inclusive design guidelines is to facilitate the accessibility to AV service. The design solutions can act as a reference for designing information signage in the AV context. Finally, the goal of this thesis is to raise awareness among designers and organizations about the needs of people with cognitive disabilities while making design decisions.

Keywords: Autonomous Vehicle, Inclusive design guideline, People with cognitive disability, Interaction design, Information needs.

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Xinshu Li & Premthip Yaowapatsiri, Gothenburg, June 2021

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1
Introduction

This chapter will provide a general introduction of the motivation, the objectives of the research, and the aim of the thesis. It will also introduce the research question, the delimitations of the project, and the ethical considerations.

Over the previous five years, driver-support technologies have continued to be devised and included into mainstream vehicles to support drivers in reacting correctly and making the best judgments, or, in certain cases, to take over the driving activity and launch a sequence of vehicle operations to keep the occupants safe [1]. Advances in technology will help to reduce the amount of accidents and keep people safer on the roads. However, the advantages of using Artificial Intelligence (AI) in transportation will, to some extent, raise concerns about accessibility.

Access to public transportation is a basic requirement for most people, but people with disabilities, particularly those with cognitive impairments, frequently confront transportation issues [2]. When deploying unmanned AI services in public transportation, there will be distinct interactions and requirements from people with cognitive disabilities, that may be different from traditional bus services. Currently, there is no certainty that Autonomous Vehicles (AV) (i.e self-driving cars) will be accessible to the broader disability community when they are deployed [2]. As a result, when adopting AI technology in transportation, it is critical to consider the obstacles that people with cognitive limitations would experience.
The inclusive design concept is involved in this study which focuses on creating products, services and/or environments available for a wide range of users, regardless of gender, age or abilities. The design solutions would enrich all users' experience if as many potential consumers as feasible were included in the design process.

1.1 Aim

The project aimed to improve the AV service for those with cognitive impairments. AV services utilize various sensors and navigation technologies to decrease the possibility of human mistake. However, AI still has limitations while dealing with situations involving people with cognitive disabilities. To accomplish this, interaction design approaches were used to learn about the target group's traits and habits when riding on a regular bus, as well as how to improve their experience on the AV shuttle bus using AI and sensors. The aspects that influence users' experiences were first discovered through research. Furthermore, prototypes were designed to validate

users' information requirements in the context of an AV shuttle bus. The ultimate goal was to develop inclusive design guidelines for AV shuttle buses for both people with and without cognitive impairment.

1.2 Delimitations

This thesis project focuses on identifying the information needs of people with cognitive impairments in public transportation and developing solutions to meet those needs. This is due to the time constraints of this thesis, which does not allow for further investigation of elements that influence users' traveling experiences. This study will not look into how to improve the physical settlement of an AV bus. Also, the trust issues that arise in AV services will only be studied on a theoretical level. Personas, prototypes, and inclusive design guidelines are included in the final outcomes, which should serve as a useful tool for future implementations of accessible AV bus systems.

1.3 Research Question

This thesis aims to understand the information needs for an AV bus service, the research questions include two perspectives:

- What are the basic requirements and information needs that people with cognitive disabilities have, when travelling with public transportation?
- What are inclusive design challenges and opportunities for an Autonomous Vehicle service?

1.4 Ethical Considerations

When discussing or referring to a specific group of individuals, it is important to understand the meaning behind the term. Using inappropriate or disrespectful language may make people feel excluded. Based on the authors' research on this topic, referring to people with impairments, disabled people or people with disabilities seems to be the least offensive terms to use.

Moreover, the management of personal information of participants in user testing and interviews is an ethical consideration in this project. Sensitive information on cognitive impairments must be handled with caution. In addition, the data acquired must adhere to the norms of the General Data Protection Regulation (GDPR), and participants must sign an agreement form before to the testing.

2
Background

The context of the thesis is around RISE Mobility and systems connected to the next phase of trials using Autonomous Vehicle shuttle buses at Lindholmen. The self-driving minibus, which can undertake driving functions, was introduced at the beginning of 2021, however a bus steward is required onboard to monitor the the vehicle's safety. The initial route is within Lindholmen from the bus stop Regnbågsgatan to the Hugo Hammars Kaj.

2.1 Artificial Intelligence and Autonomous Vehicles

The application and development of Artificial Intelligence (AI), to enhance the performance and to create extraordinary opportunities or experiences, is gradually entering society. This trend is spreading throughout several industries, including transportation [3]. AI is a technology that is used to automate monotonous jobs that are traditionally handled by humans, and it has already become a part of our life. The autonomous vehicle, often known as a self-driving car, has become a hot topic in recent years while debating the most popular AI breakthrough. It is believed that modern transportation can use AI to automate routine tasks by planning the most convenient and fastest route as well as make decisions under some uncertain dynamic situation (e.g. driving on a slippery road or auto braking when a car is too close to a front car). Self-driving car utilizes a combination of AI techniques which are primarily based on navigation and computer vision to identify the surrounding environment. To prevent accidents, these technologies should work in tandem.

Buses and vehicles have many similarities, yet there are significant distinctions in how they are used. A bus is typically a shared space, where only one person (the driver) control the vehicle [4]. Due to the complicated information and tasks involved in the driving process, it is not possible to take control in the same way that it is in a personal car. There have been various demonstrations of AI's usefulness in public transportation, such as public safety, traffic patterns, corporate decision making, etc. For instance, a smart traffic light that can predict future traffic and can also automatically detect accidents [5].

Many sensors and AI algorithms are collaborating to solve transportation difficulties. This project, however, will not be focused on introducing smart sensors, but rather on the experience that can be created using the sensor and AI of the Autonomous

Vehicle shuttle bus.

2.2 Autonomous Vehicle Service and S3 Project

The S3 project is part of the government's collaboration program "Next-generation travel and transport" and is funded partly by Vinnova through Drive Sweden at Lindholmen Science Park. The initiative is led by RISE Research Institutes of Sweden.

In 2018 and 2019, two routes had been tested in Lindholmen and Chalmers Johanneberg Campus and currently a third route covering Regnbågsgatan - A Carlssons gata -Hugo Hammars kaj is being tested. This self driving minibus with 10 seats, reduces the need for parking spaces, which will stimulate the densification of the city. The goal of the project is to test how new, shared transport solutions can contribute to continued sustainable city development. The coalition that makes this possible includes Keolis, RISE, Chalmers, Göteborgs Stads Parkering AB, Ericsson, Västtrafik, Johanneberg Science Park and Härryda Municipality.

Figure 2.1: Pilot tests with self-driving mini buses in Gothenburg - Retrieved from S3 Project Website (2021)

Figure 2.2: The route of Automated Shuttle Bus - Retrieved from S3 Project Website (2021)

2.2.1 Design and Development of Autonomous Vehicles

As machines become increasingly capable, AI can take over some of the activities, reducing the burden on humans to a certain extent. Autonomous Vehicles utilizing AI modules and sensors to navigate and drive, have generally replaced manual controls in public transit. The evolution of Autonomous Vehicles could be traced back to 1939 when the first recorded concept of an autonomous car was introduced in New York World's Fair in the Futurama section [6]. Afterward, motors and cameras were developed to adapt the robotic vehicles. The goal of the Autonomous Vehicle concept is primarily to make driving efficient and safe. As the development of self-driving cars progresses rapidly, numerous companies are working on developing self-driving cars. Leading automobile manufacturers such as Tesla, NAVYA, Waymo, etc. have already launched their autonomous cars.

Utilizing AI and sensors, Autonomous Vehicles could detect possible collisions and steer vehicle safety and decrease accidents. While riding on automated vehicles instead of driving private cars, people would have more time to work, which benefits people by enhancing productivity. Moreover, regarding people with difficulties driving cars, automated vehicles could assist by increasing their self-reliance.

2.2.2 Levels of Driving Automation

The Society of Automobile Engineers (SAE) released the "Levels of Driving Automation" Standard for Self-Driving Vehicles in 2018 [7], illustrated 6 levels of au-

tomation: *No Driving Automation*, *Driver Assistance*, *Partial Driving Automation*, *Conditional Driving Automation*, *High Driving Automation*, and *Full Driving Automation*.

- Level 0 - *No Driving Automation*. Most vehicles on the road now belong to level 0 which is total manual control. Humans are responsible to perform all driving tasks such as braking, steering, accelerating, etc.
- Level 1 - *Driver Assistance*. Level 1 is the lowest level of automation. The vehicle could assist the driver in a single automated function, such as steering or accelerating, while the human driver needs to monitor the other aspects of driving.
- Level 2 - *Partial Driving Automation*. The vehicles in level 2 featured with an Advanced Driver Assistant System (ADAS) which could control both the steering and accelerating
- Level 3 - *Conditional Driving Automation*. Level 3 is substantial from a technology perspective compared with level 2. Level 3 vehicles have the capabilities to detect environmental conditions and perform decision-making on themselves. However, this still requires human override and the driver must remain alert and ready to take control of the vehicle whenever the system is unable to execute the task.
- Level 4 - *High Driving Automation*. For this level of automation, the vehicles can intervene in the system failure, thus it doesn't require human interaction in most circumstances. But humans still have the option to manually override. Level 4 vehicles are capable of all operating tasks and respond similarly to human control such as steering, braking, accelerating, responding to events, etc.
- Level 5 - *Full Driving Automation*. Level 5 vehicles do not require human attention during the journey, they have the capabilities to monitor the environment and work in dynamic situations. Level 5 vehicles will not be equipped with steering wheels or acceleration/braking pedals.

The AV bus tested in S3 Project belongs to the autonomous level 4, the bus has capability to monitor the situations and provide appropriate operation itself. Currently, there still requires a steward on board according to Swedish regulation and laws to ensure the security of the bus.

2.2.3 NAVYA Automated Vehicles

The researched AV bus was manufactured by NAVYA which is a leading French company providing self-driving solutions. In 2015, the fully autonomous, driverless, and electric Autonom® Shuttle was launched as a first and last mile passenger transport solution [8]. At the time of writing (2021), Autonom® Shuttle is applied in 21 countries including the United States, France, Germany, Sweden, Japan, etc. The automated shuttle busses tested in the S3 project were manufactured by NAVYA named Autonom® Shuttle Evo.

Autonom® Shuttle Evo was designed with 10 Lidar sensors to map the environment, guarantee precise positioning, and detect the obstacles. The camera on the top of the bus provides a video stream recording for data analysis and remote monitoring. Furthermore, GNSS antenna and 4G/5G ensured the positioning of the bus and communication within the bus equipment. Autonom® Shuttle Evo can transport up to 15 passengers with 11 seated and 4 standing on public or private roads. On average, the shuttle bus can operate for 9 hours straight and run at 25kph maximum speed.

The Navya Driver® software has a backbone of 3 modules: Perception, Decision, and Action. The Perception module mainly allows the vehicle to understand the surroundings and to anticipate movement. Utilizing sensors and cameras, data is collected and then processed through the software. The information regarding obstacles, behavior, speed, and estimated position is then transmitted to the Decision module. The Decision model calculates and determines the route and path of the vehicle. The trajectory and driving commands are sent to the Action module to control the performance of the vehicle [9].

3

Theory

In this chapter, the theory used for this thesis will be presented. The *Research through Design* model will be initially introduced as the project's foundation. Thereafter, the trust model that emerged in autonomous services, as well as human bus drivers' role in public transportation, will be examined. Theories related to inclusive design, cognitive impairment, and accessibility guidelines will also be presented.

3.1 Research Through Design

Research through design (RtD) is research for a specific solution to a problem. RtD commonly engages in the form of implicit conceptual work by highlighting important issues, dimensions of similarity, and criteria for choices and success [10]. A model of interaction design research was created in earlier academics demonstrating an active process of ideating, iterating, and critiquing potential solutions. Firstly, there are mainly three resources that could inspire designers in research including the new technological opportunities, the anthropological data, and behavioral theory/model gaps. Secondly, interaction design researchers create artifacts that provide concrete embodiments of theory and technical opportunities. Finally, the research contributions should be artifacts that demonstrate significant invention. [11].

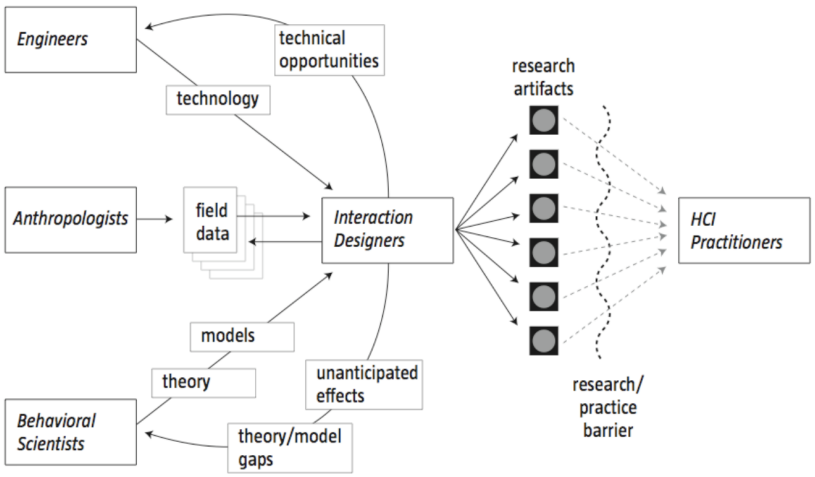

Figure 3.1: A model of interaction design research within HCI research (Zimmerman et al, 2007)

3.2 Trust in Autonomous Vehicles

Trust is a crucial precondition for users' good experience on Autonomous Vehicles. Design for trust could enhance users' acceptance. According to earlier research, people generally had lower expectations of autonomous cars compared to human drivers, they were more forgiving of the misbehavior. On the other hand, users would have higher expectations based on the fact that automated cars can eliminate human error [12].

According to the Full model of factors that influence trust in automation [13], they engage two phases of trust, prior to interaction and during interaction with AV bus. In the pre-use phase of Autonomous Vehicles, user trust is primarily based on three layers of trust: dispositional trust, situational trust, and initial learned trust. These factors can turn out to be initial reliance strategies and are mainly affected by personal knowledge.

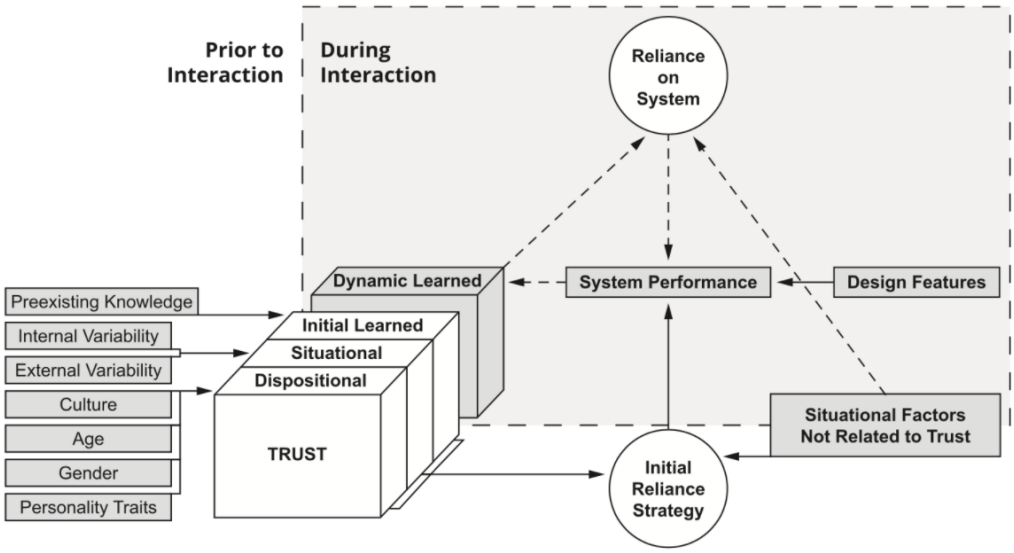

Figure 3.2: Full model of factors that influence trust in automation(Hoff , 2015)

When interacting with the AV bus, user trust is affected by the performance, purpose, and process information provided directly by the AV and interpreted by the user [14]. The way how AV perceives users' information and how AV assists users in understanding system functionality and capability are the main factors. Furthermore, the predictable and benevolent driving behavior of autonomous vehicles would increase users' trust in the bus. Robots with smoother, more fluid movements, and a speed that allowed users to react, were perceived as more trustworthy [15]. The reliability of robotic systems and the ease of interaction with those systems can break down the barriers of communication between human and robot [16]. Thus, increase users' trust in AV service can benefit users' experience.

3.3 Inclusive Design

There are various meanings of Inclusive design. One of the meanings is the principle that focuses on creating products, services and/or environments available for a wide range of users, regardless of gender, age or abilities. The goal of this design is to make people's life easier by making a usable product for more people. [17]. Another meaning is Inclusive design is the concept that includes a significant segment of people in society that are frequently missed out or set aside [18]. The core challenge of using the inclusive approach is to understand the wide range of people who are affected by a design decision.

In recent years, there are many movements to include disabled people and older people into mainstream society through an inclusive approach [19]. For example, website design may apply accessibility guidelines (such as WCAG). Inclusion is becoming more common in mainstream products and services that produce content. Also, the requirement of communicating with people with disabilities prompts designers to develop innovative devices that later became universal. For example, both the typewriter and the commercial email client were born out of a need to communicate with blind and deaf people. Design opportunities are generated based on the needs of those with impairment [20]. People with cognitive disabilities should also be included in the evaluation process so that their behaviors and thoughts while using a product may be fully understood.

Moreover, the design method Persona is an excellent approach to create awareness of users' demands throughout an inclusive design process [21]. Creating personas with data from disabled people is a way to create inclusion in the design and learn about the different types of disabilities, limits, and restraints that people have when using digital services [22].

The inclusive design project aims to include people who are the overlooked population in the design process. Designers have the responsibility to design open solutions not only just for the profession but also for users and society. Also, designers should eliminate discrimination against people with disabilities as a group and uphold their rights to participate in society. The expected result is that everyone is able to have access to the services.

3.4 Cognitive Impairment

Cognitive impairment can be a temporary or permanent condition. It can be categorized from mild to severe conditions. People with a mild impairment may notice their change in cognitive functions such as memory loss or language problems, but they still are able to perform everyday routines. People who have a severe level of cognitive impairment can lose the ability to understand, talk or write, leading to loss of their daily independence [23]. The cognitive impairment can come from the environment that causes the decline in cognitive or functional abilities for example

alcoholism, stress, economic or infection, etc. [24]. Also, there are some situations that allow people to temporarily lose their cognitive abilities, for example, a dark place where is difficult to see the surrounding environment or a noisy place where people cannot easily communicate with each other.

There are four different types of cognitive impairments which are Emotional Impairment, Intellectual Disability, Learning Disability, and Brain Injury [25]. The result of cognitive impairment causes a wide range of difficulties in public transportation.

3.4.1 Emotional Impairment

Emotional impairment is a term that covers many types of emotional and mental disabilities. There are more than 200 types of mental disorders, the most common ones include anxiety, bipolar syndrome, depression, dementia and schizophrenia [26]. People with emotional impairment have changes in personality and habit which can affect social life. Their mental health will be significantly affected by excessive stress from an unpredictable situation during their transit. They might find it difficult to cope with the situation and may need to ask several times for clarification and direction or reach out to staff or other passengers for support [26][27].

3.4.2 Intellectual Disability

Intellectual disability affects cognition, skills and self care. This limits a person's abilities and skills necessary for everyday life, such as learning, maturation, personal independence and social responsibility [28]. Intellectual disability is a disability in the brain. A person with an intellectual disability may need more time to understand, remember, learn new things, express thoughts and feelings. Intellectual disability can happen any time before a child turns 18 years old, even before birth. This can cause a child to develop and learn at a slower pace or in a different way than a typically developing child [29].

3.4.3 Learning Disability

Learning disability is due to genetic and/or neurobiological factors, and it can affect each individual differently. Learning disabilities significantly reduce the intellectual ability and increase difficulty with everyday activities such as reading, writing, speaking, reasoning, learning new skills, understanding complex information or situations as well as interacting with people [25]. People with learning disabilities need support in learning basic skills in their life.

People with learning disabilities may have trouble with fine-tuned motoric movement. Some people may lose processions or cannot follow direction. Hence, it is crucial for people with learning disabilities to learn how to make his/her needs known [27].

3.4.4 Brain Injury

Acquired brain injury is not congenital injury, it can be caused by illness or accident. People with Acquired brain injury would experience tiredness in the brain and a reduced ability to concentrate and remember. They need more time to finish tasks or to acquire new information.

Some common cognitive diseases have the combination of the symptoms above, which include Attention-Deficit / Hyperactivity Disorder (ADHD), Autism, Down Syndrome, etc [30].

- ADHD is one of the most common neuropsychiatric disabilities. Characteristics of ADHD are difficulties with maintaining attention over time, braking and controlling impulse and keeping the body still.
- Autism is a disability that involves difficulties with social interaction and mutual communication. People with Autism also have conditions of limitation in society in repetitive behaviors, interests, and activities.
- Down syndrome is due to a different set of chromosomes that leads to a developmental disorder. The symptom of Down syndrome appears in limitations of cognitive abilities, learning difficulties, or slow learning and physical growth, as well as special facial features.

This report will not focus on covering a total range of cognitive disorders. Because of the wide range and complexity of disorders, each individual may have a similar or different reaction to the same situations even though they have a similar impairment. Also, people with cognitive impairments can have more than two disorders. Cognitive disorders may affect every point of the transit journey. Each person with cognitive impairments must be treated in a unique manner, in each situation. In this project, we focus on people who were born with cognitive disabilities.

3.5 Improved Accessibility to Public Transport for people with cognitive impairments

For people with cognitive impairment or mental health problems, travelling on public transport can be a challenging experience. There is a significant requirement on the public vehicles' functions to meet the needs of people with cognitive disabilities. During an automobile journey users engage in a series of high-level activities that include planning, waiting, and moving. This can be further analyzed as a cognitive process of reflecting, choosing, and acting [31].

A significant problem for people with cognitive impairment when using public transportation is that it requires sustained attention and concentration when identifying and understanding navigation artifacts. Therefore, it is necessary for users to comprehend, manipulate, and process "essential navigation artifacts", such as maps,

schedules, labels, landmarks, and clocks [32]. Also, unusual situations such as system or user errors may cause some individuals with cognitive disabilities to panic. For many of them, maintaining a travel routine is important. In addition, caregivers express worry about their families' safety when they lack an opportunity of checking their progress on transportation [32].

On the other hand, research had pointed out unfamiliar users who are learning the route might face the same problem as people with cognitive disability [31]. A human-centered design for transportation systems can improve the experience for everyone.

The International Transport Forum [33] had designed universal solutions on public transportation system for cognitive impairment which include 7 essential points:

1. Travel awareness training prior to the journey to help people build confidence and develop coping strategies.
2. Timetable and other pre-journey information can help people who are not familiar with public transport and provide them with clear basic information.
3. Journey information should be provided in both audible and visual formats.
4. Keeping information/signage simple and clear.
5. Having staff available on vehicles and at interchanges, and front-line staff should be trained to recognise, assist people and to show empathy.
6. Station/interchange design and layout should be simple and uncluttered.
7. Requirement of technical aids, for example to help those who cannot remember a route.

Katharine et al studied which tools were considered to be the most useful for people with cognitive impairments. They discovered that the medium involved with human contact is the most useful tool when assisting people with cognitive impairment. They established a rating system for each tool and found that the highest-rated method was driver announcement, followed by customer service and visual signs. The survey also stated that there were no obvious solutions to the problems people with cognitive disorders face when traveling on the routine route. The most common and important techniques in training people with cognitive disabilities are the matched bus schedule, repetition and personal trained guide. The paper stated that standard and simple information (e.g. text, graphics, symbols, visual and audio signal, and announcement) reduced anxiety for people with cognitive impairment [25]. On the other hand, involving a bus driver is a crucial part of the transit journey. By creating awareness via training, encourage a driver to have a better understanding of people with cognitive disabilities. The training would enable the drivers to feel more comfortable serving passengers with cognitive impairment in each situation individually.

3.6 The Role of a Bus Driver for People with Cognitive Impairment

A bus driver's role is critical in the experience of a person with cognitively impairment during public transportation. Bus drivers can either create difficulty or make it easier for this target group during the trip. The behavior of a bus driver and service has a significant impact on passengers both physically and mentally. One study of travelers' complaints to a local transit in Stockholm demonstrated that the most commonly reported comments were related to boarding or exiting buses. Some drivers present rude attitudes or behaviors and used abusive words while communicating with passengers with disabilities [34]. For instance, some bus drivers ignored to help passengers when they asked for help with the ramp or lowering the bus. Some drivers also used rude language or mocked people regarding their disabilities as well as threatened them. In such cases, the passengers felt uncomfortable asking for help from the bus driver. Because of the lack of assistance from the drivers, they were helped by other passengers at the end. Due to such complaints, travelers expected that the transit company must provide educational training to bus drivers about sensitivity and awareness so that they meet the needs of different groups of people [25][34]. Due to the complexity of cognitive disorders, bus drivers should handle this target group on an individual basis. Bus drivers should use common sense to defuse the situation and treat them with respect and dignity [34].

3.7 Information Visual Design in Transit

3.7.1 Universal Visual Design Guidelines of Transit

The Federal Transit Administration created a basic design guideline about transit facilities and signage systems. The core requirements for signage designs are to be concise and informative, and to be understandable by all travelers who use the systems. In this guideline, there are three principles [35] :

1. Defining and understanding the needs of users. It is necessary to understand the user characteristics and needs before designing the information signage.
2. Applying the principles of wayfinding design. The term wayfinding is used to describe the process of reaching a destination, whether in a familiar or unfamiliar environment. The wayfinding settings should be placed out in a pattern that allows people to (1) determine where they are in relation to the rest of the environment, (2) determine that their destination is within the journey, and (3) plan a journey of action that will guide them from their current position to their desired destination.
3. Providing basic guidelines for copy style and size, terminology, uniform symbols, colors and shapes, and placement of signs.

3.7.2 Designing Visual, Direction and Information Signage for People with Cognitive Impairments During Traveling

The three design principles created by the Federal Transit Administration focus on a more general population. There is also some literature only dedicated to the design guideline for passengers with cognitively impaired. From the literature research, most of them have similar guidelines, concerns and suggestions to create effective signage. The guidelines can be summarized into three categories:

1. **Navigation**: It is necessary to have a synchronized schedule that has set arrival time of the bus and also provide clear information to confirm progress and identify bus locations, routes along with stops to get on and off [32].
2. **Content**: The sign should use a proper color code and brightness, it must also follow standard symbols and pictographs which are helpful in training persons with cognitive impairments. The printing should be big and should not be printed on a glare surface. The content should be easy to read, and it should use simple words [36] [37]. Pairing the message with other sensory approaches, such as vibration, tactile or auditory text, would help people who are uncertain or anxious to receive a precise message and confirmation [32]. The text approach is not only a way to communicate with passengers but photos of the destination can help reassure passengers with intellectual disability. The overall sign should be minimal in order to be clear and unambiguous [32].
3. **Accessibility**: The information should be accessible to all. It must allow everyone to access and receive the same message. The information should be both audible and visual information [23]. The voice should be queryable and understandable by users. No matter the method of query the information(e.g. voice or text), the application or signage should provide suggestions for failure or success [36]. Lastly, the designers should be aware that if there are any changes to information, the content should be updated as soon as possible to avoid potential confusion.

3.7.3 Related Work

This section will present the existing design solutions related to effective visual signage for people with cognitive impairment. These designs and studies directly or indirectly provide target users with a fluent transportation journey. The examples can be found below.

A script: Using visual tools can help people with autism to cope with unexpected events such as missing the bus. This can be a script in text or picture form. The script should detail every step needed when using public transportation (e. g. What should they do when the bus is late, How to offer the seat, What to do if their journey does not go according to their routine, etc) [38].

Footprints: This is a design approach that can be normally seen in public or pri-

vate places. There is an experiment in Liverpool, England. The researcher painted an intuitive, large and uncomplicated footprint with the word “Bus” written inside it on the pavement. This represented the direction to the bus stop [33].

The landmark pictograms: The local public transportation in Umea, Sweden places a well-known landmark pictogram on the side of the public bus. This helps people with cognitive impairments to memorize and recognize which is the direction the bus will head toward [33].

These ideas assist people with cognitive disabilities in the transportation context which can be used to inspire the ideation in this project.

4

Methodology

This chapter will describe the intended methods to use for accomplishing the aim of this thesis. The design process will follow the *Double Diamond* model, which involves four phases: *Discover*, *Define*, *Develop*, and *Deliver*. In each of these phases, relevant methods will be introduced.

4.1 Design process

This thesis project would follow the Double Diamond design process created by the Design Council [39]. In this framework, the design process is divided into four distinct phases: *Discover*, *Define*, *Develop* and *Deliver*, which maps the divergent and convergent stages of the design process.

1. In the *Discover* phase, the objective is to diverge the design thought. Through implementing literature and user research, insights of users' behaviors and potential improvements could be figured out.
2. During the *Define* phase, insights from the previous stage are analysed, defined and refined as problems. Ideas of the potential solutions are pitched and prototyped.
3. The principle of the *Develop* phase is to prototype and iterate the concept. When testing the concept, feedback should be provided by target users through communications.
4. In the *Deliver* phase, a product or service should be designed and it should solve the problem identified in the Discover stage.

4.2 Discover

4.2.1 Literature Review

A literature review is a method to discover knowledge in research. Literature review mainly includes two parts: Summary and Synthesis [40]. Summary usually involves a recap of the important information from the literature. Synthesis is a reorganization of the information in a way to assist investigate a research problem. Literature review can be conducted at the beginning of a project to locate research within the context of existing literature and to understand the research problems being studied. Further, an analysis of the literature could be conducted to discover the

relationships and conflicts among previous studies. However, one critical factor of literature review is that finding relevant and credible sources takes time.

4.2.2 Expert Interview

Expert interview is a method to discover many aspects and identify issues during a design process. An expert is a person who relates with a target group in some ways and that makes them understand the user behaviour. Experts can often provide a systems-level view of a project area, and offer the perspectives of organizations [41]. Also, experts can identify usability problems in compliance with heuristically known guidelines, and principles of usability-related fields. However, since experts are not real users, this technique will be unable to comprehend target users' thoughts. Before interviewing experts, it is better to choose experts with varying points of view to avoid the same opinions [41]. Moreover, it is essential to prepare an interview guide and ask the researched questions in order to find certain regularities.

4.2.3 Autoethnography

Autoethnography is typically defined as a form of qualitative research in which an author puts one's own self at the center of cultural analysis [42]. It involves self-observation and reflexive investigation in the context of ethnographic field work [43]. Autoethnography has the advantage that it is easy to access the data since the researcher or designer calls on his or her own experiences as the source from which to investigate a particular phenomenon [44]. On the other hand, even though researchers and other users had the same experience, different individuals will tell various stories about it [45]. In this case, researchers will have a different perspective and bias on the result. An autoethnography method can be conducted at the beginning of a project to assist researchers to have a rough understanding of the subject.

4.2.4 Field Observation

Field observation is a qualitative data collection method, which is used to observe the naturally occurring behavior of target users in natural situations. Through conducting field observations, it becomes easy to understand users' behavior, habits, needs, and social relations in the actual environment [46]. Also, field observations can provide information from the perspective of the observer instead of relying on other's verbal interpretations of situations. However, the result of field observation is described by researchers, it is difficult to speculate about the motivations of users' interactions with the product or service.

4.2.5 Survey

Survey research is a method that concentrates on a mass of unconnected individuals to gain information and insights into various topics of interest [47]. Simple surveys can be done utilizing online questionnaires to gather public opinions and their concerns. Online surveys have several advantages. In an online research study, the

margin of error is low, as the respondents register their responses by easy selection buttons. Also, since all the responses are registered online, it is straightforward to analyze the data in real-time [48]. Surveys, however, have the disadvantage that researchers can only get information from what people write, with no opportunity to ask follow-up questions.

4.3 Define

4.3.1 Affinity Diagram

An affinity diagram organizes ideas, problems, and solutions into related groups after brainstorming [49]. The purpose of a project should be identified initially, in order to decide on a logical set of related categories for grouping. The insights from other research methods should be summarized and organized according to categories. Duplicate issues need to be combined and simplified. The goal of an affinity diagram is to organize a large number of fragmented uncertain information into logical cohesive groups [49]. One limitation of affinity diagram is that the categories are determined by researchers which means the results may be biased.

4.3.2 Persona

A persona is a fictitious user constructed from different types of field data such as interviews, surveys, observations, etc [50]. Compared to segmentation, personas are with the focus on the problem embraced in the real research context. Within a persona, it usually includes the ingredients such as the background, problem, needs, and goal of the person. Personas allow researchers to put themselves in the shoes of these archetypal users, thus the design decisions can be made with the concern of user experience [51]. However, personas rely heavily on the quality of data gathered, and inaccurate user data may lead to design misdirection.

Furthermore, personas are useful tools in inclusive design projects. It can be used to raise awareness of universal design and accessibility needs of people with disabilities [21]. Personas should be based on experiences with and information from real users. In this case, they can either be people with disabilities themselves or others who aid people with disabilities or research issues in the studied field [21]. When creating a persona, real-life stories should be filled in and connected. Later in the project, project participants need to remember these stories and keep the personas alive in mind. Within a project, it is found that three to six personas with diverse and different abilities is a manageable amount of work and covers important aspects of the target groups [21].

4.3.3 User Journey Map

User journey map is used to map the interaction between the customer and the service or product over time [52]. Utilizing the analytical data from interviews and surveys, users' touchpoints in the research context can be concluded. An empathy

map should be created to determine the user's needs and feelings throughout the experience. Therefore, the barriers and sources of annoyance during the journey could be figured out. The quality of user journey maps, on the other hand, is determined by personas and user data. User thoughts and problems were assumed by researchers, which may be inaccurate. The goal of a user journey map is to figure out how customer experiences meet customers' expectations and to find areas that need improvement [52].

4.3.4 How Might We (HMW)

How Might We questions are used to reframe the insight statements into opportunities for design. A properly framed How Might We question doesn't suggest a particular solution but provides the perfect frame for innovative thinking [53]. However, the inappropriate question may lead to design misdirection. Utilizing the How Might We format questions can offer designers the chance to answer them in a variety of ways and inspire Brainstorming process.

4.4 Develop

4.4.1 Google Design Sprint

The design sprint is a method proposed by Google to inspire business strategy, innovation, behavior science, and design thinking in design teams. The sprint involves a five-day process for answering critical business questions through design, prototyping, and testing ideas with customers [54]. The tasks to be done in the process can be various, but usually, on Monday, the design focus should be defined; on Tuesday, solutions should be sketched on paper; on Wednesday, ideas should be determined and turned into a testable hypothesis; on Thursday, a high-fidelity prototype needs to be created; and on Friday, the prototype should be tested with real users. Working together in a sprint, design teams can shortcut the endless-debate cycle and compress months of time into a single week. Also, design sprints enable teams to fast-forward into the future to see the finished product and customer reactions, before making any expensive commitments [54]. On the other hand, the risk that must be addressed while adopting design sprints is that there is little time to dive deeper into all of the concepts throughout the sprint period.

4.4.2 Crazy 8's

Crazy 8's is a fast sketching exercise that challenges people to sketch eight distinct ideas in eight minutes [55]. The sketches in crazy 8's do not need to be perfect or beautiful, they just need to communicate the idea. The goal is to push beyond the first idea, frequently the least innovative, and to generate a wide variety of solutions to the challenge. Crazy 8's has a constraint in that everyone comes up with ideas on their own and there is no collaboration.

4.4.3 Scenario Based Design

User scenarios are valuable aids to visualize aspects of design solutions that users might appreciate most in their contexts of use and with their unique needs and motivations [56]. Scenario-based design illustrates taking a problem at its root and focus on creating a user-centric solution [57]. Through mapping out the scenarios in the research context, possible paths can be proposed. Important ingredients of the use scenario include the users' background, motivations, tasks, and context. Scenarios, however, have the disadvantage of being fictional, and hence may have an impact on design solutions.

4.4.4 Storyboard and Sketching

A storyboard is a graphic organizer that consists of illustrations or images displayed in sequence. The global storyline should be initially clarified with the steps of the story and the way of communicating them in images [58]. Afterward, the story should be converted into quick sketching on paper. It is important to make the sketch clear for the readers to understand. A storyboard should then be presented to stakeholders and target users to get feedback in order to iterate. However, while creating a storyboard, designers may bias the story and make it restricted.

4.4.5 Role-playing

Role-playing, also called experiential prototyping, is often used during co-design sessions. It allows to designer to explain a service or product idea by acting out an exemplificatory scenario of use [59]. The role play typically requires to define some roles (e.g. the user, the service employee, etc.) and prepare rough prototypes or other materials that can facilitate the performance [60]. When physically reenacting scenes and situations that are considered to be improved, it is easy to get the sense of what the experience may actually feel like and where it needs improvement. While role-playing has its disadvantage that researchers are unable to act in the same way as real users and be empathetic.

4.5 Deliver

4.5.1 Wizard of Oz

The Wizard of Oz method is a process that allows a user to interact with an interface or product without knowing that the responses are being generated by a human rather than a computer [61]. Commonly, there is someone behind-the-scenes who is providing the feedback according to users' interactions. Wizard of Oz can be used to test whether the potential functions in the system would work before investing the time and money to developing prototype. When creating a Wizard-of-Oz prototype, a hypothesis of the design improvement needs to be defined first. Then the method of how to fake the functionality need to be figured out in order to provide users a realistic experience. In this case, the risk of faked functions not corresponding the

real system should be considered. The outcome of Wizard of Oz test is to verify the design hypothesis.

4.5.2 Heuristic Evaluation

Heuristic evaluation is a usability engineering method for finding the usability problems in design [62]. Heuristic evaluation should be used in conjunction with usability testing. Ten usability heuristics were defined by Nielsen and Molich include: Visibility of system status, Match between system and the real world, User control and freedom, Consistency and standards, Error prevention, Recognition rather than recall, Flexibility and efficiency of use, Aesthetic and minimalist design, Help users recognize, diagnose, and recover from errors, Help and documentation [63]. Involving multiple evaluators, different problems within the design would be figured out. The output of the heuristic evaluation method is a list of usability problems in the service with the opinions of the evaluators in each use case. These issues should also be prioritized in terms of severity to assist when making decisions in design. On the other hand, heuristic evaluation is typically performed by experts, and experts' opinions may differ from real users. Also, the assessment standards are designed for testing website usability which may not be appropriate for physical services.

4.5.3 Cognitive Walkthrough

Cognitive Walkthrough (CW) is used to examine the usability of a product. In contrast to heuristic evaluation which is a holistic usability inspection, CW is a task-specific approach [64]. Usability experts will evaluate the product by completing a variety of tasks and answering how they would complete the task. However, this may result in the limitation that the experts' opinions may differ from those of real users. The common usability questions used in CW include "Will the user know what to do at this step?" and "If the user does the right thing, will they know they did the right thing, and are they making progress toward their goal?" [65]. CW can provide researchers with quick feedback and assist in making design decisions.

4.5.4 Think-Aloud Protocol

Think-aloud is the concurrent verbalization of thoughts while performing a task [66]. Think-aloud is used to gather qualitative data in usability testing during product development. During a think-aloud procedure, participants are asked to say whatever comes into their mind as they perform the tasks. This might include what they are looking at, thinking, doing, and feeling while interacting with the prototype [67]. Think-aloud protocol allows researchers to understand participants' cognitive procedures and mental models while interacting with the product or service. However, since what people say may differ from what they are thinking, the think-aloud outcome may be inaccurate to some extent.

4.5.5 A/B Test

A/B testing is a design methodology to test new products or new features, especially regarding user interface, marketing and eCommerce [68]. In an A/B test, users are commonly split into two groups; the control group that is shown with the existing product and the experiment group that is shown with the new product. Users' behaviors and responses would then be collected and compared. Finally, an evaluation should be conducted to determine the better version. On the other hand, there is a risk of applying A/B test with a small number of testers. Individual may differ in their characteristics, resulting in the inaccuracy of comparison.

5
Planning

This chapter describes how the research process of this thesis is planned over 20 weeks to achieve the project goal. The plan follows the Double Diamond design process described in Chapter 4, with a selected set of suitable Interaction design methods that have been chosen to be used.

5.1 Literature study

During the first four weeks, the primary goal is to learn from the field-related literature. Literature studies mainly include four perspectives: inclusive design theories, cognitive impairment, AV service, and interaction design methods.

Since the project results will be designed based on inclusive design theories, having a concrete understanding of the concept is essential. Research papers related to inclusive design are planned to be reviewed. At the same time, literature research will be conducted to better understand the needs of persons with cognitive impairment, with a focus on the target user group's characteristics, their interactions with a regular bus, the issues they encountered, and the suggested design guideline for them. In addition, the AV shuttle bus context will be investigated to comprehend how it operates and what its functions are. This will make it easier to see the benefits and drawbacks of the current system. Furthermore, the relevant interaction design methodologies will be analyzed and selected during the process.

5.2 Designing process

This project will follow the *Double Diamond* design process model. It is divided into four phases: Discover, Define, Develop, and Deliver.

5.2.1 Discover

Conducting literature studies on people with cognitive impairment is not enough. Typically, it is necessary to conduct interviews with people too. However, under the epidemic situation, conducting interview with target users is extremely challenging. As a result, the focus of the user study will shift to an expert interview to determine the benefits and drawbacks of the AV shuttle bus from the perspective of people with cognitive impairment. This will include a series of questions about how people with cognitive disabilities commute a regular bus, such as how they plan their

route, board a bus, and exit a bus. The study also aims to identify whether the AV service is accessible to all users by learning the perspective of people with disabilities.

The field observation will be utilized as a technique to learn how the AV shuttle bus operates and the interaction between it and people with cognitive disabilities. However, researchers can only observe the AV shuttle bus operations in Lindholmen to summarize the positive and negative features compared with the regular bus, rather than observe users' activities.

Furthermore, an autoethnography method will be conducted to help the researchers have a rough understanding of the subject. This involves self-observation and reflexive investigation in the real context of AV service.

In addition, questionnaires can be conducted to gather the public opinions on AV services and their concerns. The results of the surveys will be manually processed, and the information can be compared and combined with the research from experts and literature.

5.2.2 Define

In the Define phase, insights from literature reviews, expert interviews, surveys, etc. will be summarized on Post-its and categorized. The categories will include the negative or positive design of a regular bus, user behaviors, user problems, etc. Afterward, personas will be created to represent target users' characteristics and requirements. Personas allow the researchers to put themselves in the shoes of these archetypal users, thus the design decisions can be made with the concern of user experience. Utilizing the user journey map method, users' touchpoints within the AV service can be concluded. Also, the obstacles during the journey could be identified. After identifying the problem areas that pose challenges to people with cognitive disabilities, How Might We questions are used to rephrase insight statements into design opportunities. Within this project, questions around "How might we solve the specific problems encountered by people with cognitive disabilities in an AV shuttle bus?" should be raised. Hypotheses will be formulated based on HMW questions. The hypothesis will be determined to enhance users' experience and be a guideline to develop a potential solution.

5.2.3 Develop

The development process will follow the five day Design Sprint described in Section 4.4.1. During this phase, idea iterations will be conducted. A specific design goal will be set at the beginning of the sprint. Ideation can start with mapping out the scenarios while interacting with AV shuttle bus, then providing possible paths. Storyboards will be created to visualize our design hypotheses. The testable hypotheses will be evaluated through surveys and interviews.

5.2.4 Deliver

The last phase of the project will concern iterations of design solutions including building and testing with prototypes. A heuristic evaluation method will be conducted to find usability problems in the proposed design solutions. During this process, a cognitive walkthrough evaluation will be conducted through the given task to users. People will be asked to follow and complete our given tasks as well as give feedback by think-aloud protocol. These methods will assist researchers in making a design decision.

5.3 Formalisation

In the rest of the project, the design process and result will be formalized in the final thesis report. Presentations both in the company and in the university will be prepared. Additionally, a Gantt schedule is used for complementing the description of the plan by giving a better visual overview of all the activities (see Figure 5.1).

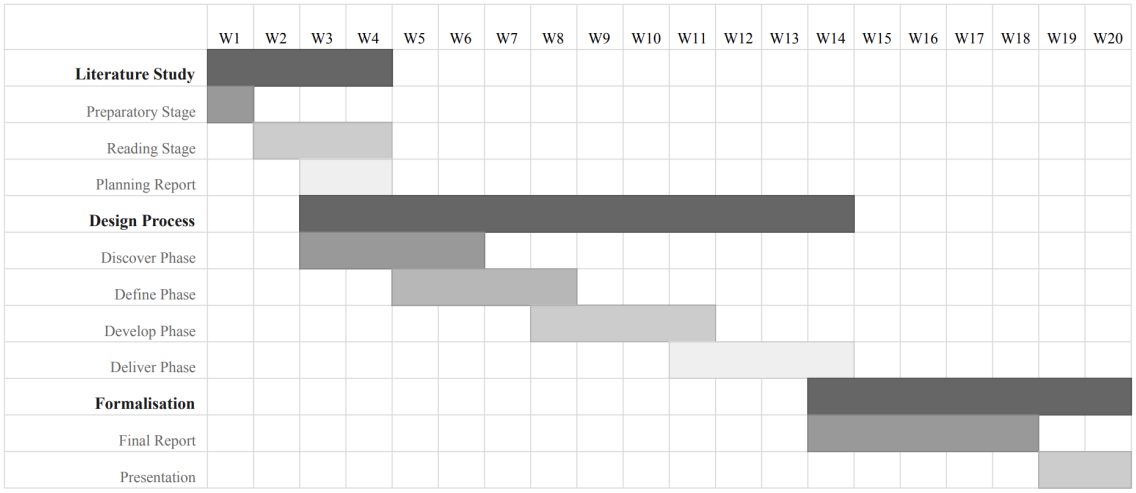

Figure 5.1: Time Planning Gantt Chart of Thesis Project

6
Execution and Process

In this chapter, the overall thesis process, following the Double Diamond model, will be introduced. Each section will describe in detail how different methods from Chapter 4 have been used for achieving the result.

6.1 Discover

6.1.1 Literature Review

The thesis started with investigating the development of AI and how it was implemented in AV services. Following that, the levels of driving automation and the functional modules of AV service were investigated in order to gain a thorough understanding of the AV bus tested in the S3 project. Combining this with the investigation in the real bus testing context, it was discovered that the AV bus tested in the S3 Project belonged to the autonomous level 4, which involves human monitoring while the vehicle operate itself.

Furthermore, theories and methods to be utilized in this project were selected from articles and books to refine the project planning. This research would follow the model of RtD to propose solutions for specific problems (see Section 3.1). To identify problems and deliver solutions, the design process followed the Double Diamond model(see Section 4.1). Additionally, the research on trust in AV service (see Section 3.2) and inclusive design (see Section 3.3) facilitated our further design for AV bus. The definition and common symptoms of cognitive impairment were examined in the literature related to people with cognitive impairment (see Section 3.4), which assisted in the search for target users and potential experts. Also, existing accessibility solutions in transportations (see Section 3.5) and information visualization design in transit (see Section 3.7) were summarized. The responsibility of human bus drivers and their impact on people with cognitive impairment was also examined (see Section 3.6) to discover the difference between regular buses and AV buses.

6.1.2 User Research

6.1.2.1 Expert Interview

To understand the characteristics and experiences of people with cognitive impairment during transportation, qualitative research was required to be conducted such as interviews or field observation. However, due to the continuing pandemic, the

target group who belonged to one of the risk groups, advised against taking public transit, making field observation impossible to be conducted. Furthermore, the interview session had to be conducted in English, which was a challenge when working with people with cognitive impairment in Sweden. As a result, the research strategy was shifted to conduct interviews with professionals who worked closely with people with cognitive disabilities. More than 20 invitation emails were sent out to the institutions and experts both in Sweden and the United States who work with people with cognitive impairments, but no one responded. The final option was to publish the interview invitation on a Facebook group for nurse assistants. Finally, three experts expressed an interest in being interviewed.

These experts were asked a series of questions about the target group's behavior on public transit as well as their experience as a caregiver. According to Swedish Mental Health Definition, the persons they looked after mostly belonged to the Lindrig Level (Mild Level) and Måttlig Level (Moderate Level) [69]. The Mild Level indicates that a person have a mental age of 9-12 years old, and that he or she can almost do everything on their own with only minor assistance. The Moderate Level denotes that the person most likely require the assistant of another person. One caregiver who looked after a person with Mild Level person mentioned that while on the bus, he had to assist the person to maintain balance, talk to calm the person down, and also teach the person how to get off at the correct bus stop. Another caregiver with a Down Syndrome child mentioned that she accompanied her daughter to school every day since her daughter liked to talk to strangers and might forget the time or destination. For example, it is good for people with cognitive impairment if everything follow a routine with a precise sequence. This reduces the risk that they will breakdown and lose their ability to solve problems. The detailed interview conversation can be found in Appendix A.

The results of the interviews illustrated some of the challenges that people with cognitive impairment might have when using public transit. The interviewees shared their expertise and experience with dealing with unexpected situations when assisting people with cognitive impairment. Utilizing the Affinity Diagram design methodology, the characteristics of people with cognitive impairment were summarized into nine categories: **Activity** (i.e. maintain a stable routine), **Attention** (i.e. keep focus on the journey), **Information** (i.e. have difficulties understand the announcement), **Problem-solving** (i.e. lose the capability to solve problems in the journey), **Memory** (i.e. need to be trained to remember the route), **User Conditions** (i.e. eyesight problem), **Body Control** (i.e. keep hands/feet still), **Emotion Control** (i.e. have difficulties keep mood under control), and **Transportation Status** (i.e. track people's progress in transit journey). See more detail in the figure below.

Figure 6.1: Characteristics of People with Cognitive Disability

6.1.2.2 Autoethnography

The autoethnography approach was introduced as a technique for investigating a particular phenomenon. It was conducted in parallel with interviews throughout this project. The researchers took a ride on an actual AV shuttle bus as part of the autoethnography method to learn about the AV bus's function and commuting procedure. The autoethnography research process includes finding the AV bus platform, viewing the AV bus instruction, boarding the AV bus, and exiting the AV bus. Appendix B contains a detailed description of the outcome.

The first issue with using the AV service was locating the bus stop platform. Because it was a new bus stop platform that was not visible from the main road, the AV bus stop was difficult to locate. Several solutions were tried out including Google Maps and the Vasttrafik App. The bus platform location has not been updated and displayed in Google Maps. Furthermore, the Vasttrafik App (Gothenburg's public transit application) was inefficient because the researchers were using an older version of the app. Finally, the researchers were able to locate the bus stop by observing and following the AV bus from afar. It took 10 minutes to discover the platform totally. Another issue after arriving at the AV bus station was the time mismatch between the scheduled and actual arrival of the bus at the bus stop. Although the schedule stated that a bus would arrive in 10 minutes, the actual wait time was 30 minutes.

Figure 6.2: Autoethnography Research - AV Bus Platform

After boarding the AV bus, the interior of the whole bus was observed. The AV bus had a space of about 4 square meters, and when 5 people aboard, it became congested. To protect the passengers' safety, the bus had multiple emergency buttons. In addition, the AV bus had eight sensors that detected traffic data on the route.

Figure 6.3: Autoethnography Research - Emergency Button on the AV Bus

According to Swedish regulations, a bus steward must monitor the bus's behavior and assure the passengers' safety. If any issues arise, the bus steward will deal with them and report them to the organization. In addition, the bus steward might use an Xbox-like controller to adjust the bus's behaviors to prevent accidents. Several times during the drive, the AV bus abruptly stopped in the middle of the road, but the bus steward quickly resolved the situation. The steward assessed the outside conditions, identified the problems, and manually relocated the AV bus with the controller. Furthermore, the testing route included three stops, and the AV bus automatically stopped at each one, but the bus steward or passengers had to manually open the bus door. The researchers experienced light motion sickness at the end of the voyage as a result of the several sudden stops made along the way.

Figure 6.4: Autoethnography Research - The Manual Controller of AV Bus

During the research, the idea of interviewing the AV bus drivers informally arose. This interview will be explained in more detail in the next section. Following this research investigation, interview questions for experts and people without disabilities were developed. The questions would be asked to discover the advantages and disadvantages of AV buses from the perspectives of experts and general passengers.

6.1.2.3 User Interview

This research aims to improve the travel experience of those with cognitive disabilities as well as persons without cognitive impairment. Through comparing the

differences between people with and without disabilities, the design solutions could be comprehensive and inclusive. In order to interview passengers, researchers had to be on board, at the bus stop, or ask users to test the AV bus and then have an interview afterward. However, due to the requirement of avoiding needless travel by public transportation during pandemics, waiting for a passenger onboard or at the bus stop was not an efficient manner of doing research. For a few hours, there were no passengers on board. Finally, 3 people who had tried commuting in the AV bus were contacted and interviews were conducted with them. One of them is a student, while the other two work at an office. See the interview script in Appendix C.

The interview results revealed a number of advantages and disadvantages of the current AV bus:

Advantages:

1. There was one bus steward on the AV bus monitoring the bus activities. People's trust in the bus system increases as a result of the combination of human, AI, and sensors.
2. The software was well developed with multi-sensors to detect the traffic information.

Disadvantages:

1. The seat was small compared with the regular bus and it lacked privacy when another person sat next to you.
2. The bus has a limited amount of space. It is awkward to stare at the individual on the opposite side of the bus.
3. Passengers near the exit found it inconvenient to press the door button to open or close the door.
4. The AV bus could not gradually decelerate when another vehicles approached from the opposite direction, thus a harsh brake was deployed.
5. There was no announcement about the bus's present location.
6. Without any music or radio, the atmosphere inside the bus was tense.

In addition, the expert was presented the record of the AV bus ride. The experts offered suggestions on how to use the AV bus from the perspectives of both caregivers and people with cognitive impairment. The responses are listed below.

1. For those with Down syndrome, especially those who have hearing impairments, the warning sound of an AV bus approaching the bus stops may create a headache.
2. The AV bus's handles were insufficient to maintain riders' balance.
3. The emergency buttons were located at an inconvenient height. It's possible that hyperactive persons will press it by accident.
4. The seats were arranged too close together. People with autism and Down Syndrome, particularly those who have Obsessive-compulsive Disorder (OCD) or social anxiety, may be uneasy.
5. On the bus, there was no announcement or information board. People with

Down syndrome and autism are more likely to miss their bus stop and become disoriented.

In the previous section, the bus steward on the AV bus was asked to provide his thoughts on the unmanned bus and his future responsibilities. The interviewee compared the bus drivers' responsibilities in a regular bus with an AV bus. Meanwhile, the researchers observed the extra tasks of bus drivers in both a regular and an autonomous bus. The figure below depicts the outcome of the bus drivers' main and extracurricular activities.

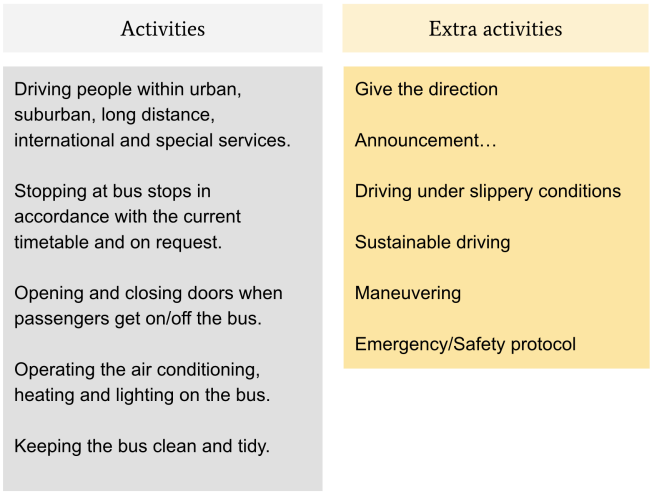

Figure 6.5: Bus Drivers' Responsibilities in Regular Bus

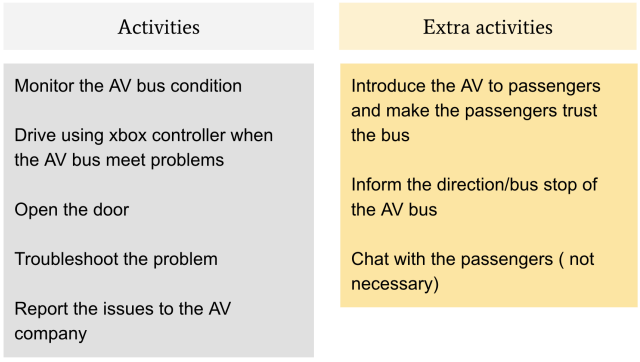

Figure 6.6: Bus Drivers' Responsibilities in AV Bus

6.2 Define

The goal of the Define phase is to identify the issues underlying the transportation experiences of people with cognitive impairment. Personas were firstly concluded according to previous literature research and user research. The personas were then

used to develop user journey maps, which included the problems and design opportunities at each step. The typical challenges that people with cognitive impairment face were finally defined for further development.

6.2.1 Persona

Personas were created in this phase to categorize the characteristics of people with cognitive impairment and to find the challenges and requirements of target users in the context of the AV bus. According to previous literature studies (Section 3.4), the disabilities differ in each individual. Also, people without disabilities should be considered, since designing for people with cognitive impairment can benefit the mainstream users as well. After discussion, five personas were determined to be appropriate for the thesis project, which include three with different types of cognitive disabilities, one caregiver, and one without disability. The personas were based on expert interviews, user interviews, and literature studies. Each persona includes fictional user's image, background, needs, goals, and problems. The overview of five personas can be found in the figure below:

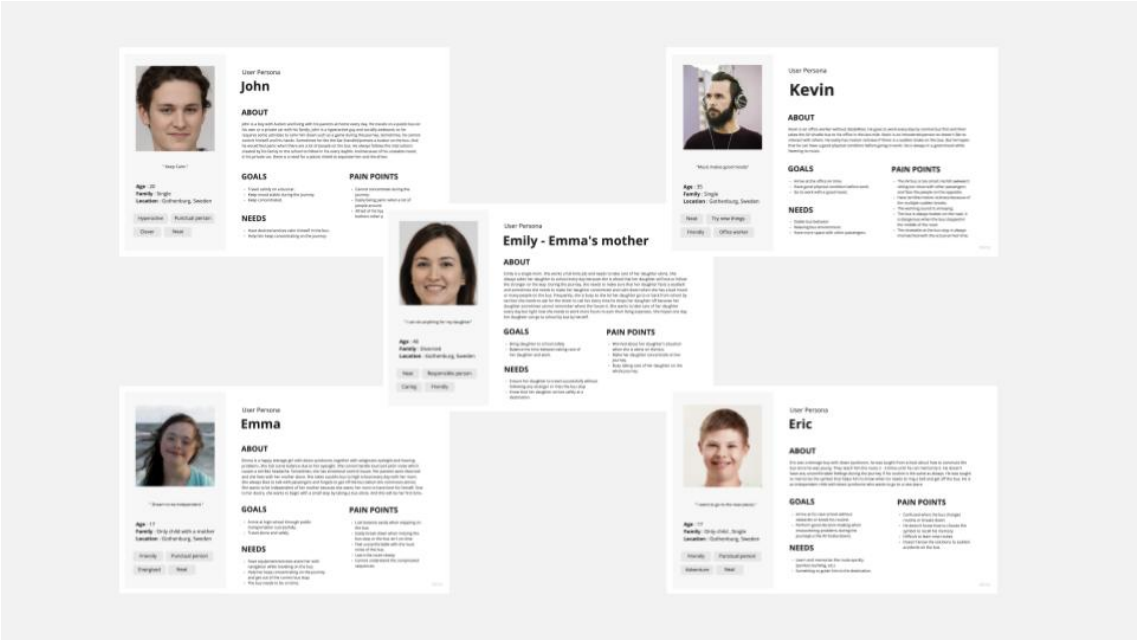

Figure 6.7: 5 Personas

- **John** is a 20-year-old person with autism symptoms, which include hyperactive actions, and unstable mood. His preferred mobility methods are public buses and a private car. The problem he encounters on public transit is that he is easily upset in a crowded environment, and he is afraid that his hyperactive behavior may bother other passengers. Thus, he requires a service or product to help him concentrate on the journey. His goal is to remain focused and calm on public transportation.

- **Emma** is a 17 years old teenage girl who has Down syndrome, astigmatism,

and hearing loss. Emma rides the bus to school every day and she requires her mother to accompany her on the bus. Emma has difficulty understanding the complicated sequences, so she learns the route slowly. Also, she easily breaks down when she misses the bus stop or when the bus is late. Emma needs a service that can help her navigate on the bus as well as remind her exit at the correct bus stop. The goal of Emma is to travel alone and arrive at high school safely.

- **Emily** is Emma's mother and acts as a caregiver for her. Emily is responsible for taking care of her daughter, including guiding her during the journey and guaranteeing her safety. Emily is busy taking care of her daughter on the whole journey. Her goal is to find a balance between caring for her daughter and working. Also, she needs to ensure her daughter's safety while using public transit.

- **Eric** is a 17 years old boy with Down syndrome, but with mild symptoms. He has been trained to remember the transportation route and perform the appropriate activities during the journey. Thus, he can commute on public transportation himself. The problem Eric encounters is when the bus's schedule disrupted, and he has no idea how to deal with it. His goals are to arrive at new places without encountering any impediments and to make appropriate decisions when faced with issues along the way.

- **Kevin** is an office worker who takes both regular and AV buses to get to work. He used to ride the bus with headphones on and keep a distance from other passengers. Kevin experienced terrible motion sickness due to the the AV bus's sudden brake. Also, since the AV bus is too small, he always feels awkward facing people on the opposite side of the bus. Kevin requires stable bus behaviors as well as a relaxing bus environment. His goals are to arrive at the office on time and have good physical condition before work.

6.2.2 User Journey Map

Utilizing the personas generated in the previous step, a user journey map study was conducted. The selected personas are John, Emma, Emily, and Kevin since they are matched with this research aim and have unique requirements when riding the AV bus. The user journey template was firstly created including Persona, Scenario, Task, Problem, Existing solution, Emotion, User thought, and Possible improvement. See Appendix D. According to different backgrounds of the personas, different scenarios were created. Also, the user journey maps were visualized for a better understanding of each journey. The emotional graph was an essential element of the user journey map since it illustrated users' satisfaction and dissatisfaction along the journey. Problems would be discovered in the trough where users' negative emotions emerged.

User Journey Map 1 - Kevin

Kevin's user journey map was essential since this project aimed to design inclusively for a varied range of passengers. Persons with impairments may face the same issues that people without impairments do. A scenario was created for Kevin that "*Kevin was going to work as usual. He loved to put his headphones on to keep his mood up during the journey. The regular bus was late and the information on the App was not displayed. When he hurried to transit the AV bus, it was also late and had many harsh brakes due to technical issues. Kevin experienced light motion sickness while on board. Finally, he arrived at his office on time.*"

The whole transit journey was divided into two parts: the journey on the regular bus and on the AV bus. The design focus was mainly the second part, but events in the first part were still included since they continuously affected Kevin's emotion until the end of the journey. On the journey map, it can be found that Kevin had a difficult time riding on the AV bus. When he left the regular bus and transited to the AV bus, the long walking distance forced him to run to the AV bus station. However, the AV bus timetable and the actual arrival time did not coincide. The long-time waiting resulted in Kevin's anxiety. As he finally boarded the AV bus, the narrow space made him feel uncomfortable, and sitting close to strangers made him feel awkward. Moreover, the headphones caused Kevin to experience a temporary hearing loss. Thus, he required a reminder on the AV bus of the upcoming bus stops. (See figure below)

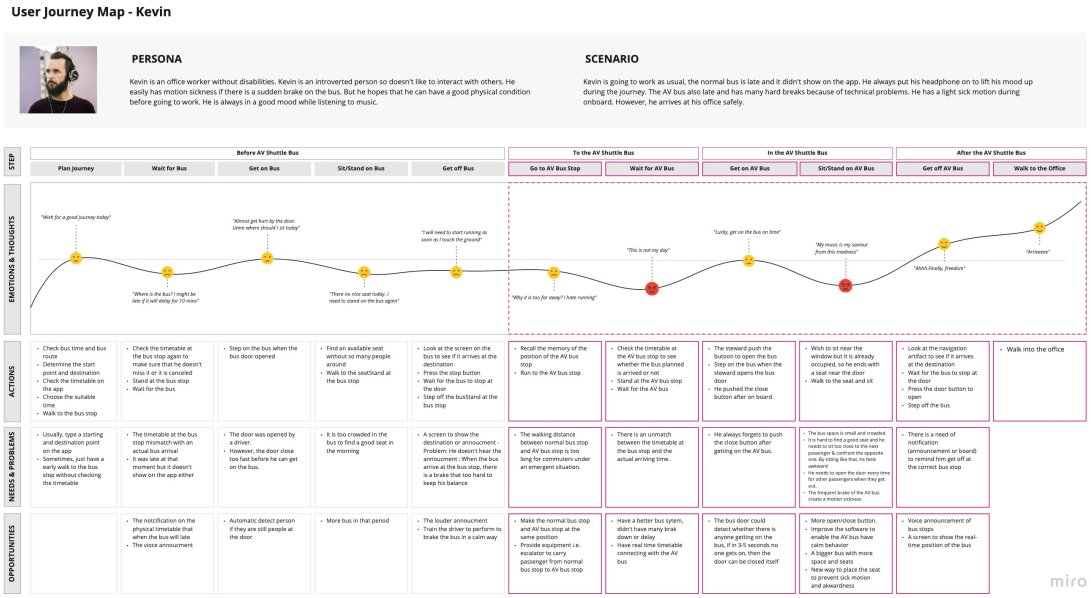

Figure 6.8: User Journey Map 1 - Kevin (see larger version in Appendix H)

From Kevin's journey, problems were mainly generated in the period of waiting for and traveling on the AV bus. Design opportunities could be concluded to solve these problems. For instance, reducing the distance between a regular bus stop and AV bus stop to save time during the transition; tracking the AV bus position to

calculate the accurate arrival time, enabling the AV bus to drive calmly to prevent passengers' motion sickness, and informing each bus stop via an announcement, etc.

User Journey Map 2 - Emma and Emily

According to previous personas, Emma and Emily always commute together. Emily usually takes care of Emma and helps her with her troubles (see Section 6.2.1). Thus, the user journey map was created, which included both Emma's and Emily's journeys and problems. To better distinguish different actions and problems of each person, Emma's actions and problems were displayed in the yellow background, Emily's were displayed in the pink background (see figure below). A scenario was created for this journey: "*Emma is a girl with Down syndrome and Emily is her mother. Emily took Emma to school as usual in the morning. They boarded the regular bus first and then transferred to the AV shuttle bus. During the journey, Emily taught Emma the direction and route to school. The regular bus arrived on time, but Emma didn't sit on the seat she expected. While waiting at the AV bus stop, the AV shuttle bus was late and many passengers were waiting at the same time. When they finally boarded the AV bus, there was only one seat left near the bus door. Emily had no choice but to let her daughter sit alone.*"

Similar to Kevin's journey, the journey of Emma and Emily was also divided into two phases: on the regular bus and on the AV bus. Since in previous user research, researchers were unable to have people with cognitive disabilities test the AV bus, the second part of the journey was created based on literature research and the target group's experience in conventional transportation. Moreover, this user journey aimed to compare the experience of riding a regular bus against an AV bus.

In the whole journey, Emma's emotions were unstable, especially when unexpected events happened, such as other passengers occupying her favorite seat, the AV bus's lateness, the loud warning sound, and the AV bus's frequent harsh braking, etc. Emily also experienced a hard time keeping track of Emma's experience and and resolving the problems since she is unable to sit next to her.

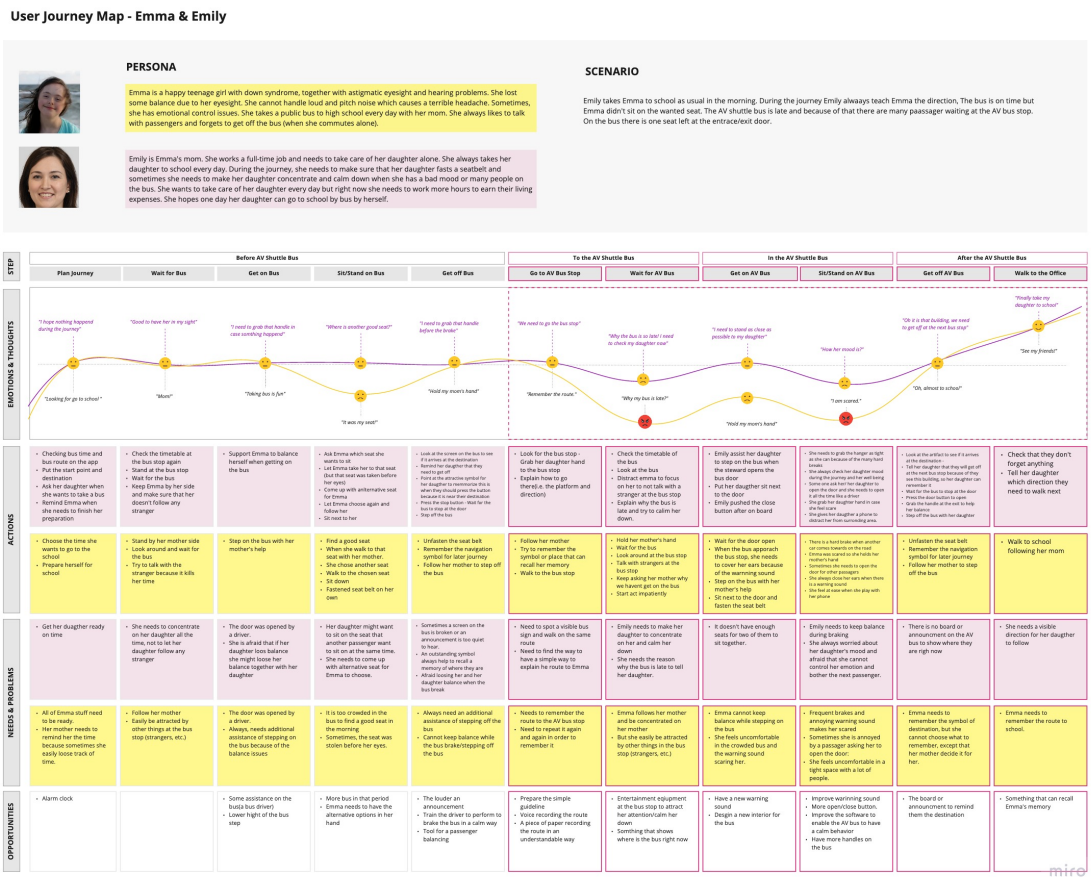

Figure 6.9: User Journey Map 2 - Emma and Emily (see larger version in Appendix H)

It can be concluded that Emma's main problem was that she couldn't remember the way to school and required her mother's guidance. The potential design opportunity would be a personal guiding system for Emma that can also be connected to her mother. Moreover, Emma was easily distracted by strangers, thus she required some support to keep concentrating on the journey. Other possible improvements include improving the warning sound to be friendly, using navigation artifacts to recall the memory of the route, and having visual and audible bus stop announcement.

User Journey Map 3 - John

The persona of John was selected for developing the user journey. John is the one who has autistic symptoms such as hyperactivity, social awkwardness, and unstable mood. He is capable of traveling by himself. The aim of this user journey map was to explore comprehensive problems people with cognitive disabilities can have while using public transportation. The scenario of John's journey was "*John lived one bus stop away from the AV bus stop, so he always walked to the AV bus stop, and took the AV bus to his school. Today was his third time going to school. When he was following his script on his phone to the bus stop, his mobile phone ran out of battery. John was stressed with finding his way to the platform. He finally*

arrived at the bus stop by recalling it correctly. When he was on the AV bus, he mistakenly pressed the emergency button which resulted in the hard stop of the bus. This situation made John feel anxious and panic."

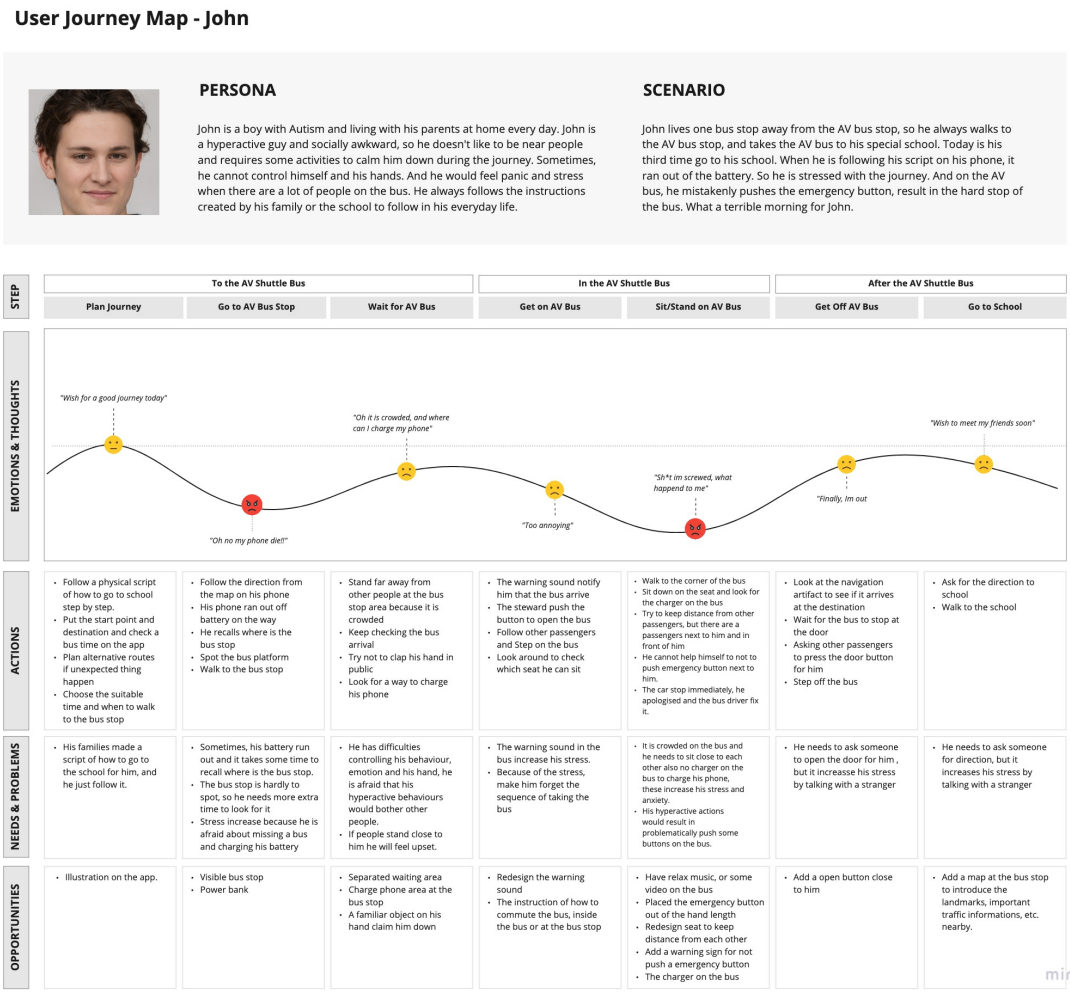

Figure 6.10: User Journey Map 3 - John (see larger version in Appendix H)

In John's journey, there were mainly two depressed emotion points. The first it happened was when his mobile phone ran out of battery. Since John highly relied on the routine script on the mobile phone, the unexpected power down increased his anxiety. The second depressing point was when John pressed the emergency button on the AV bus by accident. He had difficulties being concentrated and controlling his hyperactive behaviors under stress. In addition, since John lost the assistance from the route script after he left the AV bus, he needed to ask other passengers for directions.

Regarding the problems discovered above, design opportunities can be a visible navigation information display that assist John to find the AV bus stop, as well as a service to help him check the route at the bus stop. In addition, instruction on how to travel on an AV bus was required for those with impairments and those who were

unfamiliar with the AV bus. Additionally, due to John's hyperactive actions, there required a large space on the AV bus to help him keep distance from other passengers. Another potential enhancement would be having a map of nearby locations at the AV bus stop to aid people in finding their way once they exit the AV bus.

6.2.3 Defining problems with the AV bus

Based on the previous three user journey maps, the problems that each persona encountered during each step were summarized. Utilizing the method *Affinity Diagram*, the problems were categorized into six groups: **Space**, **Sound**, **AV Software and Equipment**, **User Behavior**, **Information**, and **Memory**.

Category	Problems
Space	The space in the AV bus is small. User feels uncomfortable and awkward when sitting or standing next to other passengers.
Sound	The warning sound of the AV bus is annoying which increases users' stress.
AV Software	The frequent brake of the AV bus creates motion sickness. The number of the stop button is only one. There is no charger on the AV bus when user runs out of battery.
User Behavior	User has difficulties controlling behavior and emotion. For example, the user's hyperactive actions would result in problematically push some buttons on the bus. User easily be attracted by other things at the bus stop and on the bus (strangers, etc.)
Information	There is an unmatch between the timetable at the bus stop and the actual arriving time. There is no board or announcement on the AV bus to show where is the current position.
Memory	User has difficulties remembering the route to the AV bus stop. User needs to remember the direction after the journey.

Table 6.1: Problems People with Cognitive Impairment Encountered in AV Bus

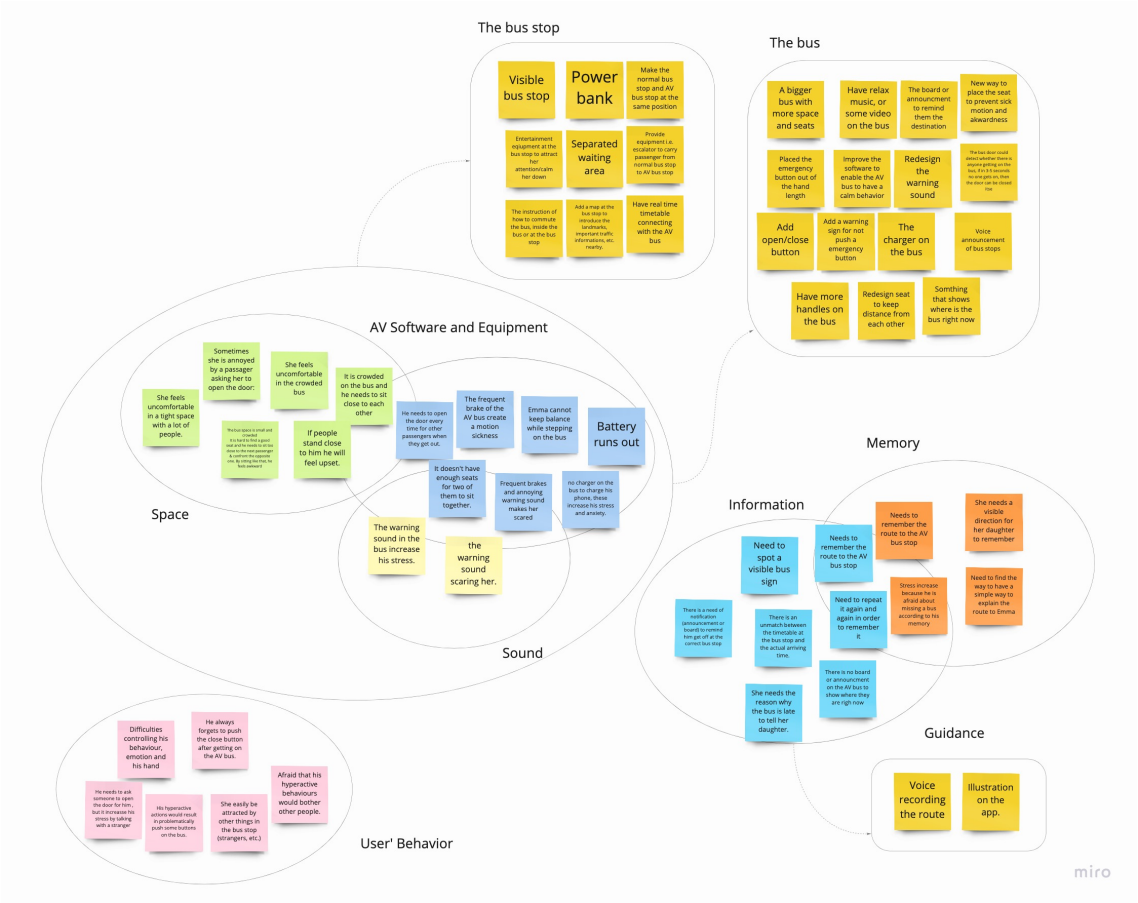

Figure 6.11: Problem Defined from User Journey Maps (see larger version in Appendix H)

At the same time, the general opportunities were divided into three categories: AV Bus Stop, AV Bus, and Guidance enhancements. Firstly, the AV bus stop should be visible to the passengers and provide all relevant information about the AV bus such as bus schedule, commuting instructions, nearby landmarks, etc. Also, the AV bus stop had the opportunity to be developed into a multifunctional smart bus stop, which integrates the power bank, ticket vending machine, entertainment equipment, etc. together at the waiting area. Secondly, the AV bus should be designed with more space and larger seats to reduce passengers' stress and anxiety. There should have audio announcement illustrating the current position of the bus and the bus warning sound should be improved. The AV software system should be improved with more accurate detection and friendlier driving behavior. Finally, feasible guidance is crucial to our target users to learn the transportation route. The guidance could be in the format of voice recording, digital script, etc.

6.3 Develop

The Development phase included two phases: Design Iteration and Design Refinement. In order to fasten the design process, a three-week Google Design Sprint was adopted as the Design Iteration guideline. In Design Refinement, all design was reviewed and improved.

6.3.1 Design Iteration

Google Design Sprint is a five-day process that involves brainstorming, prototyping, and assessment to find good design solutions [54]. The three-week design sprint was scheduled during the development stage to filter concepts, narrow down the scope, and test with target customers. The weekly tasks followed the design sprint guideline of finding important problems to focus on Monday, ideation and sketching for solutions on Tuesday, selecting feasible ideas and turning them into testable hypotheses on Wednesday, prototyping on Thursday, and finally testing the design with target users on Friday.

6.3.1.1 First Week Design Sprint - Narrow Down Design Scope

In the first week of the design sprint, the findings from Problem Define phase were recategorized according to feasibility. Problems were divided into two groups: those that can be solved by users and those that require innovative design. The latter ones were summarized into seven "How Might We" questions which served as the week's design goals.

1. HMW make the warning sound less annoying?
2. HMW make the bus stop visable and distinguishable?
3. HMW decrease the stress and anxiety in the bus?
4. HMW inform users where is the bus right now?
5. HMW make the instruction/information of the AV bus simple to remember?
6. HMW help users get off the bus at the correct destination?
7. HMW help users navigate to the correct direction after bus?

Utilizing the *Crazy 8s* design method, a piece of paper was folded into eight frames and one idea was sketched in each frame. Afterward, related ideas were grouped together, and viable solutions were chosen to be developed in the rest of the week. Since the AV bus was manufactured by the NAVYA company, design improvements related to the physical AV bus was voted to be less feasible. The majority of the "winner" ideas revolved around Sound, Emotion, Information, and Memory. According to the "winner" ideas, four design hypothesizes were proposed:

1. The physical information display can better navigate users to the AV bus stop.
2. Interactive AV bus instructions can assist users commuting the AV bus.
3. Music can decrease users' anxiety while it is crowded on the bus.
4. The color code of the bus stop can assist users to get off the correct bus stop.

Four solutions were designed regarding each hypothesis. The design was based on the scenarios of **User navigating to the AV bus stop from a regular bus stop**, **User waiting for the AV bus**, **User travelling on the AV bus**, and **User getting off the AV bus**. Below we present sketches of four solutions:

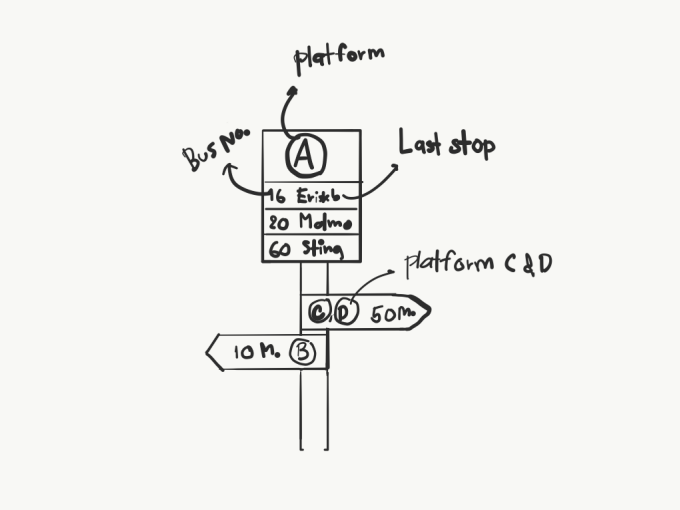

Figure 6.12: Solution 1: When users transit from a regular bus stop to an AV bus stop, there are physical signs indicating the direction and distance to the AV bus stop.

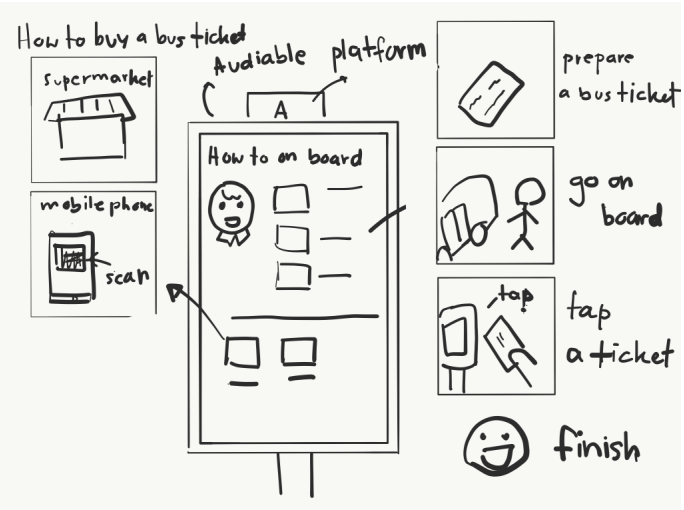

Figure 6.13: Solution 2: When users arrive at the AV bus stop, interactive signs will provide instructions on how to purchase tickets and commute on the AV bus.

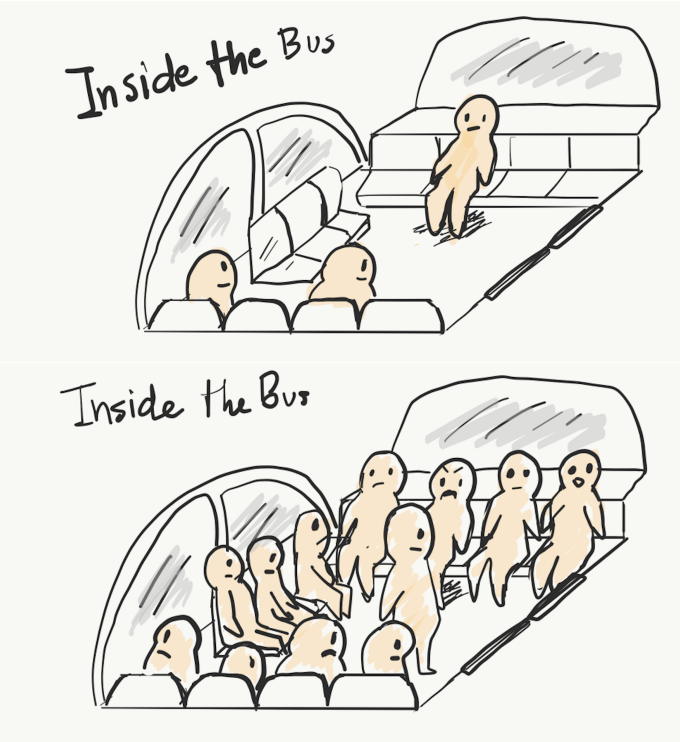

Figure 6.14: Solution 3: When users board the AV bus and the number of passengers increase continuously, AI and sensors will identify the bus's crowdedness and the music player will play music that can help to relieve stress and tension.

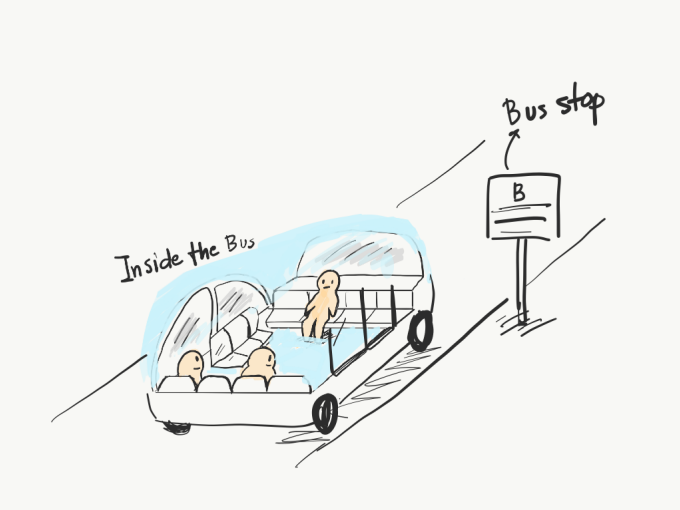

Figure 6.15: Solution 4: When the AV bus approaches the AV bus stop, the LED light inside the bus changes color to indicate the bus stop to the passengers.

To evaluate the design solutions, a survey was created utilizing the innovative Cognitive Walkthrough method. Unlike the traditional Cognitive Walkthrough method, which involves experts as participants, the survey participants are the intended users. In the survey, the background of the AV bus was explained initially, and participants were then asked to imagine themselves riding the AV bus for the first

time. Afterward, participants were asked to compare the existing solutions with the design proposals. The survey (see Appendix E.1.1) was posted in the existing Autism and Down syndrome groups on Reddit, and four responses (see Appendix E.1.2) were collected.

In addition, the survey's responses were analyzed. After the comparison of existing solutions and our design, the hypothesis that "Physical information display can better navigate users to the AV bus stop", and "Interactive AV bus instructions can assist users commuting the AV bus" was supported. The other two design proposals were not supported Therefore, the design focus was narrowed down to optimize target users' information collecting process within the AV bus system. Moreover, people with cognitive impairment have a strong requirement for clear and explicit information. Previously, it was considered that people with cognitive disability preferred graphs and graphics in information display. However, the result demonstrated text was more acceptable in some cases to convey the information. Thus, the existing information visualization guideline of signage design should be considered. After this, the design sprint focused on design the information needs in AV bus system.

6.3.1.2 Second Week Design Sprint - Design Information Display at the AV Bus Stop

In the second week design sprint, researchers focused on proposing solutions to improve the information collecting process when riding AV buses. The tasks of this week include: summarizing the existing effective information signage design guidelines, identifying the problems related to information perceiving during the journey of commuting AV bus, and providing design solutions to the problems defined.

Effective Information Signage Design Guideline Summary

Initially, the signage design guidelines from literature were summarized into four perspectives: **Content**, **Visualisation**, **Audio**, and **Support** (See Table 6.1). In the future, all design would follow these guidelines.

Topic	Guidelines
Content	Use simple, clear, unambiguous, and understandable information. Have standardized content. Have consistent placement. Have labels and signs to identify where to go. Have landmarks to confirm progress and identify locations. Have clocks to synchronize schedules with arriving transportation vehicles.
Visualization	Have proper luminance, color, and brightness. Pictograms or icons are easily recognizable while provided in signage. Color coding and symbols are helpful in training people with cognitive impairments.
Audio	Have audible and visual information in parallel.
Support	Help users understand what things are and how to use them. Help users find what they need. Help users to maintain focus. Help users avoid mistakes or correct them. Provide several possible paths. Support adaptation and personalization.

Table 6.2: Signage Design Guideline for People with Cognitive Impairment

Problems Related to Information Perceiving When Commuting AV Buses

At the same time, the user journey maps that concluded in *Define* phase were reviewed to identify the questions users might have related to information perception. The whole journey of commuting on AV bus was divided into seven steps and the related questions in each step were summarized in Table 6.2.

Step	Questions Users Have
Planning the journey	How to commute the AV bus beforehand? What are the alternative routes? How to go to the AV bus stop? How long do I need to be ready and go out? What is the schedule of the AV bus?
Go to AV bus stop	Where is the AV bus stop? What is the Platform No.? Is there any landmark to track the process? Is this the correct bus stop? Where am I on the journey of going to AV bus stop?
Wait for AV bus	Where is the bus right now? How long that I need to wait? When is the bus arriving time? Can I use the same ticket as a regular bus? How to commute the bus in detail?
Get on AV bus	Do I need to open the door myself or the bus driver will open it or it will open it by itself? How to close the door?
Sit/stand on AV bus	Where to sit/stand? What is the current position of the bus?
Get off AV bus	How long is the distance to the destination bus stop? When to press the stop button? Where am I right now? Where is the button? When should I start to go to the exist? When the bus will park at the bus stop? Where is the exit?
Further activities	Where is the direction to the school? Where is the school located? How to get to school? What is the distance to school from here? Is there any landmark to track where I am?

Table 6.3: Questions Users Might Have Related to Information Needs During the Journey of Travelling on AV Bus

Design Solutions

Various solutions were generated in response to these questions. The results were divided into three categories: **Mobile application**, **Bus stop information display**, and **Bus information display**. See figure below. Considering the factors of time and feasibility, the design and development of the application were time-consuming. Therefore, the project design will only focus on physical sign design in the further development process. The ideas of bus stop signs design were supposed to be further developed this week. And the ideas of information display design on

the bus would be developed in the next week.

Figure 6.16: Ideation Results in Second Week (see larger version in Appendix H)

Three scenarios were defined as the basis of design solutions: **User navigating to the AV bus stop**, **User checking the AV bus time**, and **User searching detailed information about the route**. In each scenario, two low fidelity prototypes were developed in order to choose a more desirable design.

In the scenario of **User navigating to the AV bus stop**, the first idea was to stick continuous footprints on the ground until the AV bus stop, indicating the correct direction. The second design include placing navigation signage on street corners with arrows and text indicating the direction and distance to the AV bus stop. See figure below:

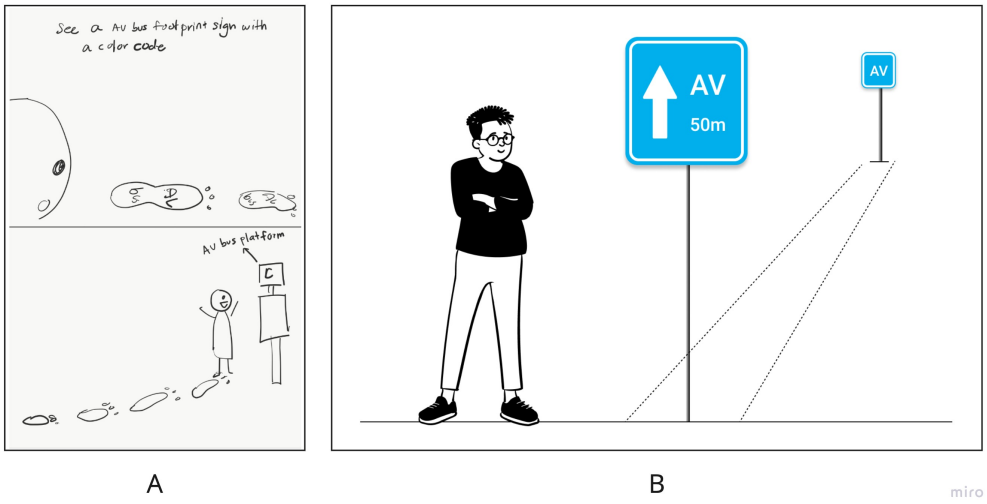

Figure 6.17: Scenario 1: User navigating to the AV bus stop. Solution A: Continuous footprints showing the direction. Solution B: Navigation signage with arrows.

In the scenario of **User checking the AV bus time at the AV bus stop**, different information were selected in two ideas to be visualized. The first concept contained the status of bus position in different colors, and involved an AI assistant that could interact with users. Also, it included instructions on how to purchase AV bus tickets. The second design provided users with information such as the bus's estimated arrival time, the bus schedule, and audio support. See figure below:

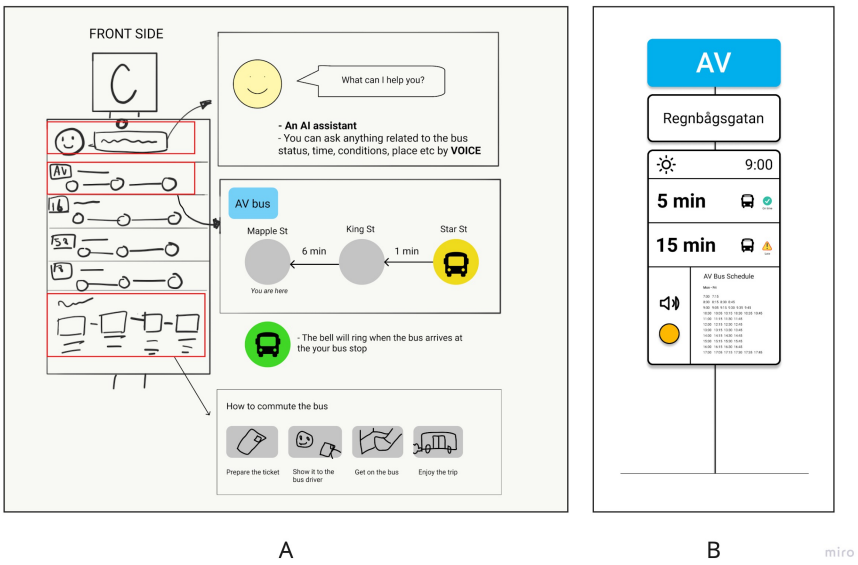

Figure 6.18: Scenario 2: User checking the AV bus time at the AV bus stop. Solution A: Visualizing the AV bus status by symbols. Solution B: Directly showing the estimated arrival time and schedule.

In the scenario of **User searching the detailed information about the route**, the first design emphasizes adapting to the existing information shelter in Sweden

with transportation routes, ticket instructions, and bus stop position. The second design only focused on the independent AV bus system including AV bus commuting directions, AV bus route and nearby landmarks. See figure below:

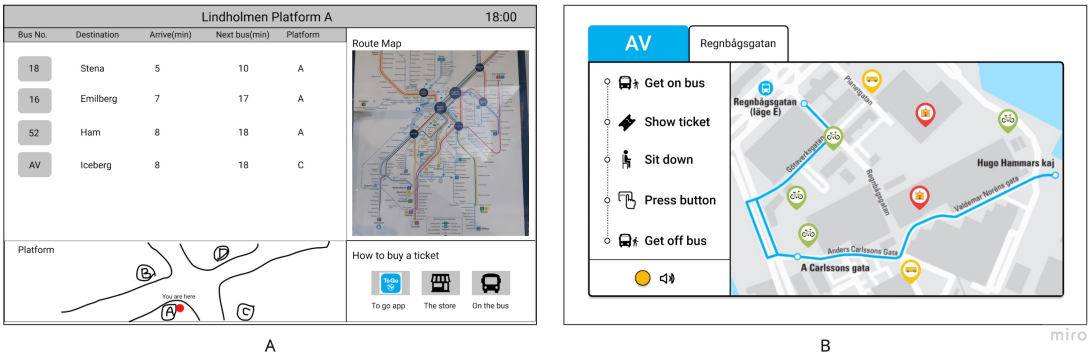

Figure 6.19: Scenario 3: User searching detailed information about the AV bus route. Solution A: Adapting the AV bus information to other bus information. Solution B: Independent AV bus information system.

A survey was conducted to evaluate the six prototypes mentioned above. Similar to the first survey, the Cognitive Walkthrough method was utilized in this survey as well. Participants were initially introduced to the context of commuting on an AV bus. Afterward, participants were asked to imagine the three scenarios: Navigating to the AV bus stop, Checking basic AV bus information, and Exploring detailed AV bus information. The design solutions were proposed under each scenario, and participants were asked to rate the usability of each design. Moreover, users were asked to choose the information they required at the bus stop and on the bus. (see Appendix E.2.1). The survey was sent out to the existing Autism and Down Syndrome groups on Reddit. Finally, four responses were collected in this survey (see Appendix E.2.2).

According to survey feedback, people with cognitive impairment appreciate the footprint design since it was simple and clear. However, the visibility of footprints in various environment must be taken into account. The navigation arrow design was user friendly, but the direction in which the arrow pointed was unclear. When it came to bus stop information display, the design with less but clear information was favoured by target users. Too much information can lead to users getting lost in their search for the right one.

6.3.1.3 Third Week Design Sprint- Design Information Display on the AV Bus

The major goal of the third week's design sprint was to create informative display on the AV bus. In most cases, bus drivers would be considered as the information resource on a bus, thus conversations between passengers and bus drivers were planned to be researched. A survey was created and sent out to both users with cognitive disability and without cognitive disability. (see Appendix E.3.2). 6 responses

were collected from people with cognitive disability, 23 responses were collected from people without cognitive disability (see Appendix E.4.2). The result revealed that questions about direction were most frequently asked by both types of users.

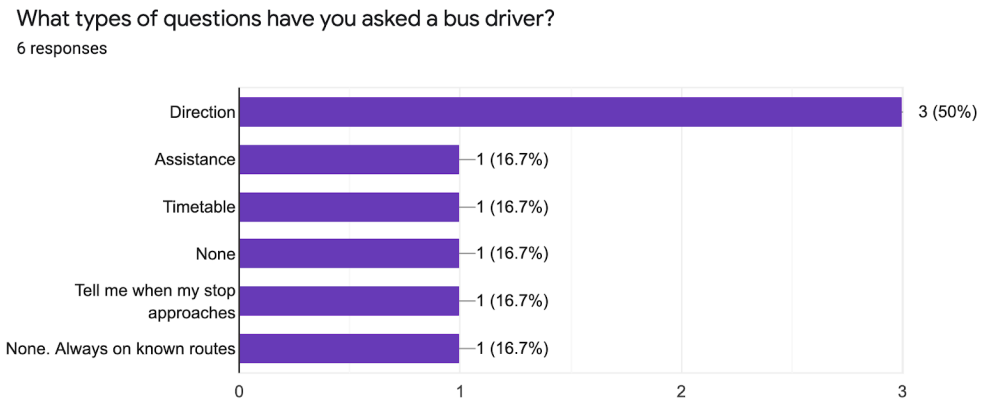

Figure 6.20: Conversation between passenger and bus driver survey responses from people with cognitive impairment

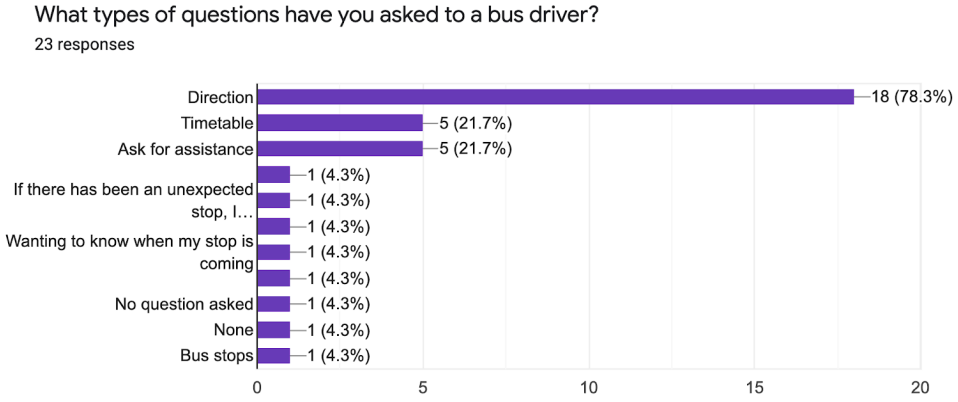

Figure 6.21: Conversation between passenger and bus driver survey responses from people without cognitive impairment

In addition, the survey collected samples of the questions. The required information on the AV bus was divided into 9 categories: **Direction**, **Ticket**, **Unexpected Events**, **Bus Departure**, **Bus Timetable**, **User Error**, **User Confirmation**, **Nearby Information**, and **Other Passengers' Condition**. See table below:

Category	Example Questions
Direction	Does the bus stop at/go to my expected stop/destination? (Several stops before the destination,) how many stops before the destination?
Ticket	How to purchase a bus ticket?
Unexpected event	What happened to the bus and why stop? Can you take us to XXX instead?
Bus Departure	When will the bus depart?
Bus Timetable	How often does the bus go? Is there another bus coming soon after?
User Error	Can you open the door I entered the wrong bus?
User Confirmation	Make sure if this is the correct bus?
Nearby Information	How do I get to XXX (after bus)? When do I get off/Which stop should I get off, if I want to go XXX?
Other Passengers' Condition	Someone forget wallet... There is an uncomfortable person, can you assist?

Table 6.4: 9 Categories of Information Users Required on the AV Bus

In the above 9 categories, questions related to User Error and Other Passengers' Conditions were mainly caused by passengers themselves. Other Passengers' Condition questions were varied and unpredictable, thus they were excluded from this project. While User Error questions required additional investigation. Therefore, another survey was undertaken to look into the causes of user errors (see Appendix E.5.1). This survey elicited a total of 10 replies (see Appendix E.5.2). According to the study, 7 people had experience of getting on the incorrect bus, and 9 people had experience of getting off at the wrong bus stop. There were two main reasons for users' mistakes: **Users' stressed/distracted mental condition** and **Transportation system's unclear/mismatched information**. Hence, by enhancing the information display design, user errors can be reduced

Considering all the information needed by passengers while commuting on the bus, some of the information should be provided both at the bus stop and on the bus to prevent mistakes, ie. Direction, Ticket, Timetable, etc. Therefore, two scenarios were created: **Checking the direction at the bus stop** and **Commuting on the bus**. Based on each scenario, design solutions were proposed for testing.

In the scenario of **User checking the route of the journey**, an AI assistant was designed to provide personalized route information regarding passengers' destinations. Three solutions of inputting the destination were designed: **Audio input**, **Select by first alphabet**, and **Type text**. Design solutions were situated in the real context of the bus shelter. See figure below:

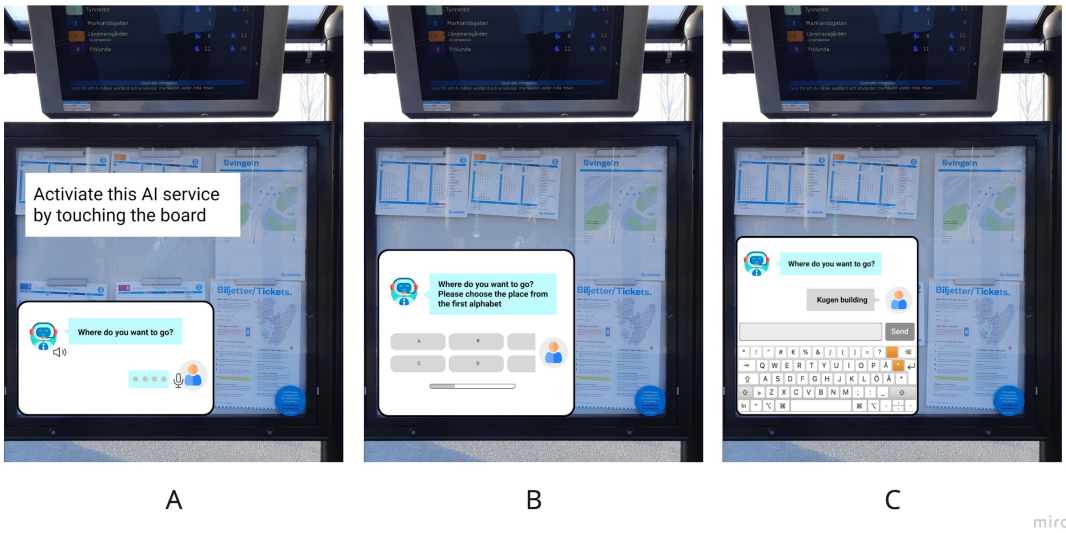

Figure 6.22: Three solutions of inputting destination. Approach A: Audio input. Approach B: Select by first alphabet. Approach C: Type text.

After users input their destinations, the AI assistant would provide route details. Two solutions were designed: **Visualize the route on the map** and **Provide a route script**. See figure below:

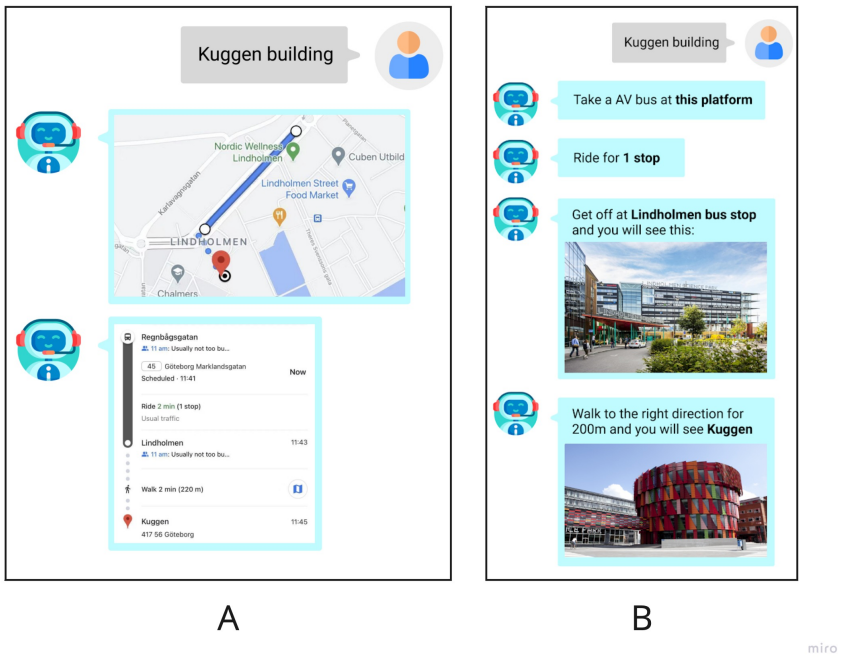

Figure 6.23: Two solutions of AI assistant's feedback. Approach A: Visualize the route on the map. Approach B: Provide a route script.

In the second scenario of **User traveling on the bus**, an unanticipated incident

was created that the AV bus experienced a hard stop due to the error of sensors. In this case, two designs for providing the information users need have been proposed: **AI assistant** and **Digital information display with voice announcement**. See figure below:

Figure 6.24: Two solutions of providing information on AV bus. Approach A: AI Assistant users can interact with. Approach B: Digital signage along with voice announcement.

Same as the previous two weeks' evaluation, a survey was created utilizing Cognitive Walkthrough design method. Participants were first given an overview of the situation of waiting at an AV bus stop without access to mobile data. Participants were then asked to imagine to interact with the AI assistant and compare the design solutions. In the second scenario, users were asked to imagine the AV bus experiencing an error and provide feedback on the two design solutions. (see Appendix E.3.1). The questionnaire was sent out to the existing Autism and Down Syndrome groups on Reddit. Six responses were collected. (see Appendix E.3.2)

According to the survey result, 2 respondents indicated that they disliked speaking in public places, and that typing was a more user friendly input approach. The route script was considered to be an comprehensive design, providing the pictures of the destination environment was helpful and innovative. For those with cognitive impairment, the design of sign with audio announcement was more clear and easy to interpret.

6.3.2 Design Refinement

The opinions and comments from the surveys were summarized after three weeks of iterating the design. Some ideas were combined and the design was refined into four

solutions that assist users to collect information during the journey of commuting on an AV bus:

1. Footprints as well as navigation sign assisting users to navigate to the AV bus stop from other bus stops.

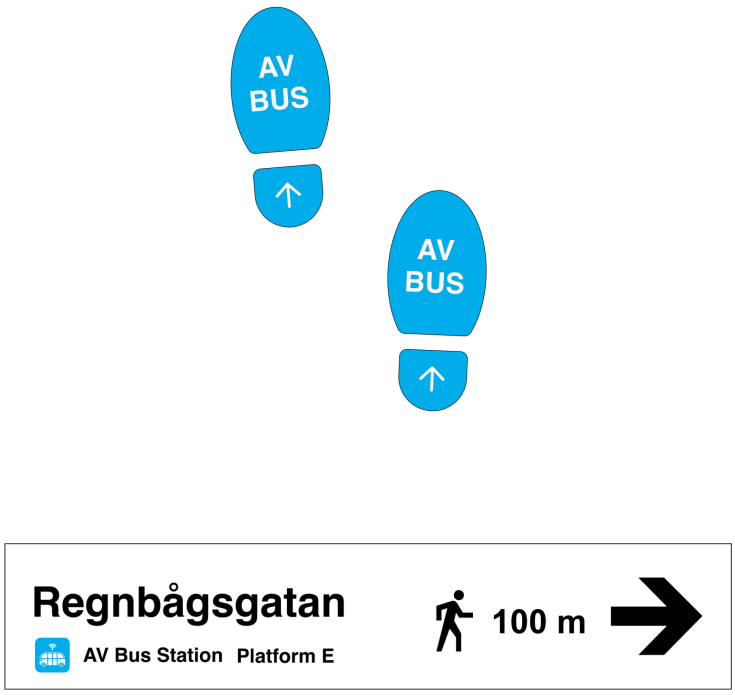

Figure 6.25: Refined Information Design Approach 1: Footprint and Navigation Sign

After the evaluation of previous surveys, the footprint design has the advantage of being simple to comprehend and follow, but it has the disadvantage that the performance highly relied on the physical environment. For instance, the footprint will be difficult to recognize under snow. The advantage of the navigation signs is that it can adapt to most situations, but the disadvantage is that the arrows are difficult to follow. Therefore, the two solutions are integrated together to help people match information with each other. The visual design of the sign, including arrows and icons all followed the universal sign and graphic design guidelines.

2. AV Bus stop information display illustrating the basic information about bus arrival time, bus direction, bus schedule, ticket information, etc.

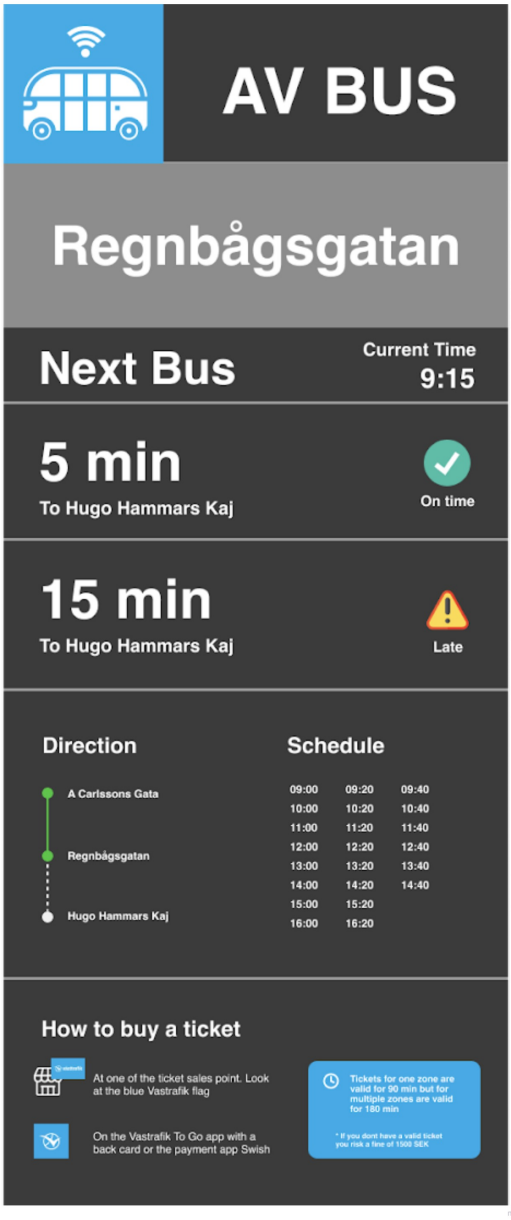

Figure 6.26: Refined Information Design Approach 2: Basic AV Bus Information Display

In this information display, basic information about the AV bus is supplied. According to literature studies and survey results, users with cognitive disability are always concerned about the schedule being under their control. Additionally, people who are unfamiliar with the route need confirmation that they are on the correct track. The information of AV bus arrival time, AV bus direction, and ticket information are crucial to the passengers.

3. An interactive route information display under the bus stop shelter providing information about bus arrival, bus route, bus status, personalized route planning, bus instruction, bus ticket, etc.

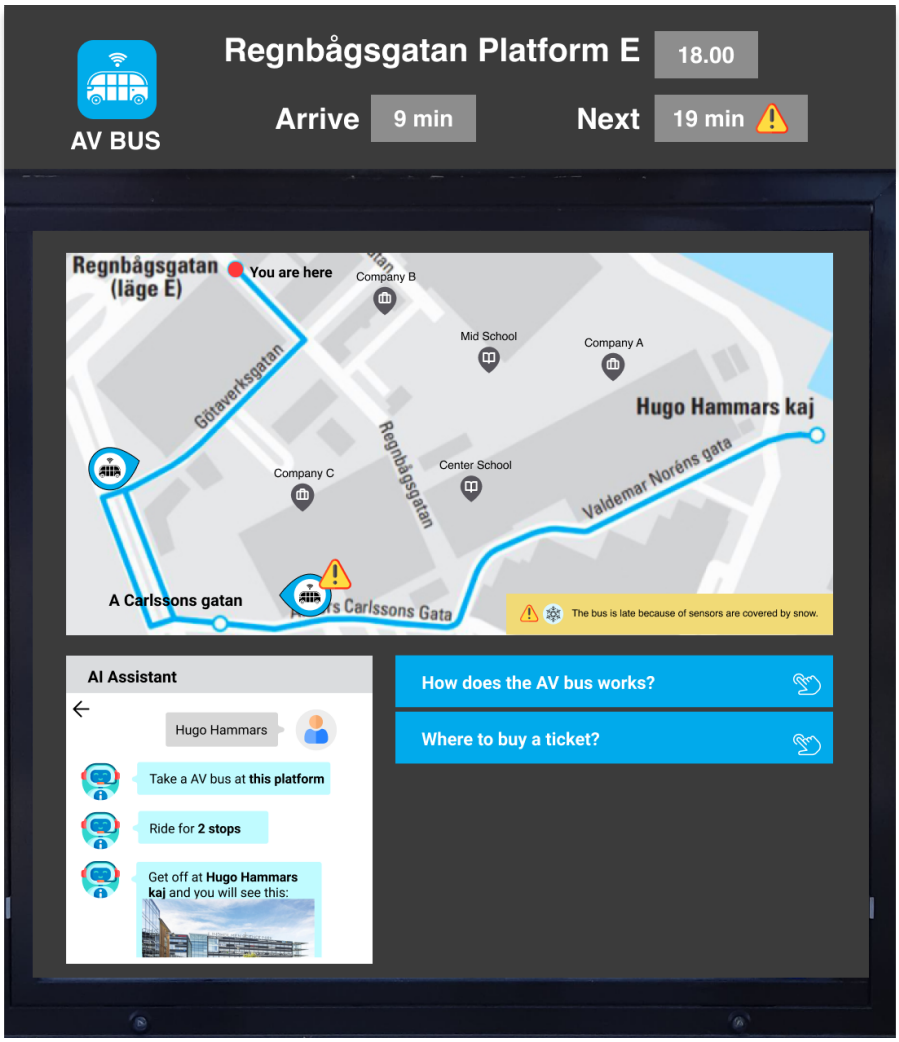

Figure 6.27: Refined Information Design Approach 3: Interactive AV Bus Information Display

According to previous research, one of the main reasons why people require transportation information is that they cannot use mobile phones to search the information. Hence, this interactive information display was designed to help people plan and check their journey. Considering the feasibility, this display can be placed under the bus stop shelter. There are three types of information on the signage: A dynamic map, AI route planning assistant, and AV bus information. The dynamic map displays information about the AV bus route, AV bus position, and AV bus status. AI assistant can provide users with personalized route planning service. After users input their destination, the AI assistant will generate a script on how to reach the destination. Also, the basic information of how to commute on the AV bus and how to buy the ticket is displayed in collapse panels.

4. Information display inside the AV bus along with the audio announcement providing information about bus status, direction, error information, etc.

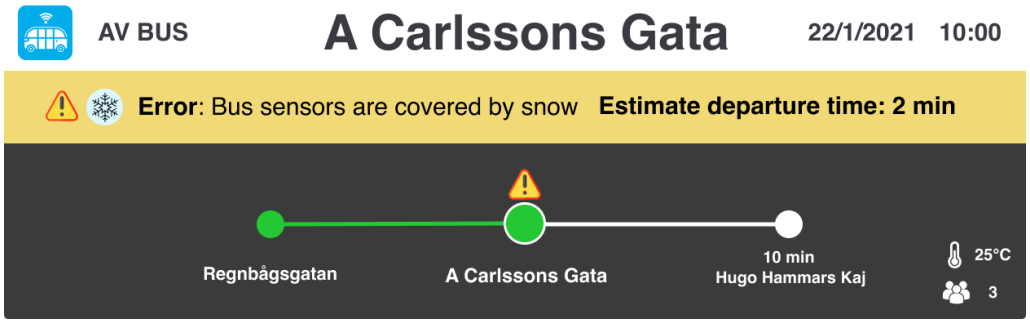

Figure 6.28: Refined Information Design Approach 4: information display inside the AV bus along with audio announcement

In the future there may be no bus steward on the AV bus, thus the information display inside the bus will play an important role in informing passengers. All of the information on the prototype was based on the research in previous phases, which are all presented in a combination of both visual and audio forms to especially support people with cognitive impairment.

6.4 Deliver

In the Deliver phase, existing design solutions were tested with real users. Under the special pandemic situation, conducting physical evaluation was extremely difficult. Thus, both physical and digital tests were applied according to the features of different designs. According to literature studies, unfamiliar users without cognitive disabilities may encounter the same difficulties as those with cognitive disabilities [31]. This project focused on finding the requirements of people with cognitive disabilities initially, but the design solutions intended to benefit all types of users. Therefore, participants without cognitive disability who were unfamiliar with the Autonomous Vehicle context were recruited in the tests.

6.4.1 Physical Test

After refining the design solutions, the usability of the first two design solutions required to be tested in a real-world setting.

To test the first design solution of navigation footprints and signs, an A/B test was implemented at the bus platform Regnbågsgatan in Gothenburg. Four participants were recruited in the A/B test, two people in the control group and two people in the experimental group. Since most users considered the AV bus station difficult to locate during the previous phase's user research, participants in this test were assigned the task of finding Regnbågsgatan Platform E (the AV bus platform) from Regnbågsgatan Platform B (the regular bus platform). This test also aimed to simulate the real scenario of passengers transferring buses between bus platforms.

In the control group, participants were required to find the destination using whatever existing methods they were familiar with, such as mobile application, etc. In

the experimental group, participants needed to find the destination using the navigation footprints and signs approach. The illustrations of footprints and displays were printed initially. Then the visibility of illustrations in different shapes and at different distances was then compared. Finally, the footprints were sticked on the ground consistently following the path in the figure below, and the signs were placed in the three corners.

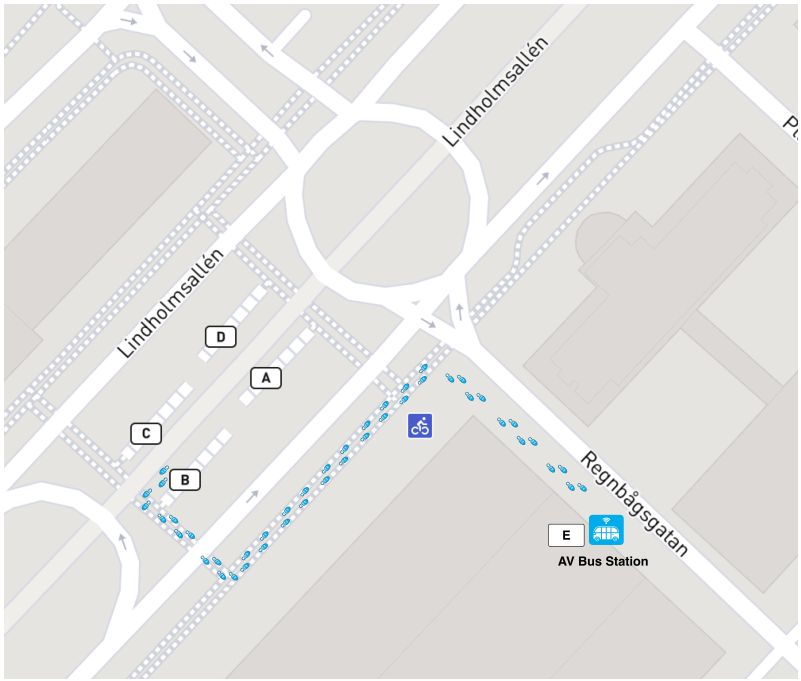

Figure 6.29: Planned Footprint Path in Regnbågsgatan Bus Platform

Figure 6.30: Footprints Approach Settled in Real Context

During the test, all participants in two groups were led to the start point Reg-

nbågsgatan Platform B and were provided with the task of finding their way to Regnbågsgatan Platform E. At the same time, participants were asked to perform the Think-aloud with whatever they were looking at, thinking, doing, and feeling while finding their way to the AV bus stop. The experiment group was asked to conduct a heuristic evaluation of this project design's visibility, recognition, assistance, efficiency, and aesthetics after the think-aloud process. See testing procedure and feedback in Appendix F.

According to the testing result, people in the control group mainly used Google Map to search for a destination when they could not see it within visible distance. However, since the bus station was new, there was no result in the App. Users, particularly those with cognitive impairment and those unfamiliar with the environment, would experience frustration and anxiety as a result of this. Furthermore, some people who disliked using mobile phones attempted to use their own experience of finding ways in this situation. Some participants tried to walk around the platform and check each corner. This would waste users' time, especially if they were in a hurry. As a result, information should be made available in a variety of formats to benefit each individual.

On the other hand, people in the experiment group initially spent time to locate the first navigation sign at the start point. After participants spotted the navigation arrow sign and matched it with the blue footprints, it became easy for them to follow until the destination. The whole process took less than 5 minutes. The heuristic evaluation revealed that the graphics on the prototype was different from the local transportation system, making it difficult to be spotted at first. In further improvement, the first navigation display (indicating the direction) should be placed in a prominent position so everyone who arrived at the bus platform could see it. The blue color of the footprint enabled it to be easily recognized outside, all participants thought it was efficient to follow. Moreover, the match between footprints and navigation signs enables the solution to be more accessible. This design solution allowed all participants to feel confident while finding their way.

The second design solution of basic information display was also tested physically. The sign was printed and placed at the AV bus platform (see figure below). Two participants were included in this test. During the test, participants were given the context that they were planning to take the AV bus. Then participants were asked to view the information display and think aloud what they were looking at, thinking, doing, and feeling. Furthermore, participants were asked to perform a heuristic evaluation of the information display's visibility, recognition, assistance, efficiency, and aesthetics. See testing procedure and feedback in Appendix F.

Figure 6.31: Physical Test on Information Display

The test results demonstrated that people's first impression of the overall information display was that it was a bit overwhelming, since it contained too much information. People tended to perceive the information from top to bottom, they saw the name of the bus platform first, then the bus schedule, bus direction, and how to purchase a bus ticket. The two columns of arrival time and bus status were not understandable for the participants. Also, people were concerned about the bus arrival time and they would calculate the current time and bus timetable to double-check if the bus would come on time. Moreover, the bus ticket information proved to be useful for first-time users who were unfamiliar with the city.

6.4.2 Digital Test

The third design solution require an interactive prototype, and the fourth design solution required to be settled on the AV bus. Both of these prototypes were difficult to evaluate in a physical context. Therefore, digital evaluation was conducted for these designs. There were two iterations in the digital tests. Three participants engaged in the first iteration, and five participants engaged in the second iteration. During the testing procedure, two solutions were tested together. Participants were introduced with the context as well as the tasks. Evaluations were conducted based on the actions and responses of the participants..

Regarding the test of the interactive information display design solution, participants were firstly introduced with the scenario that they came to Regnbågsgatan Platform E to take the AV bus for the first time while their mobile data was running out. Then, participants were asked to assume they were standing under the bus platform shelter and seeing the interactive information display. Afterward, participants were asked to perform the Think-aloud with whatever they were looking at, thinking, doing, and feeling while searching the route to their destination. After people completed their tasks, a heuristic evaluation of the design's visibility, assis-

tance, and efficiency was conducted. The procedure and results of the test can be found in Appendix G.

After the first iteration test for the interactive information display design solution, feedback was collected from the participants. See Appendix G. Here are some disadvantages of the design that need to be improved. Firstly, the AI assistant's functions were unclear, people were unsure how the AI could help at first glance. Secondly, users were confused by the terms "Arrive" and "Next" on the signs. Thirdly, the error information should be visualized in a more visible way, since most participants didn't notice it. Otherwise, everyone engaged in the test agreed that the information script was useful in finding their way, especially for those who were unfamiliar with the city. Based on the feedback, the prototype was improved. In addition, because the initial introduction was not clear to participants, the tasks in the test and interview questions were modified.

In the second iteration test, participants from various nations were invited to evaluate. The main feedback was the information display should support both Swedish and English, as several participants mentioned that the existing transportation system only have Swedish instruction. Moreover, participants were concerned that they may forget the script once they exited the AV bus, so they expected to download the script on their mobile phones.

For the design solution of information display inside the AV bus, (along with audio announcement), participants were introduced with a scenario in which they were traveling on the AV bus but suddenly encountered an accident. The information display on AV bus would then inform the cause of the accident both visually and audibly. Participants were asked to explain how they would handle such a situation with the assistance of the design solution. Moreover, additional questions such as participants' previous bus accident experience and their trust in AV buses were asked. The interview questions and results can be found in Appendix G.

According to the results of the first test iteration, all participants believed the information provided was sufficient to deal with the problem. One common question was people doubted whether the information of estimated departure time was accurate. In the second test iteration, there was a suggestion of adding a support number in the AV bus to ensure passengers' safety. Moreover, the interview revealed that human bus drivers on regular bus were responsible for evacuating passengers and giving them the instructions to transit another vehicle. When it came to trust in AV services, the majority of participants expressed they didn't have complete faith in AI, but they would still follow the instructions provided by AI. People tended to believe in the combination of AI and humans, they preferred the AV bus which can provide the service of asking for human support under emergency situations.

6.5 Summary

The design process of the project followed the *Double Diamond* model to first *Discover* and *Define* the problems people with cognitive impairment might encounter during a journey on the AV bus. Then the design opportunities and solutions were filtered and iterated through the *Develop* and *Deliver* phase.

Initially, utilizing *Persona* and *User Journey Map* methods, the problems and requirements in the whole journey of commuting an AV bus were identified. Problems in 6 categories including Space, Sound, Information, etc. were defined. After research and discussion, it was found that some problems were not feasible to be solved within the design scope of this thesis project. Therefore, the design focus was narrowed down to 4 topics including Sound, Memory, Emotion, and Information. In the further development, the design scope was narrowed down again to only focus on solving the problems related to **Information Needs**. Multiple solutions were designed based on different information people needed in different scenarios within the AV bus system. Finally, four design solutions were selected for four stages during the commuting process. See the visualization of the design process below.

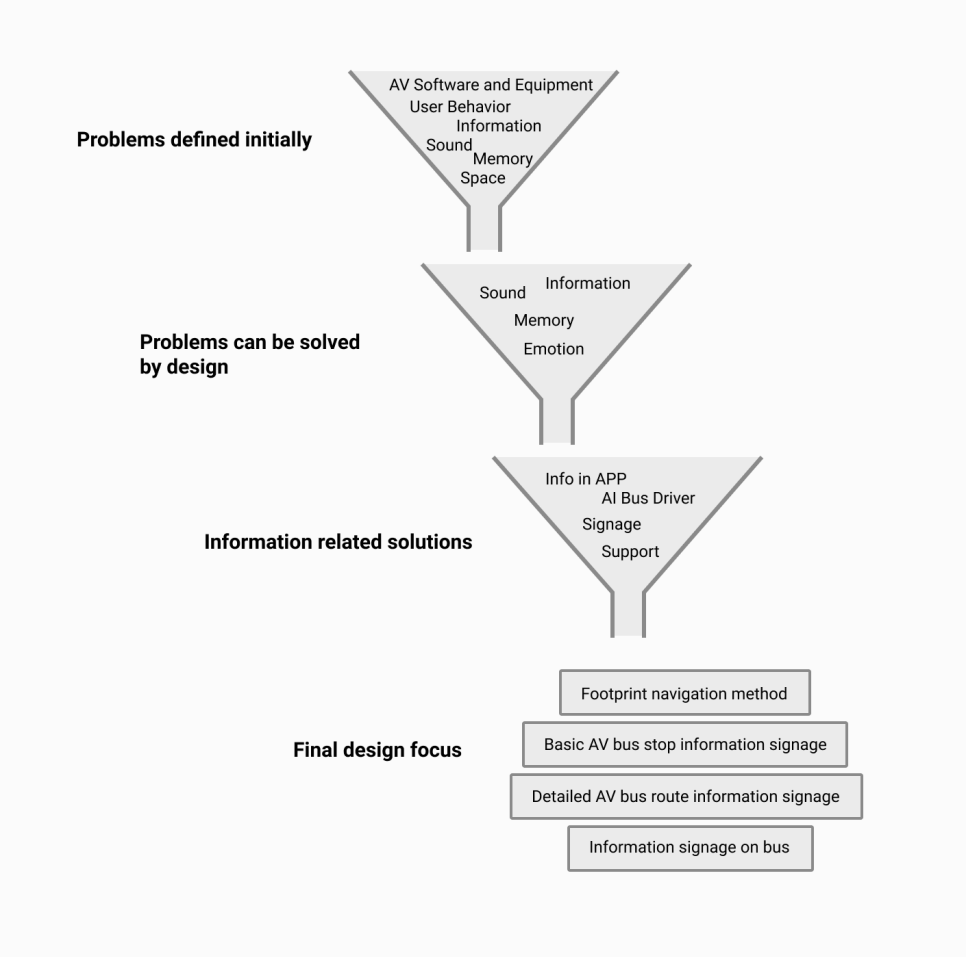

Figure 6.32: Visualisation of the Design Process

7
Results

This chapter will present the final results, which answer the research questions:

- *What are the basic requirements and information needs that people with cognitive disabilities have when traveling with public transportation?*
- *What are inclusive design challenges and opportunities for an Autonomous Vehicle service?*

Five personas (i.e. fictive people made from data) were created initially based on literature reviews and interviews. Four prototypes for transportation services were designed based on the requirements of the personas. Seven inclusive design guidelines for information needs in Autonomous Vehicle services were proposed based on user research and theory.

This project involves data collection from both people with and without cognitive impairment. Since people without long-term disabilities can benefit from inclusive design, and may encounter disabling situations. Overall, the researchers aimed to investigate inclusive solutions that would benefit a wide range of passengers.

7.1 Persona

Personas are useful tools in inclusive design projects. Personas can be used to raise awareness of universal design and accessibility needs of individuals with disabilities [21]. Through remembering the personas' background and stories, designers can keep the personas alive in mind when making design decisions. Throughout the design process, five personas were created, including three with different types of cognitive impairment, one caregiver, and one without a disability. The created personas could be useful in other types of design projects where the project group wants to include people with cognitive impairment. The personas introduce the potential cognitive disabilities and illustrate the requirements of those with cognitive disabilities when using public transit. The images, tags, goals, requirements, and issues of each persona will be specified and displayed in the figures.

Persona 1 - John

The first persona of John was created according to the description of one expert from a previous interview (see Section 6.1.2.1). He was caring for a person with autism and hyperactive symptoms. Normally, the caregiver needs to assist the individual to maintain balance, talk to calm the person down, and also keep the person concentrate on the journey. Additionally, people with autism involve difficulties with social interaction and mutual communication. They also have conditions of limitation in society in repetitive behaviors, interests, and activities [30].

Hence, the characteristic of John can be concluded as:

John is a person with autism symptoms, which include hyperactive actions, and unstable mood. His preferred mobility methods are public buses and a private car. Some activities such as games are essential to help him relax throughout his voyage. John's requirements for public transportation include enabling himself to concentrate on the journey, controlling his hyperactive actions, and preventing his hyperactive actions from bothering other passengers. See the detailed persona in the figure below.

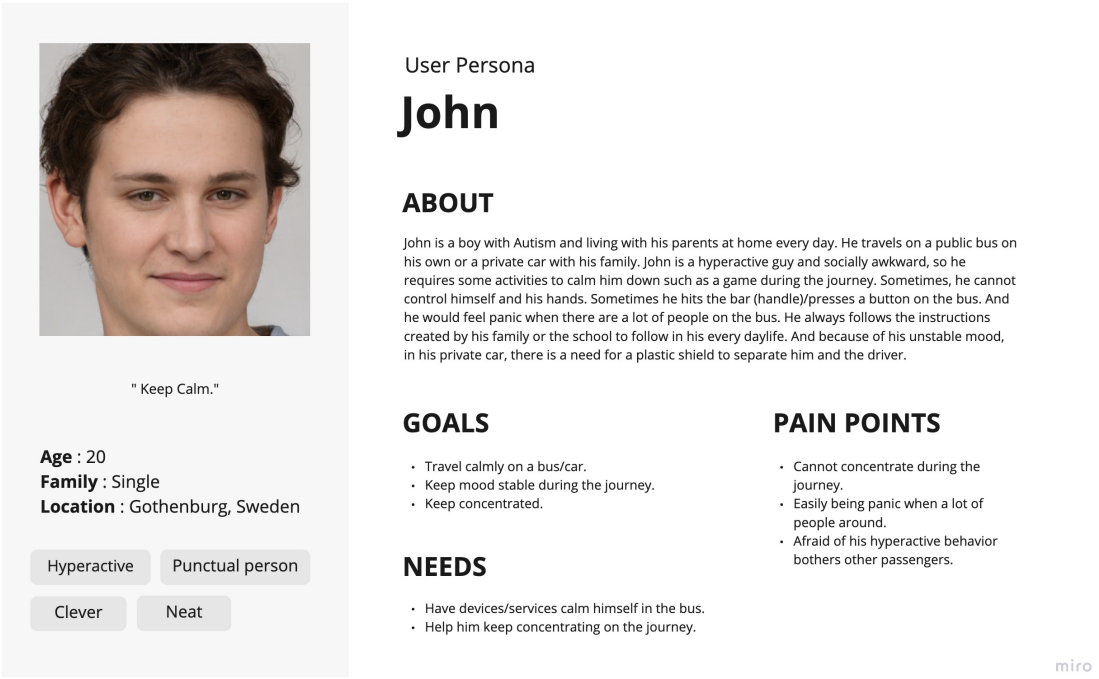

Figure 7.1: Persona 1 - John

Persona 2 - Emma

The persona of Emma was created using a combination of literature reviews and expert interviews. Down syndrome has an impact on cognitive abilities, such as learning difficulties [30]. One expert revealed that her daughter has Down's syndrome in the interview. She accompanied her daughter to school every day since her daughter has vision problems and face other difficulties on public transportation. The Emma persona was created from expert interviews.

Emma is a girl who has Down syndrome, astigmatism, and hearing loss. Emma rides the bus to school every day and she requires a caregiver to accompany her on the bus. Her mother always takes on this role of caregiver to support her, for example to prevent her from loosing track of time and place by talking to strangers. Emma is eager to be independent. She needs a service that support her to navigate in public transit and keep her focused during the journey. Emma also requires training in learning the route. See the detailed persona in the figure below.

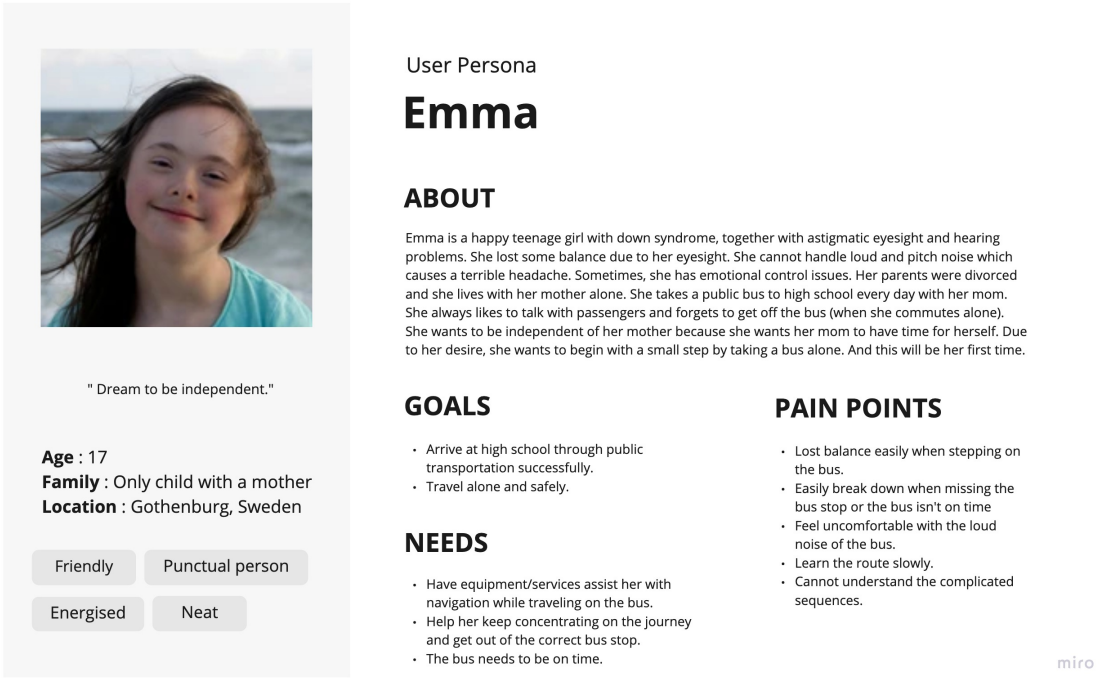

Figure 7.2: Persona 2 - Emma

Persona 3 - Emily

Emily's persona was created as a representative of caregivers, and also she has a close relationship with Emma. This persona is also based on expert interviews. The expert mentioned that she was responsible to plan her daughter's schedule and guide her on public transportation. She will solve the problems for her daughter during the journey. In addition, the purpose of creating Emma's persona is to discover the requirements of caregivers or families of people with cognitive impairment.

The characteristic of Emily can be concluded as:

Emily is Emma's mother and plays a role as a caregiver. Emily is responsible for taking care of her daughter every minute outside, including guiding her during the journey and ensuring her safety. Since Emily is busy with work every day, a good solution would support her to track her daughter's transit status as well as remind her daughter to stay focused on the journey. See the detailed persona in the figure below.

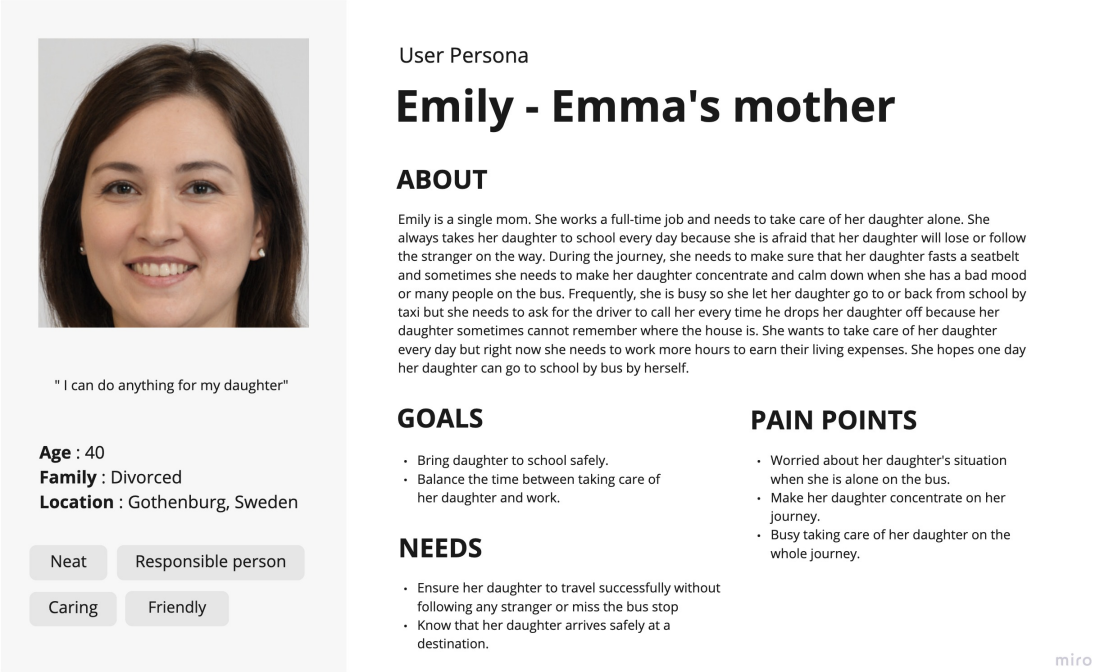

Figure 7.3: Persona 3 - Emily

Persona 4 - Eric

According to expert interviews, persons with mild cognitive impairment can almost accomplish everything by on their own and only require assistance sometimes. They are trained in school to remember the transportation route as well as the problem-solving skills. People with a mild impairment may notice their changes in cognitive functions such as memory loss or language problems, but they still are able to perform everyday routines [23]. Therefore, the persona of Eric was created.

Eric is a teenager with Down syndrome, but with mild symptoms. He has been trained to remember the transportation route and perform the appropriate activities during the journey. Thus, he can commute on public transportation himself. However, if the bus schedule changes, he may be unable to solve the problems immediately. This may result in panic and anxiety. Eric would like a device that will help him quickly learn and remember the route, as well as guide him if he gets lost. See the detailed persona in the figure below.

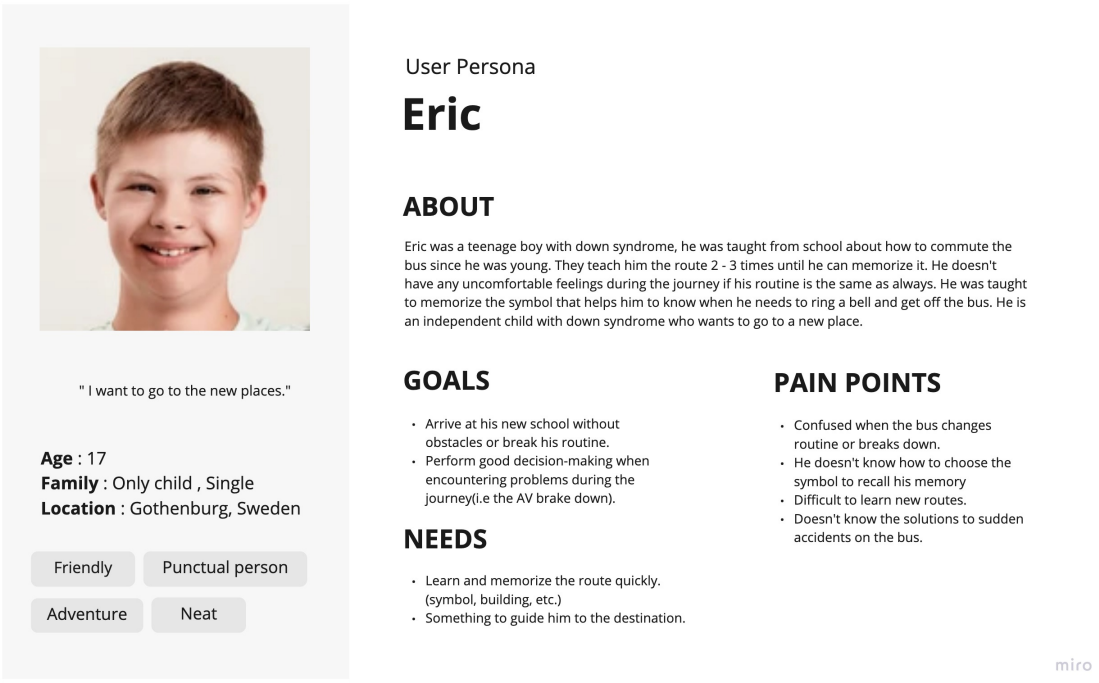

Figure 7.4: Persona 4 - Eric

Persona 5 - Kevin

The last persona of Kevin is a person without a long-term disability, but who exemplifies a common situational and temporary impairment. This persona was intended to support a diversity perspective of the personas. According to user interviews conducted in the Discover phase, passengers thought the AV bus seats and the space on AV buses were small. Also, unknown errors will cause the bus to brake suddenly on the road and result in users' motion sickness.

Hence, the persona of Kevin can be concluded as:

Kevin is an office worker who takes both regular and AV buses to get to work. He used to ride the bus with headphones on and keep a distance from other passengers. He is motion sick due to the AV bus's frequent stops. The requirements of Kevin include being in good physical condition after commuting, keeping a safe distance from other passengers, and maintaining a comfortable environment on the bus. See the detailed persona in the figure below.

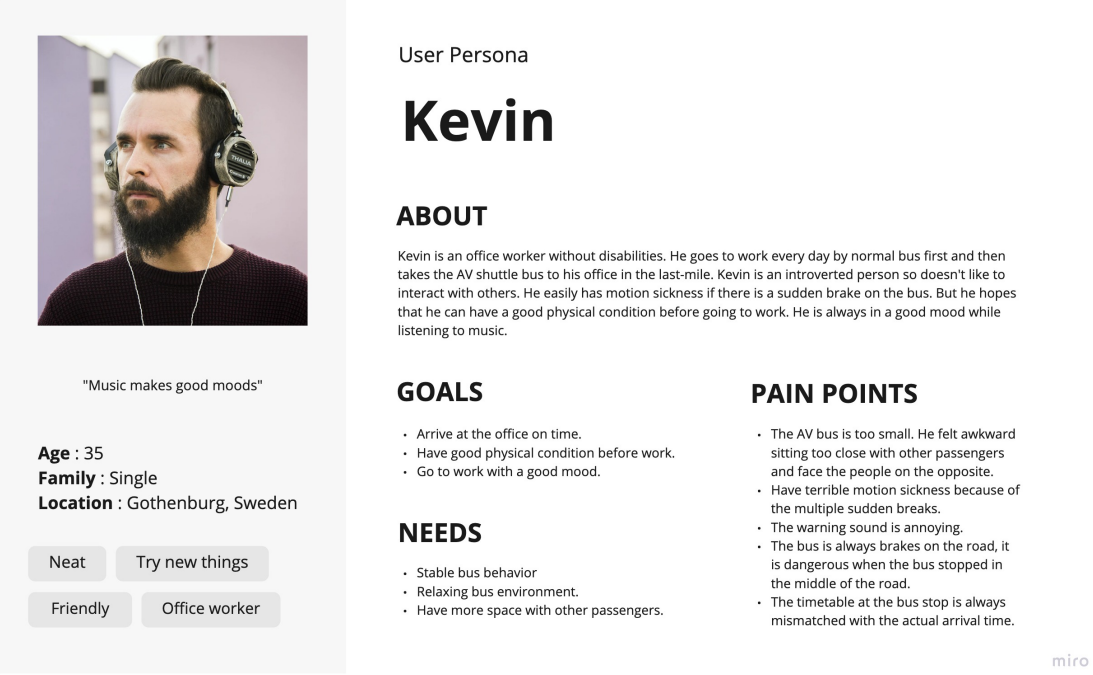

Figure 7.5: Persona 5 - Kevin

Based on personas, researchers can learn about the different types of disabilities, limits, and restraints that people face when utilizing the services [22]. The five personas are useful tools for understanding users' requirements and information needs during their transportation journey. Furthermore, the prototypes and inclusive design guidelines are all based on the personas' problems and stories.

7.2 Final Prototypes

Four prototypes are proposed in the AV service context regarding different scenarios in a transport journey. In the context of AV service, there is no bus driver providing assistance to passengers. This means that there are new solutions needed for existing requirements, for example related to information. Our solutions include the footprints and navigation display that assist people to navigate to the AV bus platform; the basic information display at the AV bus platform; the interactive route planning information display at the AV bus platform, and finally; an information display and audible announcement on the AV bus.

7.2.1 Footprints and Navigation Display

The footprints and navigation information display are combined to assist passengers to find the AV bus platform. The footprint solution is designed with blue footprint pictograms, the direction to the destination, and the destination's name. Also, there is a white circle background enabling the footprints to be distinct from the environment. Footprints are designed to be placed on the ground continuously from the regular bus platform to the AV bus platform. Simultaneously, navigation signage indicating the direction and distance to the AV bus stop is placed on the footprints' path to help people confirm their progress.

Figure 7.6: Information Design Result 1: Footprints and Navigation Signage

7.2.2 Basic Information Display at AV Bus Platform

The basic information display at the AV bus platform is designed based on the scenario that passengers travel on the AV bus for the first time. The information on the signage comprises the name of the AV bus platform, the time of the AV bus, the direction of the AV bus, and instruction of the AV bus service.

On the top of the signage, the name of the AV bus platform is displayed in large font enabling passengers to confirm that they have arrived at the correct bus stop. There are three types of time displayed on the signage: the current time, the current bus's arrival time, and the next bus's arrival time. Words such as "Arrive in" and "Next" utilized in this design are easy to follow. Also, the AV bus schedule is displayed since passengers require to know the frequency of the bus. Moreover,

the AV bus's direction is displayed repeatedly in the signage. At the bottom of the signage, there is a bus route direction bar which includes an arrow pointing to the destination platform. Under the estimated arriving time, each bus's heading is indicated separately. Additionally, different options of purchasing the AV bus tickets are provided, and the ticket price instruction is highlighted with the blue background. More information can be found in the diagram below.

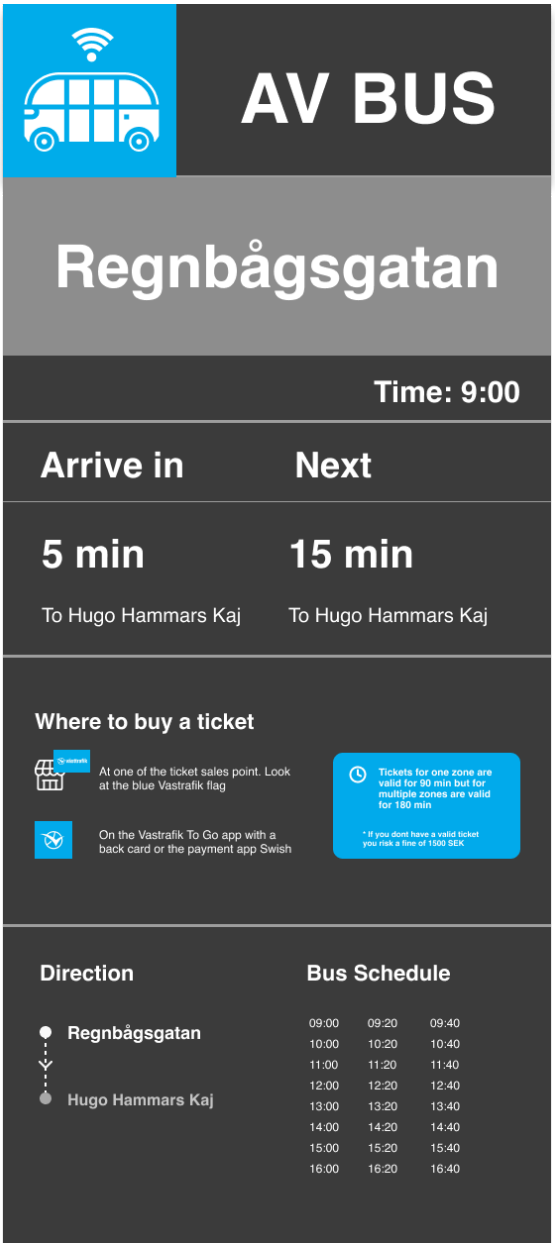

Figure 7.7: Information Design Result 2: Basic Information Signage at AV Bus Platform

7.2.3 Interactive Route Planning Information Display

The interactive route planning information display was designed to allow passengers to plan their own trips at the AV bus platform. An interactive map is placed on

the top of the signage, allowing passengers to zoom in and out to view information about the surrounding information. The AV bus route is displayed on the map with blue lines, as well as the current position and AV bus stops along the route. Also, the operating AV buses are displayed in orange icons with directions in order to be distinctive. There is an announcement in the bottom right corner of the map informing the reason for the AV bus error. In addition, there is an AI route planning assistant in the bottom left of the signage where passengers can input their destination and receive the route script. In case people forget their routes, the script can be synchronised to mobile phones or photographed. Moreover, the instruction of the ticket and the commuting sequence is also provided in this information display.

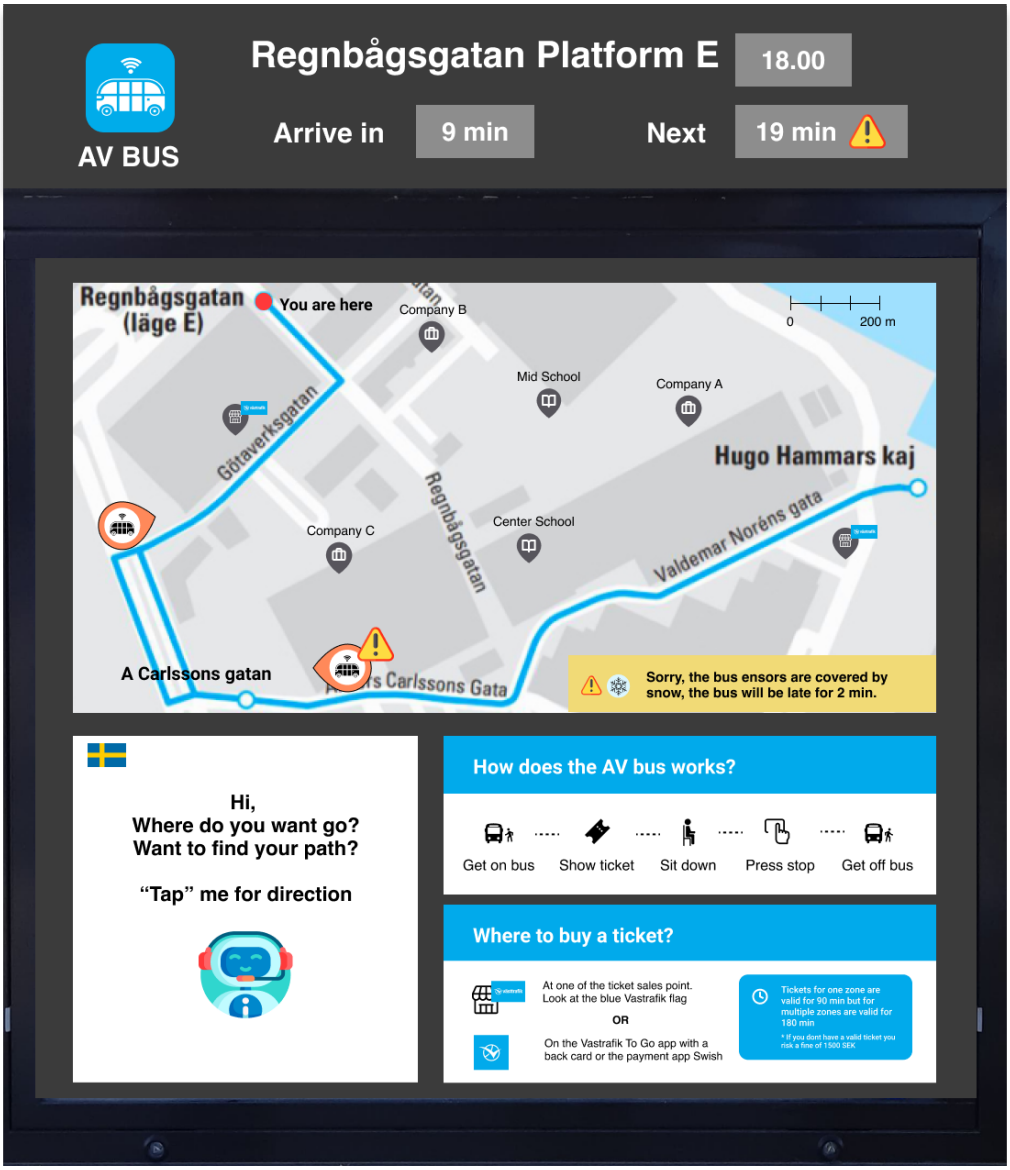

Figure 7.8: Information Design Result 3: Interactive Route Planning Signage

7.2.4 Audible Announcement and Information Display on AV Bus

The announcement in both audible and visual forms is the basic requirement of public transportation. In S3 project, however, the AV bus does not currently have this capability. In this thesis project, the audible announcement and information display are designed to convey information that was previously provided by human bus drivers. The name of the current bus stop is prominently displayed on the top of the information display. The audible announcement will provide the same information as the signage when the AV bus arrives at a bus platform. Moreover, there is a progress bar that illustrates the AV bus's progress along the route. The passed stops are green, while the next stops are white color. Also, there are arrows on the route that indicate the direction of the bus. The estimated arrival time to each bus stop is displayed on the top of the bus stop name.

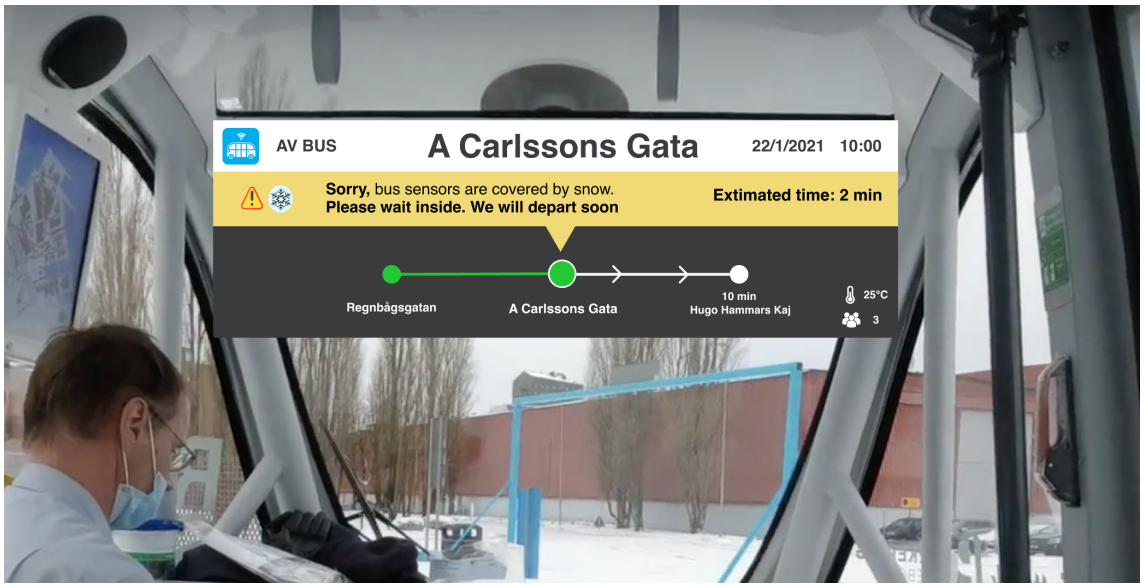

Figure 7.9: Information Design Result 4: Information Signage on AV Bus

Additionally, AI is responsible to provide the passengers with solutions when accidents happen. In the bus information signage design, a notification with a distinct background is displayed on the top of the signage. In the notification, the reason for the error is explained. Also, passengers are given instructions on how to perform appropriate actions in the AV bus and how the AV bus will act in the future.

7.3 Inclusive Design Guideline of Information Needs in Autonomous Vehicle Service

1. Using Simple and Visible Navigation Signage to the Bus Platform

Overall, navigation signage should be designed with uncomplicated navigation pictograms, have distinct colors compared to the environment, and be placed consistently.

People need simple and visible signage to be able to navigate to a bus platform. This is especially important when designing for cognitive impairment, according to the International Transport Forum [33]. Moreover, the amount of information is important. Too much information can be as distracting and confusing as too little information. Research illustrated that when designing visual signage for people with cognitive impairment, utilizing symbols and pictographs are helpful in training individuals [36]. People may use signage and other landmarks to memorize their way [32]. Regarding the expert interviews conducted in the project, individuals with mild syndrome normally learn the routines of using public transit in school. They can memorize the landmarks (such as buildings) and follow signage to find their way. Moreover, navigation signage should have distinct colors compared to the environment. Hunter et al proposed a requirement for visual signs to have proper illumination to avoid visual noise [36]. Moreover, color coding can be helpful for training people with cognitive impairment. Finally, navigation signage should be placed consistently. Effective visual signage should have large printing and consistent placement [36]. Appropriate distance between two continuous signs should be defined as one can easily view the next signage.

The AV bus investigated in this thesis has its own bus stop, which is separately from the city's public transit. In this thesis, the design solution of combining footprints and navigation arrows was proposed and iterated as a possible navigation signage solution for the AV bus. In the physical test, the footprints were consistently placed on the pavement. When testing with people without cognitive impairments, participants were given the task of utilizing the footprints and navigation arrows to locate the AV bus platform. The think-aloud process showed that people found the pictograms of footprints easy to follow and that they only needed to have a glance at the footprints to understand the route. From the survey conducted in the design process, people with cognitive disabilities were concerned about the visibility of the signs placed on the ground in extreme weather (such as snow). When creating navigation objects to be placed on the ground, the distinguishing color in comparison to the environmental color should be considered. For instance, in this project, the footprints were designed with a white circle as the background and blue footprints inside to create the distinction (see Figure 7.6). However, in order to ensure that other groups of people (such as people with visual impairment) are not excluded from this signage, this solution need to be tested and developed in the future.

2. Synchronizing Bus Arrival Time with the Schedule

Synchronizing the bus arrival time with the schedule at the bus stop is important during a transportation journey. Fischer et al proposed that a "clock" was an essential navigation artifact for people with cognitive impairment [32]. When learning a route, people with learning disabilities tend to check whether the real arrival time of the bus is the same as the schedule. They lack the ability to perform problem-solving and decision-making, so they do actions according to the routine that they learn [32]. Furthermore, according to the expert interviews conducted in this thesis study, if unexpected events happen during the journey and result in a disruption in routine, people may become anxious or stressed. Normally, a caregiver's responsibility is to guide and teach people with cognitive disabilities to be familiar with the routine. When they don't have a caregiver with them, synchronizing real bus time with the schedule therefore becomes essential.

From the questionnaire results, the bus frequency and departure time are two vital factors. Different types of time are shown differently on the information display in this thesis design (see figure below). According to the test results, people tend to check the current time and bus arrival time first to ensure they are on schedule. Passengers must know the exact time to guarantee that they can arrive at their destination on time.

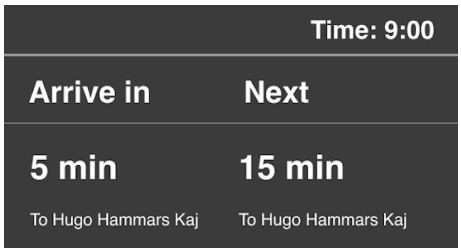

Figure 7.10: Different Types of Time Information on the Signage

3. Providing Real-Time Bus Position Information

People with cognitive impairment typically utilize landmarks as navigation artifacts to identify their position [32]. The information of the real-time position of a bus is helpful for passengers to confirm their progress during a journey. According to the survey results, people are greatly concerned about which bus stop to get off and when the bus stop solutions. This information is normally obtained from the bus drivers. Moreover, a great number of people who participated in the survey made mistakes of getting off at the wrong bus station. The nonexistent feedback on the bus and passengers' distraction are the most typical factors. As a result, the bus's position must be present and visible during the entire bus ride.

Additionally, the surrounding information at the bus stop is another essential factor. The whole journey on public transportation mainly includes three phases: navigating to the platform, traveling on the vehicle, and navigating to the destination.

Fischer et al proposed that a map was helpful for people with cognitive disabilities to identify the current location, destination, routing options, and overall trip progress [32]. Feedback from the tests conducted in this project demonstrates the surrounding information was required when people plan their route. The bus stop near the destination is spotted first and people plan their route by finding the bus route between the start and end bus stop.

In the context of AV service, AI and sensors can detect additional information about AV buses such as real-time bus position, bus errors, estimated bus delay, etc. In this project, an interactive map was designed to display real-time AV bus position, AV bus route, and nearby landmarks (see figure below). Passengers can plan their route based on the AV bus's current condition. During the physical evaluation of the prototype, the majority of people were able to find their way after viewing the map..

Figure 7.11: Interactive Map on the Signage

Another design is the progress bar on the AV bus signs that illustrates the AV bus direction and progress (see figure below). Utilizing the GPS in the AV bus, the real-time position of the bus can be located and the estimated arrival time can be calculated. From the test results, the progress bar was found to be straightforward for passengers to locate their progress in the route. Progress bars can assist people who are unfamiliar with the AV bus service to navigate to their destination without having to memorise the route.

Figure 7.12: Progress Bar Design on the Signage

4. Providing Information in Both Audible and Visual Forms

The universal solutions on public transportation systems for cognitive impairment demonstrated journey information should be provided in both audible and visual

formats [33]. They are inclusive mediums for a wide range of passengers, for example, audible information is a good solution for people with visual impairments, while visual information is a good option for people with hearing impairments. Learning difficulties and other cognitive impairments can hinder everyday activities such as reading and understanding more complex information [25]. Announcing all information in both audible and visual forms can support both people with sight or hearing impairment.

According to the survey results, many passengers with permanent or temporary cognitive impairments encountered the situation of getting off at the wrong bus station. One of the most common causes of user errors is the bus stop's imprecise announcement. When traveling on a bus, the crowdedness will result in losing sight as well as the loudness will result in difficulties in hearing.

The design solution of audio announcement along with visual signage on the AV bus proposed in the project includes both audible and visual forms of information of the bus positions (see figure below). When testing with people that had used the AV service, the results showed that providing both forms of information supported them and they understood what to do in an emergency situation (i.e. bus accident). For those with cognitive impairment, both auditory and visual announcements is critical.

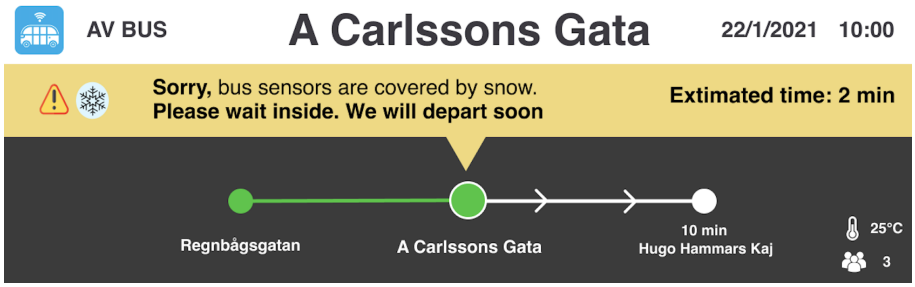

Figure 7.13: Visual Signage on AV Bus

5. Providing the Information of Bus Direction and Bus System Instruction

Overall, the direction of the bus and the instruction of local transportation are two types of essential information required before passengers boarding the vehicles.

On the one hand, knowing the bus's direction is crucial when starting the transportation journey. People with mental illness can be easily stressed in unfamiliar situations during their transit [26]. In this case, they would repeatedly ask the staff or other passengers to check the bus's right direction [25]. The most frequently asked question by both those with and without cognitive disabilities asked is related to bus direction. Furthermore, the majority of those who took part in the survey made the mistake of boarding the wrong bus because they were distracted or stressed at that moment. Enabling the information of bus direction to be easily accessible and intuitive at the bus stop can help passengers avoid making mistakes.

On the other hand, according to the surveys conducted during the process, both people with and without cognitive impairment have questions related to how to use local transportation. This includes two types of information: ticket information and commuting sequence. The ticket is the primary distinction between transportation systems in different nations and localities. People need to know where to purchase a bus ticket as well as which type of ticket to buy before starting their journey. Also, information regarding the bus commute sequence should be available at the ticket store or at the bus station.

An example proposed in this project displayed both types of information at the AV bus stop (see figure below). Signage with instructions of the AV bus as well as the bus direction information was shown to passengers who commuted the AV bus for the first time. From the testing results, all of the participants can understand how to buy a ticket of the AV bus as well as where they should go. The information assists people to ensure they act appropriately and stay on the right track.

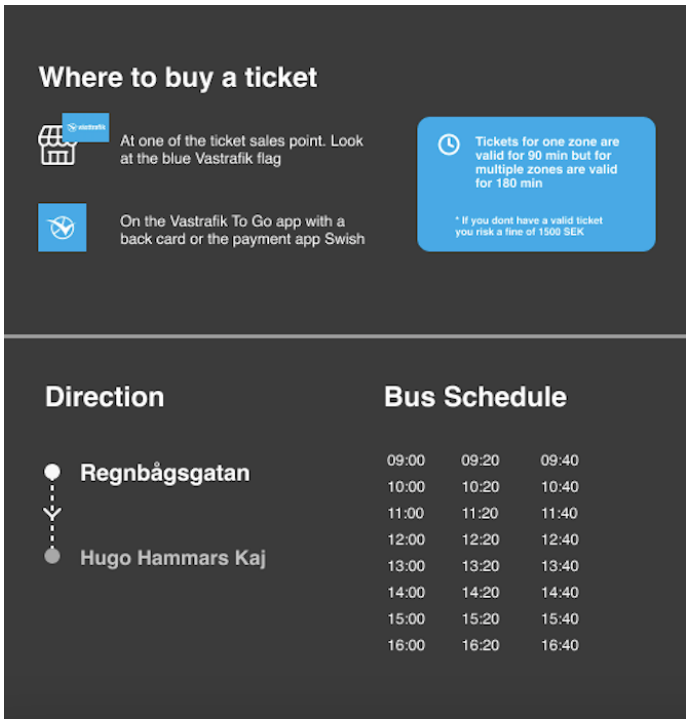

Figure 7.14: Bus Direction and Instruction of Bus System

6. Using Travel Route Scripts to Visualize Transit Information

From the studies on cognitive impairment-friendly approaches for public transportation, using visual aids can help people with cognitive disabilities to solve the problems they encounter [38]. This can take the form of a script in words or pictures detailing every step needed when using public transport, and also teaching coping strategies when unexpected events happen. As previously indicated, people with mild cognitive impairment learn how to use public transportation either at school

or by a personal caregiver. Unexpected changes such as new routes, roadblocks, and breakdowns will have a significant impact on their decision-making ability. Alternative options for assisting people with cognitive impairment in reducing anxiety should be made available. In the survey conducted in the design process, people were asked to compare the efficiency and assistance of displaying the route information in two forms: a visual script with text and pictures and a map with text description. The survey results illustrate people considered the script to be easier to understand and follow.

Moreover, user testing has revealed that people use different strategies to navigate. Some people may use mobile applications to navigate in public transportation. Others rely on their experience to find their way. There are also occasions when people's mobile phones run out of data or power, result in people losing their way. The route planning service currently provided in mobile applications should also be provided at the AV bus stop with the assistance of AI. In the design of AI route planning assistant on the interactive route information signage, a route script with the travel steps will be provided when users input their destinations into the interactive signage (see figure below). The information in the script includes the name of the bus stop to board; the number of stops to ride; the name and picture of the bus stop to exit, etc. This design was digitally evaluated with the participants, and everyone gave positive feedback on the script design.

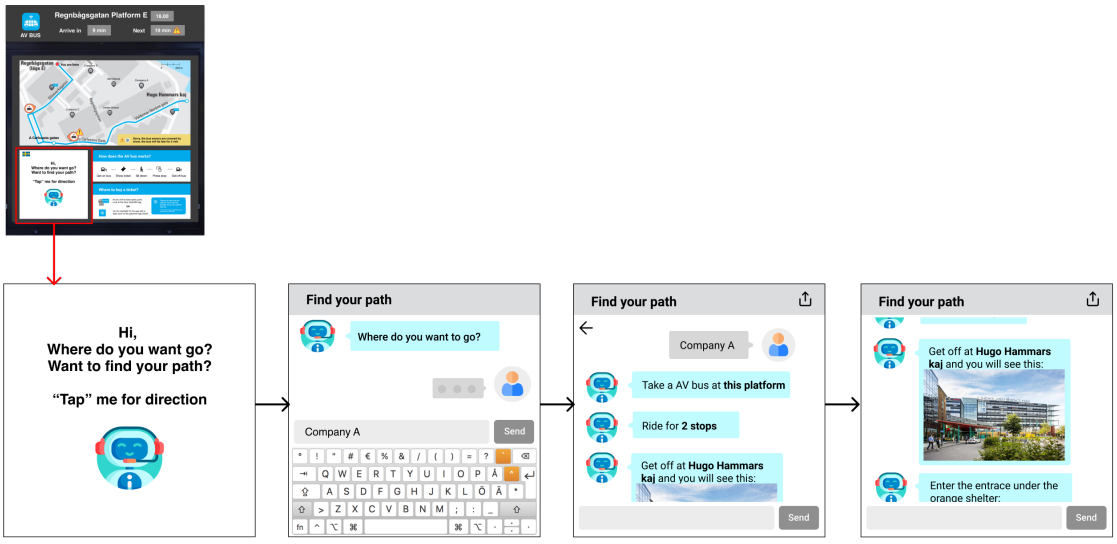

Figure 7.15: AI Route Planning Assistant

In sum, it is essential to provide route information both online and offline to meet the requirements of passengers with different navigation behaviors. Also, visualizing the route information in a script with text and pictures is efficient for people to match their current situation with the guidance and act appropriately.

7. Testing which type of bus driver information and role that AI and

related solutions successfully can handle

In public transportation, human bus drivers play an important role for those with cognitive impairment. They may require assistance from bus drivers while boarding and exiting the bus. According to previous research, bus drivers should handle the complex situations of people with cognitive impairment on an individual basis and show them respect and dignity [34]. Also, bus drivers are responsible to ensure the safety and comfort of all passengers. If the bus drivers' behaviors is rude and he or she refuse to assist, this may bring a negative impact on people in general, but have an even greater bad physically and mentally effect on those with cognitive impairment [34]. People expect the bus drivers to be trained with empathy and to provide them with appropriate assistance. In the AV bus context, AI will provide the assistance that previously provided by human bus drivers and deal with unpredictable events. Because in different situations different types of information is required, it is critical to examine which types of bus driver knowledge and roles AI can manage in the actual situation.

Even though accidents rarely happen in public transportation, it is crucial to provide passengers with evacuation instructions or solutions to deal with unexpected events such as bus breakdown. From the survey results, people mentioned that they had encountered bus errors and tried to look for solutions from the bus driver. In most cases, the bus driver is responsible for ensuring passenger safety as well as resolving bus problems. In addition, bus drivers need to inform the passengers about what they should do in emergency situations. This project is situated in the context of the AV bus without a driver, thus the solutions and instructions for coping with the situation are required to be provided by AI software. For instance, in this project, the notification is designed to inform the bus status when the AV bus accidentally stops on the road (see figure below). In the testing session of this design, participants were provided with the scenario of encountering bus errors as well as the solutions. The feedback illustrated that clear and precise instruction and calm announcements allow the passengers to perform appropriate activities.

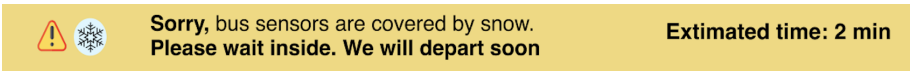

Figure 7.16: Notification Design on the Signage

Despite the errors caused by bus systems, there are also errors caused by passengers. For instance, some may forget to get off the bus. They may be affected by excessive stress in such a situation and might prefer to ask a bus driver for possible solutions. Passengers, particularly those with mild to severe cognitive impairments, require that there are proper solutions or ways to deal with such situations. In the context of AV buses without human drivers, it is essential that AI and related solutions provide feasible and appropriate options.

8

Discussion

This chapter will present the discussions about what has been made in this thesis. This involves the final results, the design process as well as the methods applied, and discussions regarding potential future work that can be done for this thesis.

8.1 Design Result

This section discusses the result of the study, by reflecting on the factors that affect the design results. As mentioned in Chapter 7, the design results are presented from different perspectives. On the one hand, basic transit requirements and information needs have been identified. On the other hand, inclusive design examples and guidelines are proposed based on these requirements. Here the difficulties when designing appropriate assistance for people with cognitive impairment, the AI aspects that may negatively affect target users, and trust and safety issues emerged in AV services, will be discussed in depth.

Design Appropriate Assistance for People with Cognitive Impairment

People with cognitive impairments are the target users in this project, with the goal to understand if they have any specific requirements for regular public transportation and autonomous bus transportation (i.e. the AV bus). According to research, cognitive disabilities are different in each individual [23], and people with Autism and Down syndrome were chosen as the main focus in this project. Design solutions were proposed according to their requirements. However, when evaluating the design solutions, some were considered to be inappropriate and may have a negative impact on users. For instance, in the design process, some people expressed their dissatisfaction with the design, claiming that it underestimated their abilities. One person with autism mentioned that the color coding of each bus stop is condescending because he has no problems locating the correct bus stop based on landmarks and the signs inside the bus. Inappropriate design will engender antipathy and even stress among users. Therefore, when designing inclusively, it is preferable to evaluate the design with a variety of people. Thus, the design can serve a wide range of users, including those with and without cognitive disabilities.

AI Aspect That May Negatively Affect People with Cognitive Impair-

ment

Considering the negative effect of AI, the most important question is whether AI can do human bus drivers' jobs appropriately - when it comes to providing information to passengers. The human bus drivers' role in transportation is discussed throughout the project. According to research, individuals with cognitive impairment require courteous behavior from bus drivers [34]. In the Autonomous Vehicle context, AI and sensors will perform the jobs of human drivers, which will have a significant influence on people with disabilities. Normally, human bus drivers are responsible to handle passengers' problems on an individual basis [34]. When it comes to AI, it is difficult to predict users' problems and provide humane strategies to cope with different situations. A qualitative study was conducted to collect frequently asked questions by passengers. After the analysis of the results, design approaches were proposed to solve common questions such as direction, timetable, etc. For instance, the prototype shows how an AI assistant can provide users with a route script and prevent users from getting lost. However, there might be many different types of problems that a system may not handle well or with the overall understanding and experience that a human driver can have.

Trust and Safety Issues Emerged in AV Service

Trust and safety issues are not the main focus of this project, but several people expressed concern about such issues during the evaluation. Due to the common brake and unstable driving behavior of the actual AV bus, some passengers preferred the combination of human and robot. 2 people stressed that they would not trust the AV bus if it was not monitored by a human. Currently, there is a bus steward onboard to ensure the safety of AV buses in accordance with local regulations, however there will be no human providing supports on AV buses in the future. The performance and process of information offered by the AV is likely to have a significant impact on user trust [14]. Regarding the information perspective, the design approach of the audible announcement and information signage on the AV bus was proposed. This aims to provide passengers with real-time information regarding the AV condition as well as solutions in the event of unexpected accidents. In one scenario developed in this thesis, the AV bus encounters a sudden error, and participants were then asked for the opinions on the incident. The majority of people expressed trust in AI's judgment, but they expected the bus to provide human support when severe accidents happen. In the development of AV service, trust and safety issues are important to be further researched.

8.2 Design Process and Methodology

This section discusses the process of the project as well as the methods applied in the process. The execution process followed the Double Diamond model. Initially, target users' behaviors and the possible problems in public transportation were defined. Iterations were conducted throughout the develop and deliver phase to improve the design. All methods used were of great importance in terms of producing the end

result. Some crucial parts of the design process will be discussed in detail below.

Inclusive Design Process vs. Product Design Process

This project applied the inclusive design process, which focuses on creating products and services that are accessible to people of all genders, ages and abilities [17]. In comparison to traditional product or service design, researchers have the inclusive design concept in mind while making every design decision. This can be reflected in three dimensions: problem definition, design approach, and evaluation process [70]. When defining the problems, the intended target users should be explicitly mentioned. For instance, the transit requirements and information needs summarized in this study are all based on caregivers' interviews and literature reviews. In addition, the appropriate design approach for the target users should be adopted. Personas with varied disabilities and their user journeys have been created in this project, to learn about the obstacles that people with cognitive impairments may experience when using the AV bus. Preferably, target users should be included in the evaluation process. Due to the pandemic, users with long-term cognitive impairment were not included in this project's evaluation. Instead, people who are unfamiliar with the AV context were invited to evaluate the design solution. Every design decision was made with the inclusive concept in mind, throughout the project.

Applying Autoethnography in User Research

The initial plan of the user research procedure in this thesis was to invite people with cognitive disabilities to ride the AV bus and evaluate it. However, under the pandemic situation, the physical investigation faced a great challenge, since individuals with cognitive impairment were suggested to avoid public transportation. The autoethnography method was then introduced in this project. It involves the researchers' self-observation and reflexive investigation in the context of ethnographic fieldwork [44]. Additionally, the data of autoethnography is easier to collect than field observation since researchers can record their own feelings and experiences. In different phases of this project, autoethnography research was conducted multiple times to help researchers answer many questions, such as understanding the functions of an AV bus, discovering the problems of passengers riding on the AV bus, etc.

However, autoethnography has its own set of restrictions. The autoethnography is based on the researcher's experience, feelings, and understanding. Even though researchers and other users had the same experience, different individuals will tell various stories about it [45]. In this case, researchers will have a different perspective and bias on this research. Moreover, researchers cannot completely perform or have the same characteristics as persons with cognitive impairment, so the data gathered is not as accurate as the data gathered from engaging real target users.

In addition, there were brief conversations with the AV bus stewards along with each autoethnography. Since the AV bus stewards had more contact with the actual AV bus riders, the feedback from a bus steward's perspective was of great value.

Moreover, the results of autoethnography had a significant impact on the thesis process. The user research questions were primarily based on the problems that researchers encountered. Also, autoethnographic experiences were used to create scenarios such as navigating from a regular bus platform to the AV platform, encountering the unexpected brake on the AV bus, etc. In sum, the autoethnography research method was efficient in this project for solving design challenges and supporting the research process.

Utilizing Persona and User Journey Map to Develop Inclusive Design Solutions

In the Define phase of the execution process, personas and user journey maps were created to assist the researchers to understand the commuting processes, challenges, and design opportunities. Due to the distinction of cognitive impairment in each individual, personas were defined to present the typical users' characteristics, needs, obstacles, and goals. Compared with user segmentation, personas are with focus on problems embraced in the project context [50]. Each persona has his or her distinct life background as the foundation. Additionally, one persona without cognitive impairment was created to complement the other personas. This persona is always wearing headphones, illustrating a common situational disability (hearing impairment). However, there are also limitations of relying heavily on personas. Personas are fictional and they have no clear relationship to real customer data. To some extent, personas distance researchers from engaging with real users and their needs. Therefore, personas should be combined with user tests in design process.

Based on different characteristics of personas, user journey maps for each persona were generated. In the user journey map, the whole journey of commuting on an AV bus was divided into different phases. In each phase, users perform different actions and encounter different problems. This promotes the researchers to discover potential opportunities and design solutions based on scenarios. This project's design outcomes, including the design solutions and the inclusive design guidelines, are all scenario based. In sum, the personas and user journey maps created in this project facilitated the research group to distinguish differences in individuals and assist to propose scenario-based design solutions.

Design Sprint

According to the Double Diamond model, the Development phase requires multiple design iterations to polish the ideas. The innovative method of Design Sprint was applied in this phase to enable the researchers to inspire ideas and accelerate the iteration cycles. In this project, design sprints were held on a weekly basis for three weeks. Each week began with the definition of a design goal, followed by the development of concepts and prototypes, and finally, the testing of prototypes with real users. Design sprints allow design teams to fast-forward into the future to see the finalized product before making any expensive decisions [54]. It is also crucial for designers to innovate strategies and develop design thinking through the sprint

[54]. For instance, in order to acquire more participants, the strategy of posting surveys were discovered. Also, the responses from people with cognitive impairment enable the designers to consider the desirability of each idea. However, there are some risks that need to be considered using design sprints. Within the sprint period, there is little time to go further into all of the ideas. This may cause researchers to overlook a more holistic perspective. Furthermore, if researchers choose this method in the early stage of the project, the number of ideas worth exploring will be limited.

In summary, the practice of applying design sprints in this project had a positive impact on the design results, and it enables the research group's diverse thinking in design. In the future, this strategy should be encouraged in interaction design projects.

Limitation of Using Questionnaires in This Project

Questionnaires were sent out to the autistic and down syndrome populations as part of the design sprints' evaluation process. According to the guidelines of design sprints, evaluation should take the form of interviews. However, with the limited contact with individuals with cognitive impairment under pandemic, surveys were chosen to substitute interviews in the evaluation. The obvious advantage of survey is that it can be sent out via the internet, where a great number of responses can be collected. Also, the opinions of people with different impairment symptoms assist the researchers to discover various requirements. However, surveys also have the disadvantage of receiving few responses to open questions since most people dislike typing words. Also, it is a great challenge to explore deeper because some responses were not adequately stated. Whether setting the open questions to be mandatory was balanced throughout the development process. On the one hand, making open questions mandatory irritates people annoyed when they are asked questions on which they have no opinions. On the other hand, setting open questions to be optional results in less responses. Surveys collect a wider range of viewpoints, which is beneficial to the design process, but it also limits people's expression, which should be considered in future study.

Filter Users' Needs and Narrow Down Thesis Scope

Initially, multiple user problems in transportation were discovered, which slowed the thesis progress since the project's aim was unclear. On the one hand, no single design approach can handle all of the difficulties. On the other hand, the project's time constraint forced the team to make design decisions. Therefore, user problems were filtered after assessing the feasibility of solving these problems through interaction design. Later, different design solutions were proposed regarding each problem. Based on users' feedback on the design solutions, the most desirable and feasible ones were chosen. Hence, the thesis scope was narrowed down to focus on information needs in transportation. The success of the thesis result can not be indispensable from a clear thesis topic. If a project's scope is too broad, the project team will be unable to conduct thorough study on all of the issues. Narrowing down

the project scope enables the research group to go further into the problem and propose effective solutions.

Physical Test vs. Digital Test

In the development phase of the project, four design approaches were proposed, and then both physical and digital tests were conducted during the evaluation phase. Considering the varied features in each design approach as well as the cost of building the prototypes, the four design approaches were determined to be tested separately. Ideally, all of the design approaches should be settled in the physical environment to evaluate usability and accessibility. However, the interactive route information signs and information display on AV bus were difficult to implement in the real environment. The former one requires a large-scale interactive prototype. The latter one needs to be settled in the AV bus where the experiment is hard to control. Hence, these two prototypes were digitally assessed through interviews. The digital test has the disadvantage that the participants need to imagine the scenario described by the host. In some cases, it is difficult for the participants to assume he or she is in a stressed situation, which leads to inaccuracies in expressing real thoughts. Compared with digital tests, physical tests provide participants with a real environment in which they may undertake a better think-aloud method. In future development, physical tests in the real setting of all the prototypes should be conducted.

8.3 Transferability

In terms of the thesis result's transferability, it discovers the general transit requirements. To a certain extent, the requirements proposed in this thesis address issues user experience issues related cognitive impairment. The basic requirements of people with cognitive impairment in public transportation are based on three expert interviews as well as literature studies. Through the expert interviews, the frequent concerns of people with Autism and Down syndrome, as well as caregivers' responsibilities, were gathered. In the inclusive design process, various personas with different impairment were created based on the research, interviews, etc. These could be reused in similar projects. Additionally, existing transportation guidelines for people with cognitive disability were analyzed and compared. General requirements were summarized, and some of the requirements are demonstrated and problematised through the proposed design solutions.

Moreover, a total of 29 responses in two separate questionnaires were used to summarize the information needs in public transportation. The results includes 6 responses from people with cognitive impairment and 23 responses from those without disabilities. Throughout the research process, requirements were also discovered from usability tests of the prototypes. The information needs that summarized in this project can be adapted to other transportation systems. As previously stated, the aim of inclusive design is to build services that are accessible to a wide range of users. Meeting the information needs of people with cognitive disability, can also benefit people without disabilities.

To meet the information requirements in the AV bus context, several prototypes were designed in this project which can be references of further studies. The prototypes were mainly designed for the AV bus service in the S3 project in Gothenburg. The physical prototypes were tested with 2 people, and the digital prototypes were tested with 8 people. Considering the local transportation information system, the prototypes such as basic information display and route planning display were also designed to improve the local signage system. The color of the signs as well as the words utilized in the signage were the same as that used in Gothenburg's public transportation. However, the standard of local visual signage varies in different countries and cities. When referring to the prototypes, the local standard and consistency should be considered first.

In this thesis, the inclusive design concept is utilized to better understand how the design affects a wide range of people in the AV context. This is adaptable to any public transport journey. Also, the design guidelines of information needs were concluded from both literature studies and evaluation of the prototypes. The guidelines have been initially tested and considered useful by people who are unfamiliar with the service. However, as previously stated, some prototype testing was not conducted in a physical environment, potentially resulting in inaccurate evaluation results. In addition, only physical information aids were considered in this project scope, the digital design alternatives were not included. When designing for the information system, digital assistance is also an essential element and should be matched with the physical settlements.

8.4 Future Work

The next step for this project would be to further evaluate the prototypes in a physical environment. Due to the limitation of physical equipment as well as the pandemic situation, two of the design concepts proposed in this project were evaluated physically while other two were evaluated digitally. Participants in the digital tests can only imagine the environment which results in inaccuracies in the think-aloud process. For instance, in the scenario that an AV bus breaks down in the middle of the road, the digital test can not create the stressed atmosphere compared to the physical test. The ideal evaluation is to create this scenario in the controlled physical environment and then conduct the think-aloud process.

Due to the project's time constraints, the thesis only proposed solutions at the AV bus stop and abroad the AV bus, and the development of a mobile application is considered to be future work. A mobile application could provide users with similar information as the public displays. Moreover, the mobile application may provide more personalized information such as real-time support, commute progress tracking, etc. Both people with cognitive impairment and their families may benefit from this.

Another essential issue that arose during this project is that of AV service trust

and safety. In fully automated vehicles, no human steward will be on board in the future. This means that trust may come from AV's good driving behavior, as well as the information conveyed [15]. Inappropriate communication between AI and passengers may increase people's antipathy. Therefore, how to increase people's trust in AV service through interaction and communication should be further researched to eventually develop a reliable and comprehensive information system for the AV service.

9
Conclusion

This thesis aimed to answer the research question:

- *What are the basic requirements and information needs that people with cognitive disabilities have when traveling with public transportation?*
- *What are inclusive design challenges and opportunities for an Autonomous Vehicle service?*

To be able to answer these questions, *Research through Design* and *Inclusive Design* theory was applied, which aimed to research for a specific solution to a problem. Initially, this study concentrated on investigating the basic requirements and information needs that people with cognitive impairment have during public transportation. Based on these requirements, inclusive design solutions could be proposed and iterated to benefit all passengers in the AV bus context.

The design process of this project followed the *Double Diamond* design model to *Discover* users' behavior, *Define* users' problems, *Develop* multiple ideas, and *Deliver* design solutions. Through autoethnography, interviews, and surveys, the problems and needs of people with cognitive disabilities in regular public transportation were discovered. Utilizing inclusive design method, four design solutions to assist passengers with information collecting in transportation were created which included: *Footprints and navigation arrows*, *Basic information display*, *Interactive route planning display*, and *Bus information display along with the audible announcement*. The design solutions were evaluated by real users and improvements were applied to each idea.

Finally, the inclusive design guidelines of information needs in AV service was summarized. The design guidelines were on the basis of literature theory as well as the design examples proposed in this project. According to different phases in AV transportation, the inclusive design guidelines can be concluded as:

1. Using Simple and visible navigation signage to the bus platform
2. Synchronizing bus arrival time with the schedule
3. Providing real-time bus Position Information
4. Providing information in both audible and visual forms
5. Providing information of bus direction and bus system instruction
6. Using travel route scripts to visualize transit information
7. Testing which type of bus driver information and role that AI and related

solutions successfully can handle

The next step for further work with the design results can be refining the design solutions and evaluating the prototypes in a physical environment. Moreover, the idea of a mobile application that assists passengers to acquire the information required can be further developed. Thus, the inclusive design guidelines in the AV service could be more comprehensive.

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A

Appendix

The Appendix contains the rough data during the design process. This includes Expert interview, Autoethnography research, User experience interview, Survey, Physical evaluation, and Digital evaluation.

Appendix A - Expert Interviews

1. First expert interview

Target users: The patient has a mental age as 9-12-year-old children. They can almost do man things by themself but only need assistance sometimes. The patient needs to have an assistant almost all the time.

Expert: She was a caregiver at Dagligverksamhe and Gruppbostad. She worked with people with autism and down syndrome.

Advice - If you want to understand their behavior, you can study children at age 9-12 years old.

Questions	**Answers**
Can you describe your experience when taking a bus with a patient?	First, we need to agree on what time we will take a bus. I will check the timetable for him and take him to the bus stop. He always needs to grab my arm to walk because he easily lost balance. When we got on the bus, sometimes I needed to fasten the belt seat for him or he can do it himself. Along the way, how he behaves is dependent on his mood on that day. Sometimes I need to talk to him to quiet down. When we almost arrived, I checked the next bus stop on the screen and tell him that we will get off at the next bus stop. However, some patients know where they can get off because it is the same they usually go. It is their routine. They are taught to notice the symbol to recall them that they need to get off the bus, for instance, if you see a red building, you need to ring a bell, etc. The symbol needs to be something that standout and easy to remember. And if it is a new place, they need someone to assist them 2 - 3 times and teach them the route so they can remember and can go to that place by themselves. Some patients might be panic about a lot of people on the bus. We need to calm them

	down by giving them choices for example, do you want to sit on another chair or do you want take the next bus. We need to offer them choices because the patients feel that they can make a decision. And some patients have a very concern with OCD.

2. Second expert interview

Target users: The patient has a mental age as 9-12-year-old children. They can almost do man things by themself but only need assistance sometimes. The patient needs to have an assistant almost all the time.
Expert: She was a caregiver for people with down syndrome and her daughter is a people with down syndrome.

Advice - you need to have something for them to interact or watch (i,g mobile phone) so they can be under control.

Questions	**Answers**
Do they take public transportation or a private car? How often do you take a bus with a patient? Can you describe your experience when taking a bus with a patient?	My daughter goes to school by taxi because she cannot help herself and manage her time. But normally, we take a bus, if we travel to different places. She has eyesight problems. She always trips and fell so I need to be with her all the time we commute by bus. Another reason is she cannot manage her time because she always talks with a stranger. Maybe she will talk with other passengers and forgot her time and destination. If I would describe our journey from the start: I will check the bus time and talk with her. We walk to the bus stop together. We get on the bus but I always assist her because she always grabs my arm whenever she walks with me. She will choose the seat and fasten the seat belt by herself because this is a routine she was taught in school.

	On the other hand, some parents taught their children to use time as a reference. For example, you need to take a bus at this bus stop at this time and get off at this time like 15 mins later. So some children can commute by train because the time is precise and everything is set and never change. The issue is everything needs to be a routine, have a precise sequence. Nothing can be changed. If the bus broke down and they need to change to another bus or the bus is late, they didn't know how to handle these situations. (You cannot break their routine) The issue is they are a hyperactive person. They need to do or play something to help them concentrate and be in control. When she takes a taxi by herself to her father's house. The taxi needs to call her father to pick her up at the entrance because she will walk to somewhere else. And he needs to search for her. And the patient that I took care of before, can do everything by herself because she was taught since she was young. However, the bus needs to be on time. It cannot be late. Everything needs to be a routine too.

3. Third expert interview

Target users: The patient has a mental age as 9-12-year-old children. They can almost do man things by themself but only need assistance sometimes. The patient needs to have an assistant almost all the time.
Expert: She is a private caregiver for people with autism.

Questions	**Answers**

Do they take public transportation or a private car? How often do you take a bus with a patient? Can you describe your experience when taking a bus with a patient?	The patient cannot take care of herself. We need to remind her of every activity. Mostly private car. The car needs to have a plastic wall, separate her and the driver so she cannot grab and hit the driver. And the door needs to be open from outside so she cannot open it during the journey. Only once that we took the bus. She needs to be in a wheelchair all the time. In the past, when we took a bus we need to have two assistance with her. We led her to do the right thing like told her to fasten the seat bell, told her that we almost arrive. She heard the announcement but she didn't understand because it was not her everyday life routine.

Summary of the interview

- The bus need to be on time
- The patient doesn't know what to do if the car is broken or late
- They need something to be concentrate on when sitting on the bus
- They need to be assist whenever they need
- Everything needs to be a routine
- Mostly, a caregiver responds to check the timetable and remain them about the destination
- The patient needs to take a bus with a caregiver a couple of times to remember the route.
- The taking bus sequence needs to be very simple as well as the symbol for them to recognize.

Appendix B - Autoethnography Research

Throughout the design process, we conducted three times autoethnography research to understand the AV bus functions, users experience, and bus steward roles.

1. First Time Autoethnography Research

This was our first ride on the AV bus. For now, the bus stop is really hard to find. We wait at the bus stop for 30 min and the bus came (not sure the reason, normally it only takes 10 min).

We observed the AV bus interior and had conversation with the bus steward on board.

Author: Why need manual control?

Steward: Just for safety, in case some other people at the station, and cars parking incorrectly. This was just a test vision, when raining/snowing, need to observe the bus.

The bus steward controlled the AV bus direction with an Xbox controller. And he connected with the supervision with ipad. When it arrives there is a sound, the operator needs to open the door, and after 20 seconds the car move itself. The bus suddenly stop and move, not stable.

Author: Why there is no led screen showing which bus stop you are in? **Steward**: Only 3 stops in test. The bus need to approve for a while. There is a route screen on the bus, showing the stop and map. The operator push the button and goes to next station.

Author: If people slowly onboard over 20 seconds? **Steward**: It is fine as long as the is opened.

There are 8 sensors on the bus. When a passenger get on board, the operator need to record, report the passengers to the organisation.

Open the door need to be manual. When there is no passenger, the operator will directly press “GO” button on the screen. Normally, the bus stop at the station, no passenger, wait for 20 second, (not open the door) and go autonomously.

The screen on the AV bus has 3 views: The map and route, The bus internal struc- ture (the sensor would say if there is any obstacle), A mode of how the bus navigates.

Author: Have you meet passenger with disability.

Steward: Not yet, it only start 3 days. If something happens to the passenger, the operator will record it.

Author: Do you have passengers yesterday?

Steward: Yes, there are people who thought it is interesting. Also reporter and people want to go to the car parking lot from Regnbagsgatan bus stop.

2. Second Time Autoethnography Research

In this second time traveling on the AV bus, we had a more detailed observation of the AV bus, such as the emergency button, the air conditioner, the instruction, etc. We also asked the bus steward about his experience on the AV bus.

Author: Can you describe your journey?

Steward: He takes the bus and goes to the garage to take the AV bus and drive it to the first bus stop, and operate. It is the same when he gets back home.

Author: How do you feel about the bus?

Steward: The bus always brakes suddenly, it stops without reason. He needs a radio on the bus since it is too quiet. He doesn't trust the AV bus. Not at all. He needs to look back and forth every time to check the bus condition. The speed of the AV bus is fast, the normal ones are slower.

Author: What is the improvement of the AV?

Steward: The space is small in the bus. The software needs to be improved. Brak- ing too much. Sensors always meet errors. The bus doesn't work with the snow. It parked in the garage all day when it snows.

Author: Do you think something missing in the AV bus? **Steward**: The space between the driver and passenger is close, in a normal bus is separate. (he doesn't want to have interaction with passengers). The radio is missing. Traffic information. Entertainment. The normal bus is big, Av bus only 15 seats and close to each other. Hope the bus could have more capacity.

3. Third Time Autoethnography Research

In the third time autoethnography on the AV bus, we mainly asked the bus steward about what is his responsibility and how did he communicate with the passengers in his past experience. Here is our conversations:

Author: What questions did passengers ask you about the AV?

Steward: "Will the shuttle knock/hit the road?". Not so much about direction. "Where does this bus going?" the bus has little stops.

Author: What is the role of bus driver towards passengers?

Steward: There are some joking questions such as: “If the bus can drive itself, you will lose you job”.

Author: What is the things that bus driver can do but AV bus cannot do? What are the questions people ask you in normal bus?

Steward: In normal bus, we don’t have contact with passengers. Passengers some- times knocking on the window, “is this bus go to...?”. Someone say thanks. In the AV, there is more contact, face to face, the most asked questions is “how long will the project go?”

Author: Is there any events other than asking for direction in normal bus? **Steward**: Once they ask “It is too warm on the bus.” because the heater was opened mistakenly. Once someone push the stop button late, there is an argument. Bus driver will handle this. As human should think about more things considerable. There are some young people traveled before. They don’t ask questions but just take photos. The workers just say hi but not take the bus. People coming from downtown to take AV bus. They said that they saw this on the news, they feel nice on the bus. There is a testing in Chalmers and Stockholm before, someone ask “is this the same as the one in Stockholm or Johanneberg?”

Appendix C - User Experience Interview

3 user interviews were conducted between people without cognitive disability in our research phase. All of the participants were asked to travelled on the AV bus and then gave us the feedback.

Interview - A

Demographics

1. Age? 20-29

2. Gender? Female

3. Main occupation? Student

Part 1 – Onboard the shuttle

1. What is your general experience of the trip?

- It was quite interesting, it is without a driver. The bus is tiny. The journey is not so smooth since it often stops. When other cars come the bus cannot decrease the speed so there will be a hard brake.

2. What do you think are the advantages and disadvantages of the service?

- Disadvantages:
    - The bus doesn't follow the time table
    - It is a mix of manual and automatic, it is not fully automated. It would be nice that the bus is fully automated without a person. But it is reasonable since the bus is not smooth and often stops. So there is a need of the steward to control the bus
- Advantages:
    - The software is well developed. It has multiple sensors which is very cool.
    - The mix of human and robot is also an advantage. You don't trust simply the human driver and you don't simply trust the robot.

3. Physical ergonomics

- How was the comfort level?
    - 2.5. The bus is so small. The seat is small compared with the normal bus. Compared to the normal bus, the space is quite small. The space between the person sitting next to you is small. Lack of privacy.
    - **Pain points**: if using a phone she doesn't want the person sitting next to her to see her phone. Feel unsafe when some other ones peep her phone. Since people sit close, if they don't sit close to the window, there will be nowhere to

look. People would just look around or look at the person on the opposite. It is awkward.
    - Pressing the door button is annoying. The bus cannot open the door automatically.

4. Cognitive ergonomics

- **Did you have the needed information for taking the trip on your own (without the onboard steward)?**
    - It needs to be safe. She preferred there is no steward on the bus but it is important to make sure it is safe.
- **Did you trust the self-driving system?**
    - This is the first time that travels on the AV bus. It is partially automated. Not totally trustable.
- **Would you take the bus without the safety steward on board?**
    - No. because don't trust. The emergency button is a kind of safety tool

Part 2 – Going to/from the shuttle

1. Would you like to say anything about your experience before and after riding with the shuttle bus? Or comparing the AV and normal bus?

She is familiar with the normal bus with an app to check the bus stop and bus time. So don't need to wait for a long time. Have a lot of options before/after taking the bus. The AV bus is not as big as the normal ones and is unstable. Will have a balance problem if stand. It is not smooth.

Part 3 – Summary

Do you have any additional comments on your experience with the self-driving shuttle bus?

- It is better to not wait for a long time since we take her to the bus. It sucks if wait for a long time. There is no noise. Not as smooth as she thought. The normal bus always has a screen to show the passengers the stop and this bus doesn't have.

Interview - B

Demographics

1. Age? 50

2. Gender? Male

3. Main occupation? Volvo office worker

Part 1 – Onboard the shuttle

1. What is your general experience of the trip?

He knew the bus because his sister is the steward. He walked to the bus stop after lunch and checked with his sister about the time of the bus. So he got on the bus without any difficulties. During the journey on the bus, there were many brakes, but he felt it was acceptable. There is a technical problem that happened when a car passed. The GPS didn't work. So his sister just fixed it. He doesn't feel uncomfortable when there is a new passenger on board. He got off the bus after one round.

2. What do you think are the advantages and disadvantages of the service?

Disadvantages: it stopped too many times.

3. Physical ergonomics

He doesn't feel the bus is small. And he has low expectations of the bus.

4. Cognitive ergonomics

- **Did you have the needed information for taking the trip on your own (without the onboard steward)?**
    - He knows the information from his sister. He needs to look at the App without his sister.
- **Did you trust the self-driving system?**
    - It would help to improve the trust if the AV bus has a special route. Now when the AV bus stops in the center of the road, it is dangerous.
- **Would you take the bus without the safety steward on board?**
    - Right now, not. If the bus is improved in the future then maybe yes.

Part 2 – Going to/from the shuttle

Would you like to say anything about your experience before and after riding with the shuttle bus? Or comparing the AV and normal bus?

- It was fun.

Interview - C

- Can you describe your journey?
    - He takes the bus and goes to the garage to take the AV bus and drive it to the first bus stop, and operate.
    - The same when he gets back home.
- How do you feel about the bus?
    - The bus always breaks suddenly, it stops without reason.
    - He needs a radio (as a driver)
    - He doesn't trust it. Not at all.
        - He needs to look back and forth every time to check the bus condition
    - The speed of the bus is fast, the normal ones are slower
- The improvement of the AV
    - The brake
    - The speed
    - The space is small in the bus
    - The software needs to be improved, so he doesn't trust it.
        - Braking too much
        - Sensors always meet errors
- The bus doesn't work with the snow
    - Park in the garage all day when it snows
- About the radio
    - Cannot know the current condition of the traffic (as a driver)
- Something missing in the AV bus
    - The space between the driver and passenger is close, in a normal bus is separate. (he doesn't want to have interaction with passengers)
    - The radio is missing.
        - Traffic information
        - Entertainment
    - The normal bus is big, Av bus only 15 seats and close to each other.
    - Hope the bus could have more capacity

Appendix D - User Journey Map

1. User Journey Map - Kevin

Scenario	Kevin is going to work as usual, the normal bus is late and it didnt show on the app. He always put his headphone on to lift hos mood up during the journey. The AV bus also late and has many hard break because of the technical problems. He has a light sick motion during on board. However, he arrive at his office safe and sound.										
Phase	**Before the AV shuttle bus**					**To the AV shuttle bus**		**In the AV shuttle bus**		**After the AV shuttle bus**	
Task	**Planning the journey**	**Waiting for the bus**	**Getting on the bus**	**Sitting/standing on the bus**	**Getting off the bus**	**Going to the AV bus stop**	**Waiting for the AV bus**	**Getting on the AV bus**	**Sitting/standing on the AV bus**	**Getting off the AV bus**	**Going to the office**
User Actions	- Checking bus time and bus route - Determine the start point and destination - Check the timetable on the app - Choose the suitable time	- Check the timetable at the bus stop again to make sure that he doesn't miss it or it is canceled - Stand at the bus stop - Wait for the bus	- Step on the bus when the bus door opens	- Find an avaliable seat without so many people around - Walk to the seat	- Look at the screen on the bus to see if it arrives at the destination - Press the stop button - Wait for the bus to stop at the door - Step off the bus	- Recall the memory of the position of the AV bus stop - Run to the AV bus stop	- Check the timetable at the AV bus stop to see whether the bus planned is arrived or not - Stand at the AV bus stop - Wait for the AV bus	- The steward push the butoon to open the bus - Step on the bus when the steward opens the bus door - He pushed the close button after on board	- Wish to sit near the window but it is already occupied, so he ends with a seat near the door - Walk to the seat and sit	- Look at the navigation artifact to see if it arrives at the destination - Wait for the bus to stop at the door - Press the door button to open - Step off the bus	- Walk into the office
What is the basic need or problem of the traveller?	- Need: Avaliable Start and Destination point	- Needs: The timtable at the bus stop - Problem: Unmatch the timetable and the acutal arriving time : It was late at that moment but it doesn't show on the app : The system in the physical bus stop is out of service.	- Need: the opened door by a driver - Problem: The door close to fast before he can get on the bus.	- Needs: Avaliable seat - Problem: Too crowded in the bus to find a good seat in the morning	- Needs: A screen to show the destination or annoucment - Problem: He doesn't hear the annoucment : When the bus arrive at the bus stop, there is a brake that too hard to keep his balance	- Needs: Get to the AV bus stop quickly - Problem: Long walking distance between normal bus stop and AV bus stop	- Needs: The timtable at the bus stop - Problem: Unmatch the timetable and the acutal arriving time : It was late at that moment but it doesn't show on the app : The system in the physical bus stop is out of service.	- The opended AV bus door - The open/clos button	- Needs: A comfortable seat on the AV bus - Problem: The bus space is too small that good seats are occupied by others. And the bus is crowded. he doesn't like to sit pretty close with a next passager and he feel akwward that he needs to face an oppisited passager. - He needs to open the door every time for other passager when they get out. - Frequent brake of the AV bus creat a motion sickness	- Needs: Notification of getting off at the correct bus stop - Problem: Forget to get off the bus : No remider annoucement or board	-
What is needed to solve the need or problem? (as general as possible)	-	- The matched timetable with the bus	- Appropriate time to close the door	- More seats/space on the bus	- Somthing to remind him that he is almost at destination - Somthing that help his balance	- Shorten the distance between bus stops - Provide tools to travel between bus stop	- The matched timetable with the bus	- The paasager needs to close the door by himself	- Large space on the bus - Good management of seats' position - Light brake	- A reminder or announcement when the bus going to arrive at each bus stop	-
What are the existing methods or solutions?	- Bus App	- He checks the alternative route to take on the app	- The driver check the situation from his mirror and decide when he will close the door - Sensor that if there is the person in between the door or not. It will close half why and open it again	- Stand on the bus - View the traffic App to see the number of people on each bus, and determine which bus to take.	- The physical timetable on the bus - The handle next to the door - The outstanding buiding next to his bus stop remind him that he need to press the button.	- Run	- Walk to the office	- The steward closes/open it for him.	- The steward closes/open it for other passagers. - The paasager open the door by themselves - His faviroute music to distract himself from surrouding area. - Sit to other seat might reduce the sickness	- Recognize the navigation artifacts along the road	-
Emotion Condition	0 (Neutral)	- 1 (bad) because it is annoyed to spend more time at the bus stop with a lot of people and he might miss the AV bus to his work	0 (Neutral)	-1 (bad) it's tired to stand in a crowded bus for a long journey	-1 (bad) he needs to run to the AV bus stop because he is afriad that he will miss it.	-1 (bad) get tired after running	-2 (very bad) because the bus is late a again	0(Netraul) - a bit annoy with a door but it is okay	- 2 (very bad) because he sits at the door next to the open'close button, he needs to open the door every time for other passager when they get out. Also he doesn't like to sit pretty close with a next passager and he feel akwward that he needs to face an oppisited passager. Also, the pretty often hard brak make him has a light sick motion. However, his mood isn't wores than this becaus of his faverite song lift his mood up during the journey.	1(good) - because finaaly, fresh air and doesn't need to be at the crowded bus anymore.	1 (good) - good to arrive on time.
User thought	*"Wish for a good journey today"*	*"Where is the bus? I might be late if it will delay for 10 mins"*	*" Almost get hurt by the door. Umm where should I sit today"*	*"There no nice seat today. I need to stand on the bus again"*	*"I will need to start running as soon as I touch the ground"*	*"Why it is too far away? I hate running"*	*"This is not my day"*	*"Lucky, get on the bus on time"*	*"My music is my saviour from this madness"*	*"Ahhh.Finally, freedom"*	*"Arriveeee"*
Possibilities for improvement	-	- The notcification on the physical timetable that when the bus will late - The vioce annoucment	- Automatic detect person if they are still people at the door	- More bus in that period	- The louder annoucment - Train the driver to perform to brake the bus in a calm way	- Make the normal bus stop and AV bus stop at the same position - Provide equipment i.e. escalator to carry passenger from normal bus stop to AV bus stop	- Have a better bus sytem, didn't have many brak down or delay - Have real time timetable connecting with the AV bus	- The bus door could detect whether there is anyone getting on the bus, if in 3-5 seconds no one gets on, then the door can be closed itself	- More open/close button. - Improve the software to enable the AV bus have calm behavior - A bigger bus with more space and comfortable seats - New way to place the seat to prevent sick motion and akwardness	- Voice announcement of bus stops - A screen to show the real-time position of the bus	-

2. User Journey Map - Emma & Emily

Scenario	Emma is a girl with down sydrome. Emily is Emma's mother. Emily takes Emma to school as usual in the morning. During the journey Emily alwaays teach Emma the direction, The bus is on time but Emma didn't sit on the wanted seat. The AV shuttle bus is late and because of that there are many paassager waiting at the AV bus stop. On the bus there is one seat left at the entrace/exit door.									
Phase	**Before the AV shuttle bus**									
Task	**Planning the journey**		**Waiting for the bus**		**Getting on the bus**		**Sitting/standing on the bus**		**Getting off the bus**	
	Emily	**Emma**	**Emily**	**Emma**	**Emily**	**Emma**	**Emily**	**Emma**	**Emily**	**Emma**
User Actions	- Checking bus time and bus route - Determine the start point and destination - Check the timetable on the app - Ask her daugther when she wants to take a bus - Remind Emma when she needs to finish her preparation	- Choose the time she wants to go to the school - Prepare herself for school	- Check the timetable at the bus stop again to make sure that they don't miss it or it is canceled - Stand at the bus stop - Wait for the bus - Keep Emma by her side and make sure that her doesn't follow any stranger	- Stand by her mother side - Look aroud and wait for the bus - Try to talk with the stranger	- Support emma to balance herself when getting on the bus	- Step on the bus with her mother's help	- Ask Emma which seat she wants to sit - Let Emma take her to that seat - But that seat was taken before her eyes - Come up with anlternative seat for emma - Let emma choose again and follow her - SIte next to her	- Find a good seat - When she walk to that seat with her mother, it was stolen before her eyes. - She chose another seat - Walk to the chosen seat - Sit down - Fastened seat belt by her own	- Look at the screen on the bus to see if it arrives at the destination - Remind her daugther that they need to get off - Point at the attractive symbol for her daugther to memmorize this is when they should press the button because it is near their destination - Press the stop button - Wait for the bus to stop at the door - Step off the bus	- Unfasten the seat belt - Remember the navigation symbol for later journey - Follow her mother to step off the bus
What is the basic need or problem of the traveller?	- Need: Avaliable Start and Destination point - Problem: get her duagther ready on time	- Need: All her stuff ready, and remember the time, need her mother to remind the time - Problem: cannot remember the time	- Needs: The timtable at the bus stop - Problem: She needs to concentrate on her duagther all the time	- Need: Follow her mother - Problem: Easily be attracted by other things at the bus stop (strangers, etc.)	- Need: the opened door by a driver - Problem : She is afraid that if her dauther loos balance she might loose her balnce together with her daugther	- Need: additional assistance of stepping on the bus - Problem: cannot keep balance while stepping on the bus	- Need: the vacant seat - Problem: her dagther might want to sit on the seat that another paasager want to sit on at the same time. : She needs to come up with alternative seat for emma to choose.	- Need: avaliable seat on the bus and seatbelt - Problem: some one else occupies her seat before her (Emma would be upset)	- Needs: A screen to show the destination or annoucment : an outstanding symbole - Problem: afraid loosing her and her daugther balance when the bus break	- Need: additional assistance of stepping off the bus - Problem: cannot keep balance while the bus brake/stepping off the bus
What is needed to solve the need or problem? (as general as possible)	- Time reminder for emma	- Time reminder for emma	- Keep emma be concentrate on her	- Keep Emma concentrate on her mother	- Something for helping with the balancing	- Something for helping with the balancing	- Have another options	- More seat on the bus to choose	- Somthing to remind her that she is almost at destination - Something for helping with the balancing	- Something for helping with the balancing
What are the existing methods or solutions?	- Remind emma that she needs to finish in X min	- Her mother remind her about the time	- Hold her daugther hand all the time	- Following her mother	- Handle on the bus	- Her mother help her	- Convice her daugther with another vancant seat	- Special seat for people with disabilities	- The physical timetable on the bus - The handle next to the door - The outstanding buiding next to his bus stop remind him that he need to press the button.	- Her mother help her
Emotion Condition	0 (Neutral)	0 (Neutral)	0 (Neutral)	0 (Neutral)	0 (Neutral)	0 (Neutral)	0 (Neutral) bacause this is somthing that she predict it and this is hapend from time to time. She knows how to handle it	-1 (bad) her favorite seat was stolen by others	0 (Neutral)	0 (Neutral)
User thought	*"I hope nothing happend during the journey"*	*"Looking for go to school tommorow"*	*"Good to have her in my sight"*	*"Mom!"*	*"I need to grab that handle in case somthing happend"*	*"Taking bus is fun"*	*"Where is another good seat?"*	*"It was my seat!"*	*"I need to grab that handle before the brake"*	*"Hold my mom's hand"*
Possibilities for improvement	- Alarm clock	- Alarm clock	-	-	-	- Lower hight of the bus step	-	- Emma needs to learn to have the alternative options in hand	- Train the driver to perform to brake the bus in a calm way	-

Phase	To the AV shuttle bus				In the AV shuttle bus				After the AV shuttle bus			
Task	**Going to the AV bus stop**		**Waiting for the AV bus**		**Getting on the AV bus**		**Sitting/standing on the AV bus**		**Getting off the AV bus**		**Going to the school**	
	Emily	**Emma**	**Emily**	**Emma**	**Emily**	**Emma**	**Emily**	**Emma**	**Emily**	**Emma**	**Emily**	**Emma**
User Actions	- Look for the bus stop - Grab her daughter hand to the bus stop - Explain how to go there(i.e. the platform and direction)	- Follow her mother and walk to the bus stop	- Check the timetable of the bus - Look at the bus - Distract emma to focus on her to not talk with a stranger at the bus stop - Explain why the bus is late and try to calim her down.	- Hold her mother's hand - Wait for the bus - Look around at the bus stop - Talk with strangers at the bus stop - Keep asking her mother why we havent get on the bus - Start act impatiently	- The steward push the butoon to open the bus - Emily assist her daughter to step on the bus when the steward opens the bus door - Put her daugther sit next to the door - Emily pushed the close button after on board	- Wait for the door open - When the apporach the bus stop, she needs to cover her ears because of the warnning sound - Step on the bus with her mother's help - Sit next to the door and fasten the seat belt	- She needs to grab the hanger as tight as she can because of the many hard breaks - She always check her daughter mood during the journey and her well being - Some one ask her/ her daughter to open the door and she needs to open it all the time like a driver - She grab her daughter hand in case she feel scare - She gives her daugther a phone to distract her from surronding area.	- There is a hard brake when another car comes towards on the road - Emma was scared so she holds her mother's hand - Sometimes she needs to open the door for other passagers - She always close her ears when there is a warning sound - She feel at ease when she play with her phone	- Look at the artifact to see if it arrives at the destination - Tell her daughter that they will get off at the next bus stop because of they see this building, so her daughter can remember it - Wait for the bus to stop at the door - Press the door button to open - Grab the handle at the exit to help her balance - Step off the bus with her daughter	- Unfasten the seat belt - Remember the navigation symbol for later journey - Follow her mother to step off the bus	- Check that they dont forget anything - Tell her daughter which direction they need to walk next.	- Walk to school following her mom
What is the basic need or problem of the traveller?	- Need: Visible bus sign, the same route - Problem: Find the way to have a simple way to explian he route to emma	- Need: remember the route to the AV bus stop - Problem: hard to remember the route, need to repeat it again and again	- Need: make her daughter to concentrate on her : She needs the reason why the bus is late - Problem: She needs to come up with a reason why the bus is late : Find the way to make her daughter calim down.	- Need: Follow her mother and be concentrated on her mother - Problem: Easily be attracted by other things in the bus stop (strangers, etc.)	- Need: vacant seat for her and her daughter, need to help with the balance - Problem : doesn't have enough seat for two	- Need: additional assistance of stepping on the bus, and seat belt - Problem: cannot keep balance while stepping on the bus - Problem: Uncomfortable environment of a crowded bus : annoying warning sound also makes her scared and hurts her ears	- Need: keep balance during braking : something to lift her daugther mood up - Problem: always worried about her daughter mood and afaid that she cannot control her emotion and bother a next passager	- Need: comfortable and calm journey - Problem: frequent brakes makes her scared - Problem: annoying warning sound also makes her scared and hurts her ears : somtimes she is annoied by a passager asking her to open the door : Feel uncofortable in the tight space with a lot of people.	- Need: The symbol - Problem: There is no board or announcment to show where they are righ now	- Need: remember the symbol of destination - Problem : She cannot choose what to remember, except that her mother decide it for her	- Need: a visible direction for her daugther to follow	- Need: remember the symbol of destination - Problem : She cannot choose what to remember, except that her mother decide it for her
What is needed to solve the need or problem? (as general as possible)	- Papare how to explain in a simpleway	- An easily remembered route	- Matched timetable and the bus	- Keep Emma concentrate on her mother - The matched timetable with the bus	- more seat or space to stand close the her daughter - Something to grab	- Something for helping with the balancing - More space and seat on the bus	- More strong handle - Something to attract and protect her daughter	- Calm driving behavior of the bus - Friendly warning sound - Distract her attention	- Obvious symbol of destination	- Obvious symbol of destination - Someone tell her	-	-
What are the existing methods or solutions?	- Tell the direction to emma over and over again	- Her mother explain the route repeatedly	- Try to talk with a reason to calim emma down	- Her mother will calm her down with talking with her, asking her a qestion and let her think about her answer and surrouding situation	- Space for standing passager - handle at the door	- Her mother/the steward helps her	- Hanger on top - Mobile phone	- Hold her mom - Cover ears - Her mom/other passengers help open the door - mobile phone	- The building on the side of the road	- Her mother explain to her	-	-
Emotion Condition	0 (Neutral)	0 (Neutral)	-1 (bad) - when her daughter feel bad, she also feel bad too and want to make her daughter mood up	-2 (very bad) the late bus makes Emma breakdown, because it breaks Emma's routine. She doesn't know what she needs to do next	0 (Neutral)	-1 (bad) uncomfortable with a crowed, and her mom cannot sit next to her	-1 (bad) - She is annoyed by people asking her to open the door and close it for them	-2 (very bad) the hard brakes and annoying sound makes her scared and breakdown. However, becaus of the mobile phone it helos her to distract he from stress	0 (Neutral)	0 (Neutral)	1 (good) take her daughter to school safely	2 (very good) - finally arrive
User thought	*"We need to go the bus stop"*	*"Remember the route."*	*"Why the bus is so late! I need to check my daughter now"*	*"Why my bus is late?"*	*"I need to stand as close as possible to my daughter"*	*"I want my mom sit next to me"*	"How her mood is"	*"I am scared."*	*"Oh it is that building, we need to get off at the next bus stop"*	*"Oh, almost to school"*	*"Finally take my daughter to school"*	*"See my friends!"*
Possibilities for improvement	- record her voice	- A piece of paper recording the route in an understandable way	- Somthing that tell where is the bus now and why it is late	- Entertainment eqiupment at the bus stop to attract her attention/calm her down - Somthing that shows her where is the bus right now	- Design for seat	- Have a new sound - How to desgin the interior of the bus	- Have more handles on the bus - More open/clos button	- improve a warinning sound - More open/close button. - Improve the software to enable the AV bus to have and create a calm behavior	- The board or announcment	- The board or announcment in her routine - Something that can recall her memory	-	- Something that can recall her memory

Scenario	John lives 1 bus stop away from the AV bus stop, so he always walks to the AV bus stop to go to his special school.						
Phase	**To the AV shuttle bus**			**In the AV shuttle bus**		**After the AV shuttle bus**	
Task	**Planning the journey**	**Going to the AV bus stop**	**Waiting for the AV bus**	**Getting on the AV bus**	**Sitting/standing on the AV bus**	**Getting off the AV bus**	**Going to the school**
User Actions	- Check his script of how to go to school and follow it step by step - Checking bus time and bus route - Determine the start point and destination - Check the timetable on the app - Palnning alternative route if unexpected thing happend - Choose the suitable time	- Recall the memory of the the route to the AV bus stop - Walk to the bus stop	- He stand far away from other people - Keep checking the bus arrival - Try not to clap his hand in public	- The steward push the butoon to open the bus - Step on the bus - Check what he needs to do next, and which seat he can sit	- Walk to the corner of the bus - Sit down on the seat - Try to keep distance from other passengers, but cannot, there are a passager next to him and in front of him - And he cannot help himself to push emergency button next to him. - The car stop immideately, he oppologized and the bus driver needs to fix it	- Look at the navigation artifact to see if it arrives at the destination - Wait for the bus to stop at the door - Asking other passengers to press the door button for him - Step off the bus	- Get off the bus - Look at his instruction - Walk to the school
What is the basic need or problem of the traveller?	- Need: Avaliable Start and Destination point : the script how to go to the school	- Need: Go to the bus stop successfully	- Need: Control his behavior, emotion and his hand - Problem: he is afraid that his hyperactive behaviors would bother other people - Problem: If people stand close to him he will feel upset	- Need: the sequence of how to get and sit on the bos - Problem: the warning sound increase his stress	- Need: Keep distance from other people - Problem: too many people on the bus and need to sit close to each other - Problem: his hyperactive actions would result in problematically push some buttons : By sitting next to stranger make his stress and axiety increase	- Need: to ask someone to open the door for him - Problem: It increasse his stress by talking with a stranger	-
What is needed to solve the need or problem? (as general as possible)	- The sequence of the step to. successful journey	- Remember the route to the AV bus stop	- Something to contorl his behavior and reduce stress	- Block out the noise	- Control his hyperactive behaviors - Somthing that tell him not to push the button	- Something to help him open the door	-
What are the existing methods or solutions?	- Script or drawing	- His families help him remember the route	- Stand a bit further away from a corwded area - Carry familar stuff for this his hand to reduce stress	- Put his headphone on	- Carry fimilar stuff for this his hand to reduce stress - DIstract himself with a familar object	-	-
Emotion Condition	0 (Neutral)	-2	0 (Neutral)	-1 (bad) the noise make his mood unstable and anxiety	-3 (Very bad) - after what happend everyone look at him. That increasses his axeity and stress level to the top.	-1 (bad) talking to other people is akward	1 - (good) he is finally alone
User thought	*"Wish for a good journey today"*	*"Going out"*	*"I want to control my hands"*	*"Too annoying"*	*"Sh*t im screwed, what happend to me"*	*"Finally, Im out"*	*"Finally, Im out"*
Possibilities for improvement	- Illustration on the app	-	- Separateed waiting area?	- Relax music - The instruction on the bus or at the bus stop	- Relax music, or some video on the bus - Placed the emergency button out of the hand length - Redesign for the seat to keep distance from each other - increase the space in the AV bus - The warnning sign for not push a emergency button	- Add a open button close to him	-
	Spend quiet sometimes to plan a route and prepare himself						

Appendix E - Survey

1. First Week Design Sprint Survey

1.1 Survey Questions

Introduction

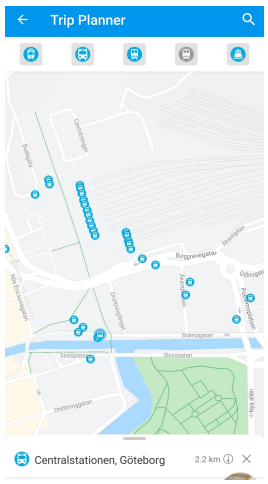
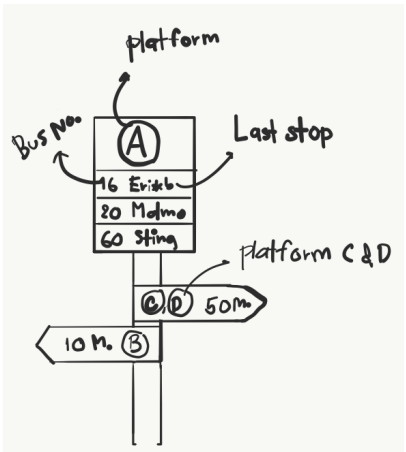
Hi, we are two students from the interaction design master's program at Chalmers University. This form is only used for our master thesis research of users' opinions on Autonomous Vehicle (AV) design solutions. Our aim is to improve the user experience on AV buses for people with cognitive impairment. We would like to ask for your opinion on our design. It will take 3 - 5 mins to finish our survey.

Background
The AV bus we design is an autonomous vehicle shuttle bus with 15 seats on board. It can perform actions such as accelerating, braking, etc.

Imagine that this is your first day at school but you need to take the AV bus to school. You have never gone to the AV bus stop before. And Now you start to walk to the bus stop from home.

Q1 You arrive at the first bus stop you found but the AV bus stop is located in another platform, How to find the AV bus stop platform from your current position? ps. The AV bus stop is at platform C.

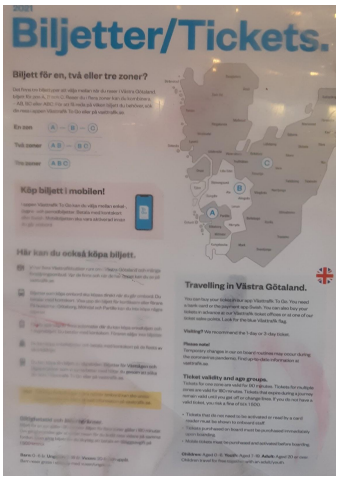
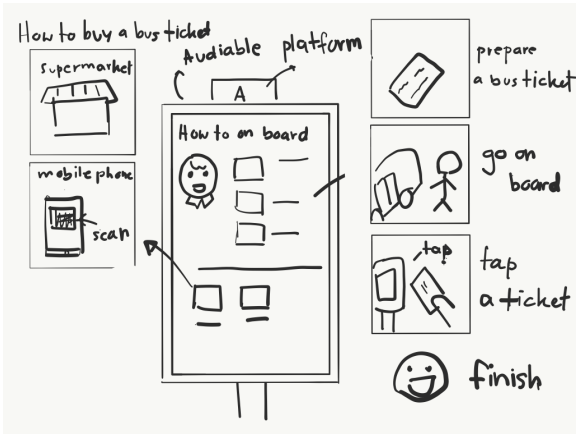
The solution of how to find the AV bus stop.

	
A. You can find the platform on the app	B. The physical signage.

Which method do you prefer?
A or B
How do you feel about this signage when navigating to the AV bus stop
Unclear - Clear scale from 1- 5
Why/Any suggestion

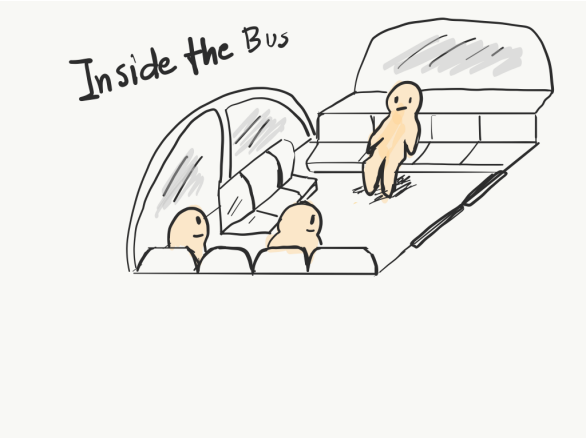
Q2 Waiting for the bus
Now you are waiting for the AV bus at the bus stop. You want to take a bus but you don't know whether the AV bus is different from the normal bus or not. (e.g a bus ticket etc.) And you are looking for the answer.

The form of the information.

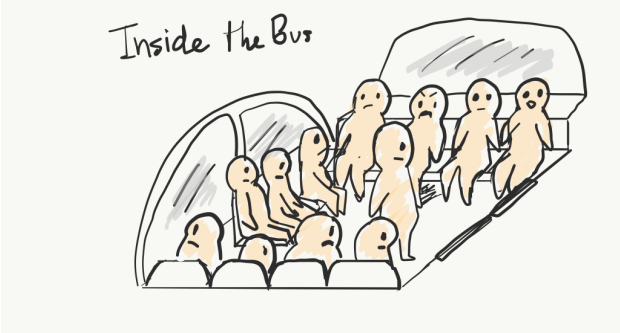
	
A. Instruction on a paper	B. Simple instruction on a digital signage

Which method do you prefer
A or B
Unclear - Clear scale from 1 - 5
Why/Any suggestion

Q3 On the bus
Now you get on the bus and find a seat. There are only 3 people on the bus, and the bus play a normal song



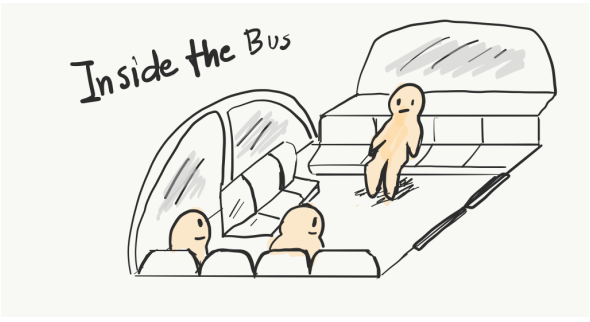
After 2 stops, there are already 16 people on board. You have one passenger at the front, left and right. This creates anxiety. But the AI and sensors detect the crowdedness inside the bus, so it plays a different song to reduce the stress and anxiety. Ex. Mozart, ASMR



How do you feel about this design to decrease anxiety on the bus?
Not helpful - helpful scale from 1 - 5
Why/ Any suggestion

Q4 Almost to your destination

Each stop has a different color code. And your destination is a blue color. Now you are near to your destination. You cannot hear an announcement but your mom tells you that if the bus turns blue, press the stop button and get off that bus stop.



And suddenly, the inside of the bus turned blue.

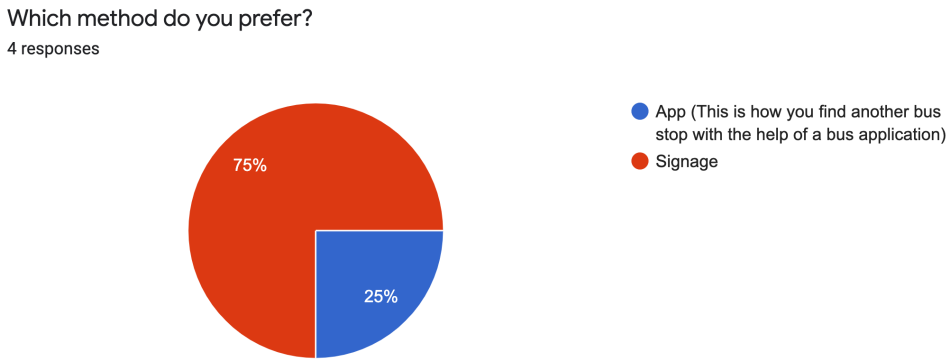
What are you going to do next?

- Still sit inside
- Press the stop button and get off

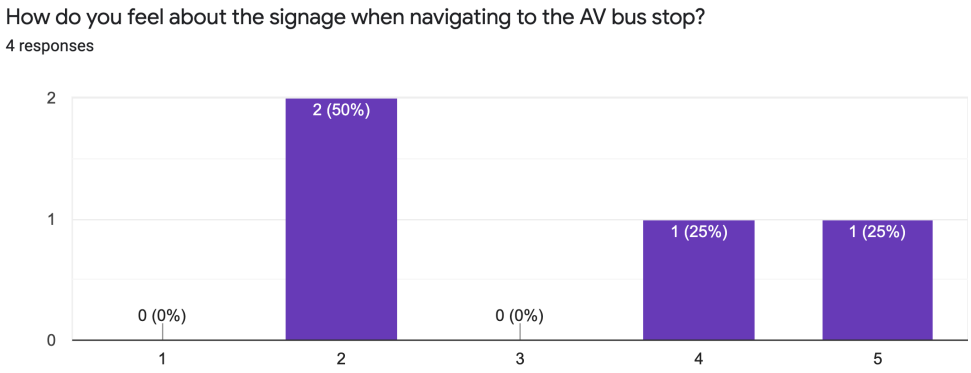
How do feel about this approach?
useless - useful scale from 1 - 5
Why/Any suggestion

1.2 Survey Responses (4)

1 Which method do you prefer? *



2 How do you feel about the signage when navigating to the AV bus stop? *



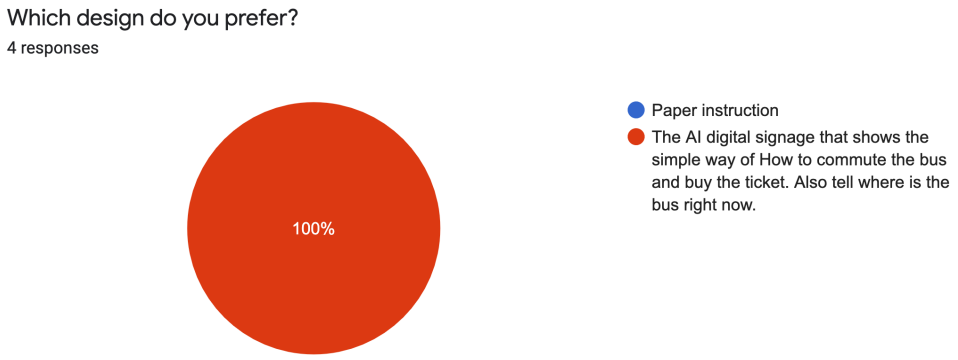
3 Why?/Do you have other suggestions?

- Because I don't want to use an app, full stop. Signs are therefore the only good option remaining. For signs to be useful there need to be ENOUGH of them, they need to be BIG enough and CLEAR in terms of what information they are communicating. A sign is useless if people have to "read between the lines" to know where they need to go. I think that if the AV bus pulls up to platform C, then the sign should have an arrow specifically to the AV bus. Sure, that's a duplication of the arrow to platform C, but I'm not actually looking for platform C, I'm looking for the AV bus. If I need to find out that the AV bus comes to platform C, that's an additional layer of abstraction,

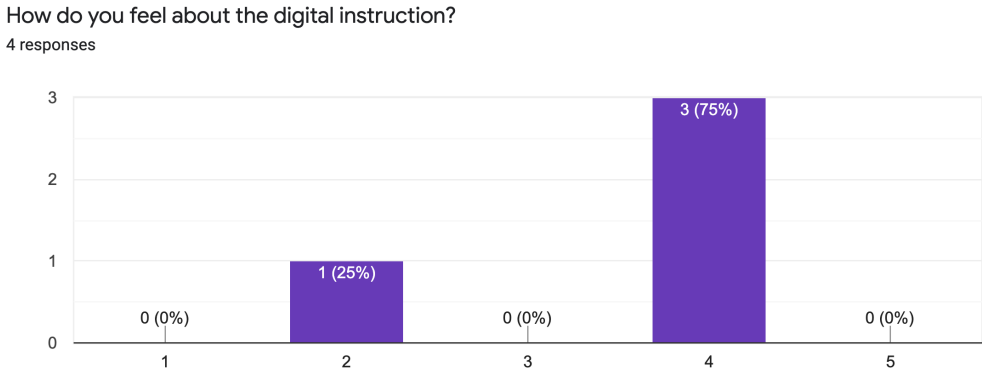
and where do I find out that information without you telling me conveniently in the text of the question?

- I usually have a lot of trouble with bus stops and understanding bus routes from signs. Though I do prefer signs over using my phone. I'm not sure how to make it more clear, maybe using more explicit language.

4 Which design do you prefer? *



5 How do you feel about digital instruction? *



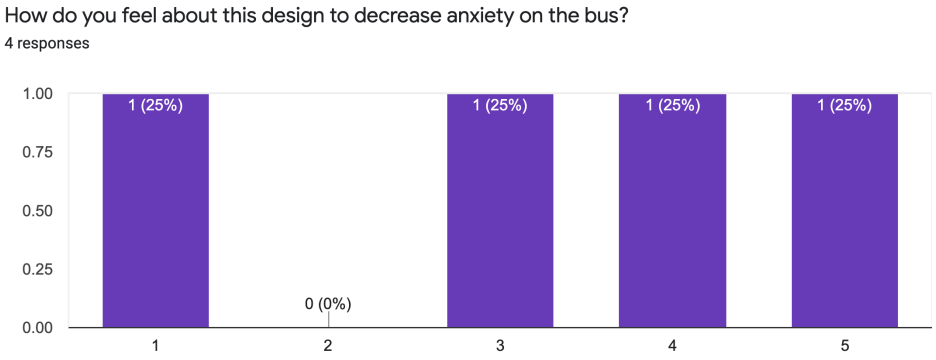
6 Why?/Do you have other suggestion?

- I don't care if it is on a paper sign or a digital sign, as long as the sign is good. If the sign is bad or unclear, it doesn't matter whether it is paper or digital. The only benefit of digital compared to any other option is that it can be updated to show when the bus is likely to arrive. In terms of making the signage clear, make it EXPLICIT. You might say "simple instruction on a digital sign", but what I see in the image above is a

bunch of images that I'm going to have to interpret in some fashion. There absolutely MUST be text as well as images, because some people work well with images and some people do not.

- The program: It would have to be well structured otherwise I couldn't use it

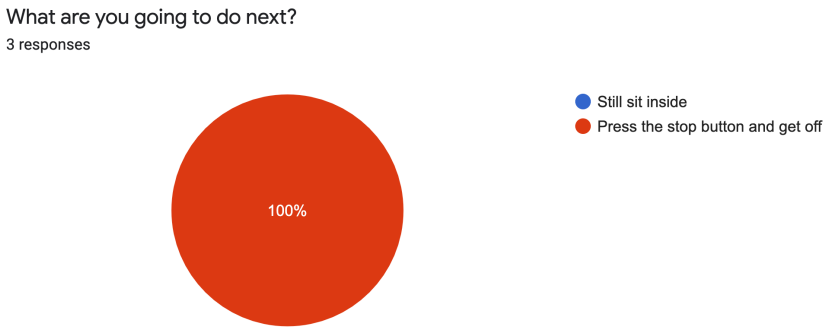
7 How do you feel about this design to decrease anxiety on the bus? (sound) *



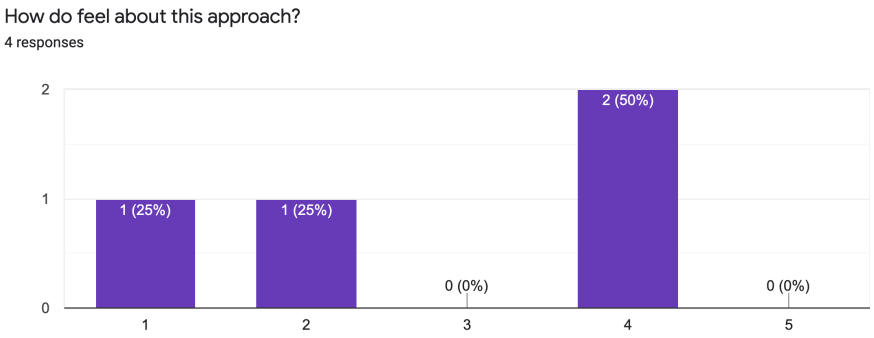
8 Why?/Do you have other suggestions?

- I think the seating design is good and fine. I'd rather there was no music at all, because any imposition of music is an imposition. If people prefer silence then the only thing that is good enough is silence; if people want music, they can listen to their own according to their own choices and preferences to increase or decrease emotional activation in a way that they know will work for themselves.
- Playing music based on the number of people on the bus just feels weird, like the computer is trying to pick your brain or assume some sort of mental state. I dunno what the word is but it sounds 'startuppy' to me--the kind of thing that would get published on Tuvie because it sounds cool, but would add no real value to your life. I like products/services that are boring and practial.

9 What are you going to do next?



10 How do feel about this approach? (color code bus stop) *



11 Why?/Do you have other suggestions?

- Initially, I would be very confused about why the bus is turning different colors. I would much rather than the bus flashed up a sign in large and clear letters to say what station the bus is AT and also what station will be NEXT. It doesn't need to be narrated, because unless the speakers are incredible and the voice recording is good, narrations are not that clear or helpful. But a big sign to say "this is where we are, that is where we will be next" is ideal.
- I rely on the driver's announcements usually. If there were some type of way to make the bus change color but also have a digital display of what stop it is, that would be nice.
- I feel like this is condescending and that it sounds cool but wouldn't offer much practical benefit. This scenario feels a little condescending because it underestimates my abilities. I'm autistic and I don't have trouble finding the right bus stop based on landmarks and the sign inside the bus. I'm very good at navigating. Just last week my mom and I drove 140 miles to a town I'd never visited before, and I drove to our destination without needing GPS or making a single wrong turn. If I took the bus, she

wouldn't tell me "Get off when the lights turn blue" because she knows I know my way around town. I think the biggest possible improvement would just be making the sign large, simple, and readable. Also, changing the color of the lighting will ultimately prove impractical. A bus route would be limited to around 10 stops unless riders are able to distinguish between fuscia and mauve more easily than they can tell the difference between "ELM ST" and "MAPLE AVE" on a sign.

2. Second Week Design Sprint Survey

2.1 Survey Questions

Introduction

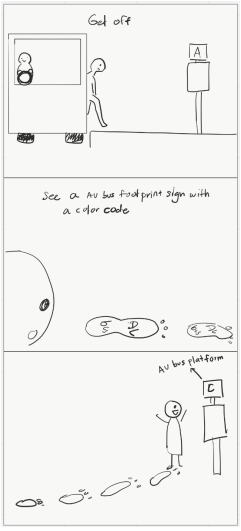
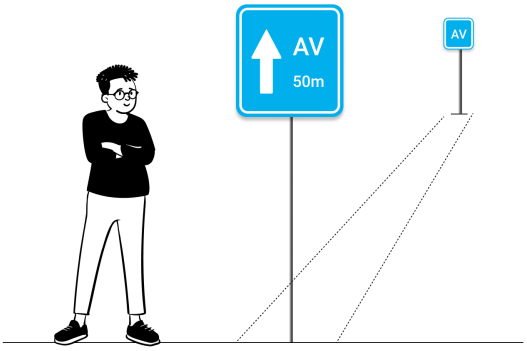
This form is only used for our master thesis research of users' opinions on Autonomous Vehicle (AV) design solutions. Our aim is to improve the user experience on AV buses for people with cognitive impairment.

Are you over 18?
Yes/No

Q1
Imagine you just get off from a normal bus, and you need to go to the Autonomous Vehicle (AV) bus stop for the first time. What information do you want to know or need right now? (Check box)

A. Distance to the AV bus stop
B. Direction to go
C. How long does it take to walk to the AV bus stop?
D. Others

Below are two navigation methods,

	
A. footprint	B. Navigation arrow
How do you feel about the navigation footprint approach?	How do you feel about the navigation arrow approach?

Unhelpful - Helpful	Unhelpful - Helpful

Which one do you prefer?
Why? Suggestion?

Q2 - bus stop sign

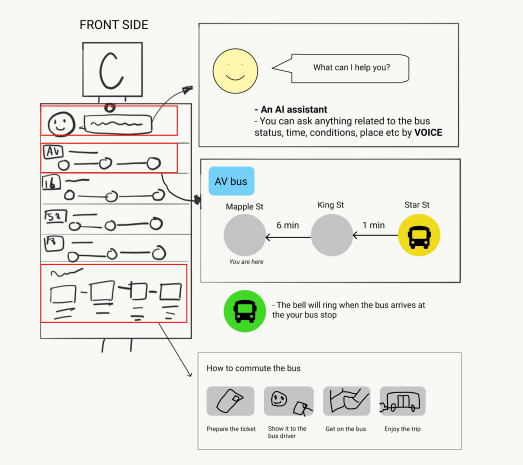
Now you arrive at the AV bus stop. Remember this is your FIRST TIME that you take this bus. You don't know how to commute on this bus before. What information do you want to know or need right now? (check box)

A. Bus timetable
B. Bus estimate arriving time
C. Bus route
D. Where is the bus right now?
E. How long should I wait?
F. How to commute the AV bus?
G. How to buy a bus ticket?
H. Is it the same ticket that I have right now?
I. Is this the correct bus stop/direction?
J. Others

At the bus stop, The bus is pretty late compared to the arrival time. What information do you want to know or need right now? (check box)

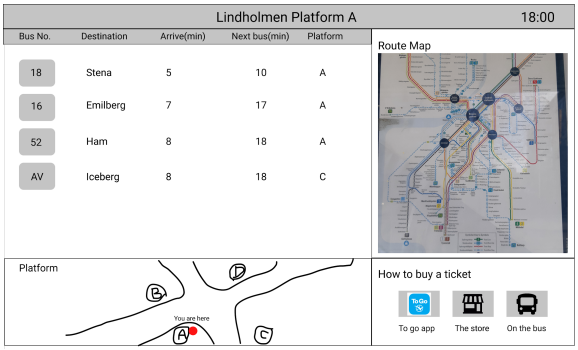
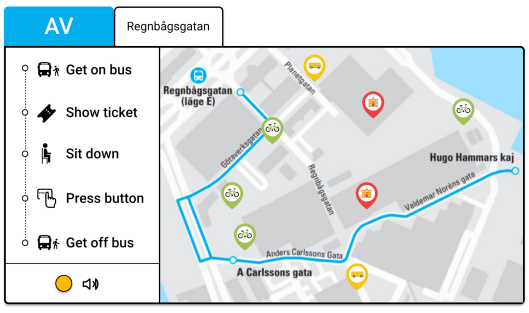
A. Bus timetable
K. Bus estimate arriving time
L. Bus route
M. Where is the bus right now?
N. How long should I wait?
O. Others

Now you see bus signage showing the info that you want to know. Below are two approaches.

	
How do you feel about this approach?	How do you feel about this approach?
Not Informative - Informative	Not Informative - Informative

Which one do you prefer?
Why? Suggestion

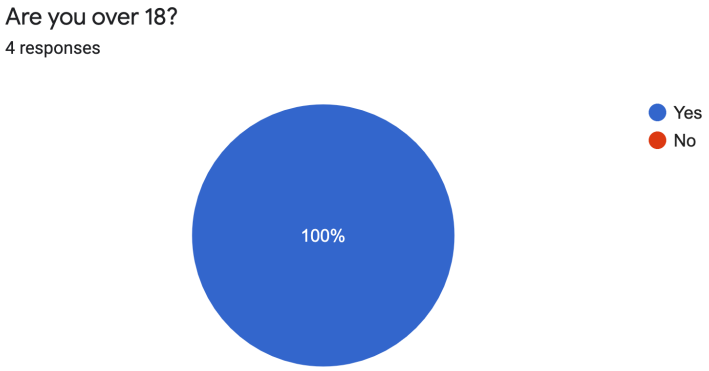
Because the bus still doesn't arrive, you still have time to explore the nearby area and you choose to stay under the bus shelter. There is a digital information board that you can see more information about the AV bus and you can interact with it. Below are two approaches.

	
How do you feel about this approach?	How do you feel about this approach?
Not Informative - Informative	Not Informative - Informative

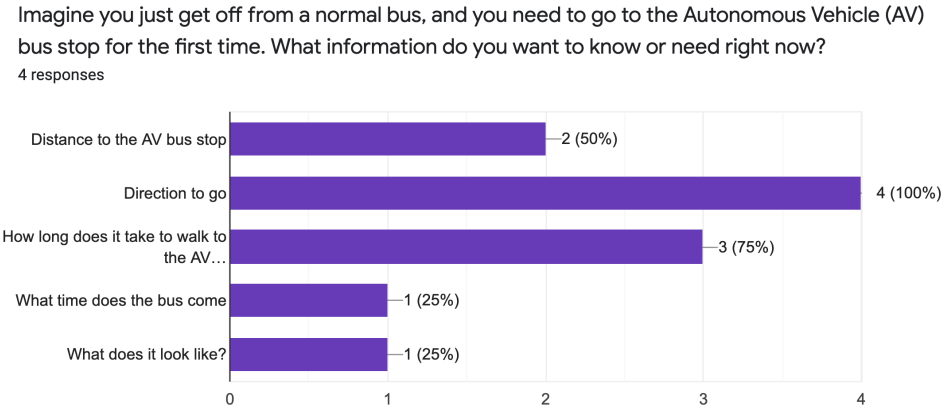
Which one do you prefer?
Why? Suggestion

2.2 Survey Responses (4)

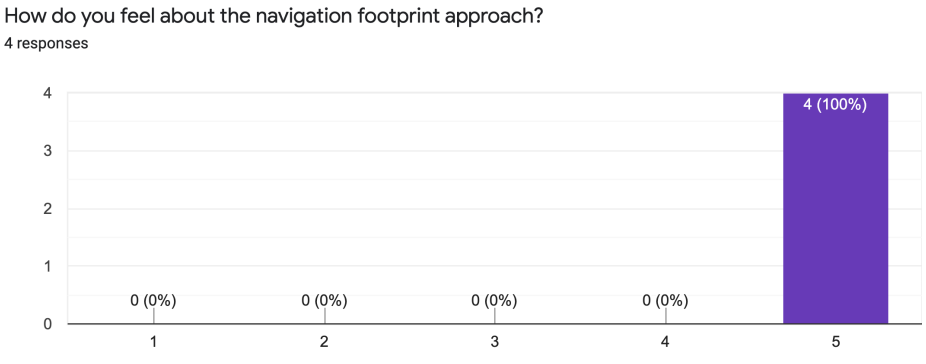
1 Are you over 18?



2 Imagine you just get off from a normal bus, and you need to go to the Autonomous Vehicle (AV) bus stop for the first time. What information do you want to know or need right now?



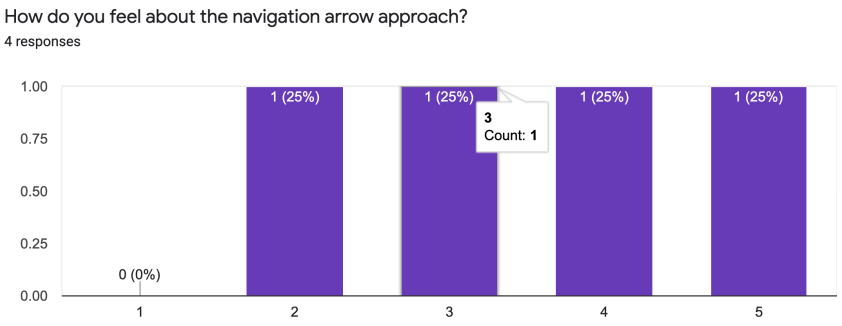
3 How do you feel about the navigation footprint approach?



4 Why?/Do you have other suggestion?

- Great, but might be hard to see under snow
- Seems simple enough.

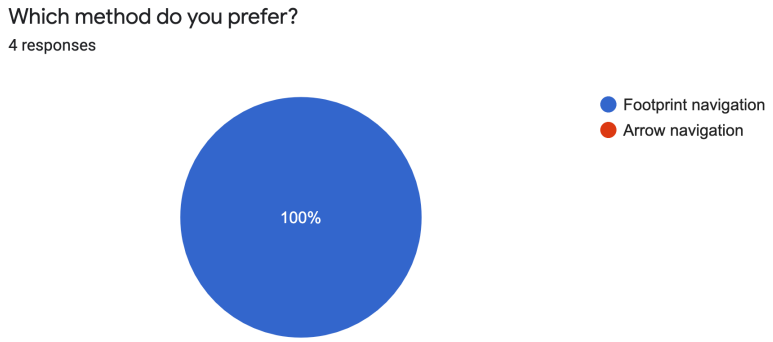
5 How do you feel about the navigation arrow approach?



6 Why?/Do you have other suggestion?

- More season friendly, but less easy for poor readers/visual learners
- If you look at a compass with 360 degrees it's kinda hard with one arrow pointed straight. It could still be like 90 degrees of options where the arrow is pointing.

7 Which method do you prefer?



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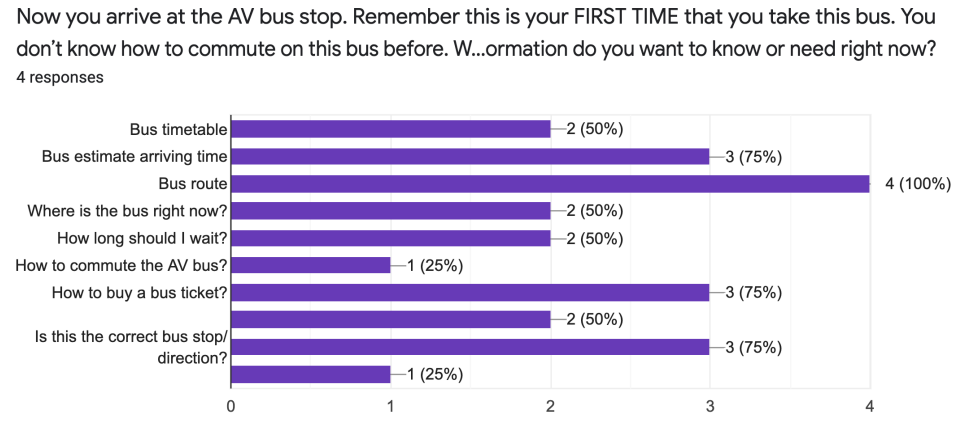

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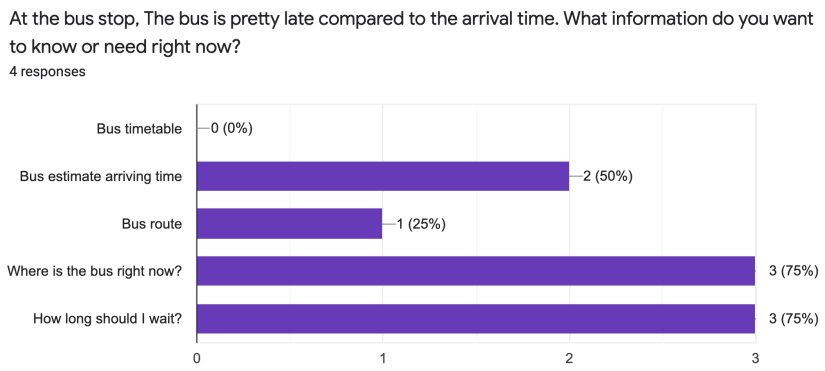
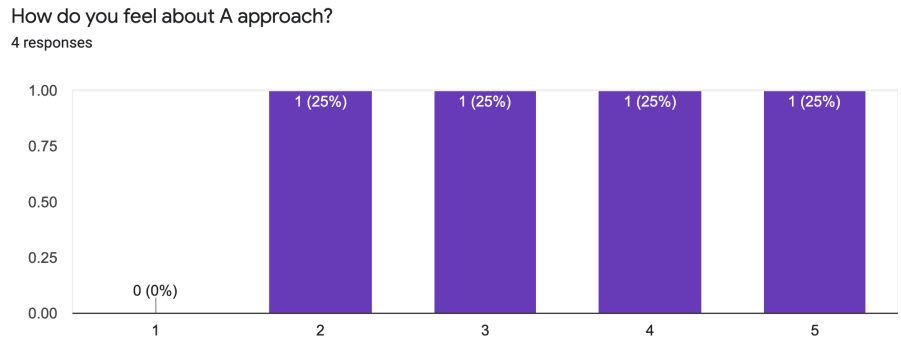


Now you see a bus signage showing the info that you want to know. Below are two approaches

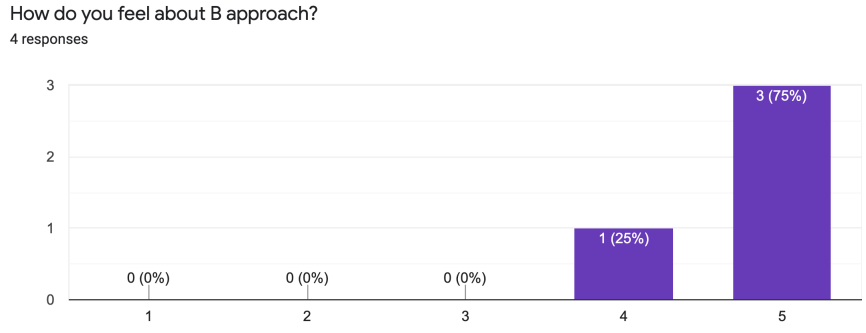
10



11 Why?/Do you have other suggestion?

- I really not like to talk. Especially not in public to an ai.

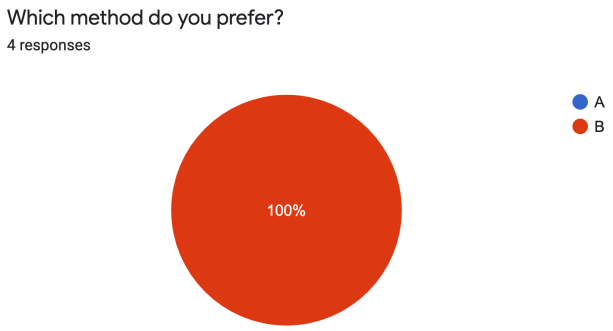
12



13 Why?/Do you have other suggestion?

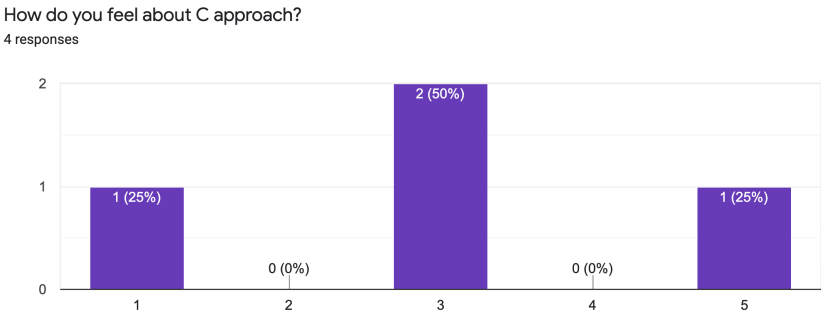
- Less cluttered, easier to read
- No pricing?

14



Because the bus still doesn't arrive, you still have time to explore the nearby area and you choose to stay under the bus shelter. There is a digital information board that you can see more information about the AV bus and you can interact with it. Below are two approaches.

15



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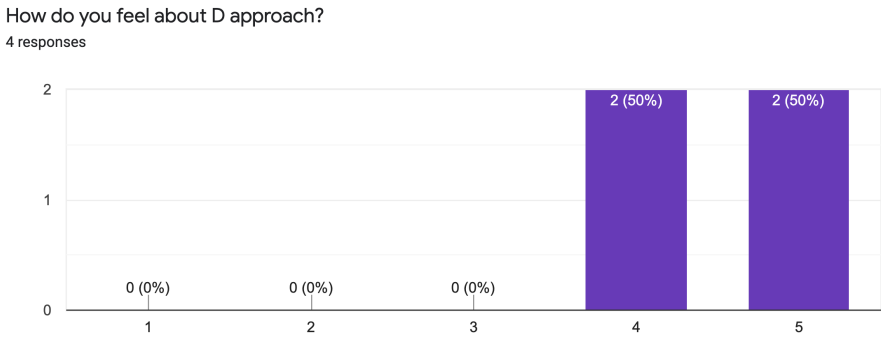
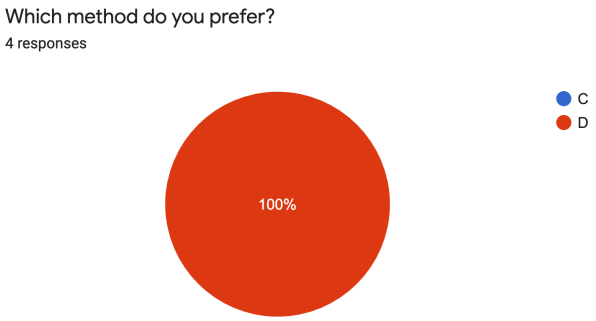


17



3. Third Week Design Sprint Survey

3.1 Survey Questions

Introduction

This form is only used for our master thesis research of users' opinions on Autonomous Vehicle (AV) design solutions. Our aim is to improve the user experience on AV buses for people with cognitive impairment.

Are you over 18?
Yes/No

What are the approaches that you use to navigate for planning and commuting on public transportation?

- Physical or digital script
- App (Google Map, etc.)
- Physical signage at bus stop

What types of questions have you asked a bus driver?

- Direction
- Assistance
- Timetable

Q1 At the bus stop
Imagine that you are waiting at the Autonomous Vehicle (AV) bus stop and check the direction you would go. You want to go to Kuggen building. But at the same time you have an issue with an internet connection. Here is the information signage at the bus stop with an AI bot that you can interact with. Below are three approaches to interact with the AI bot:

First approach: You can ask the AI bot with your voice about your destination and get the information you want. How do you feel about this approach?	Second approach: You can select the destination by the first alphabet (you can swipe for viewing more alphabet in the screen) and get the information you want. How do you feel about this approach?	Third approach: You can type the destination and get the information you want. And it will suggest a destination that you can choose. You don't have to write all the text. How do you feel about this approach?

		
How do you feel about this approach of talking with an AI bot?	How do you feel about this approach of selecting the destination?	How do you feel about this approach of typing in the destination name?
Not helpful Why? Do you have any other suggestions?	Not helpful Why? Do you have any other suggestions?	Not helpful Why? Do you have any other suggestions?

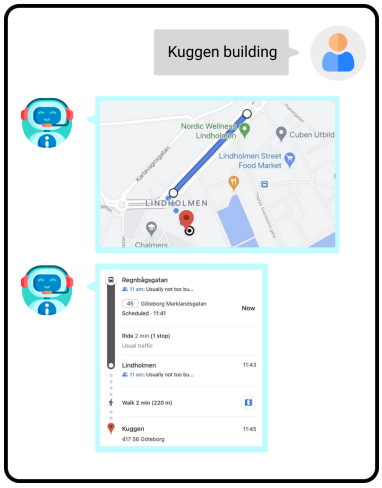
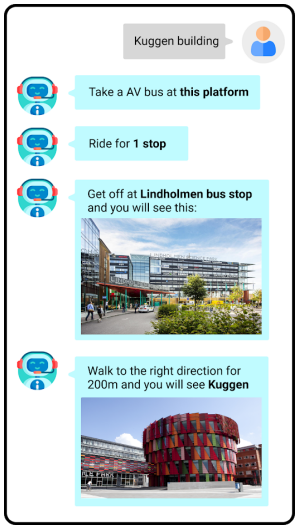
Please choose the method you like(you can choose more than 1 approach)

- Ask the AI bot with your voice
- Select the desination
- Type the destination freely

Q2 Route to destination

After you input your destination “Kuggen building”, the AI bot will provide you the route to your destination from your current position. Below are two approaches to tell you how to get to the destination:

The AI bot will provide you the route to “Kuggen building” on the map.	The AI bot will provide you the route to “Kuggen building” with a script of which bus to take and what the destination looks like.

	
How do you feel about this approach of showing the route in the map?	How do you feel about this approach of showing the route with a script?
Not useful - Useful	Not useful - Useful
Why? Do you have any other suggestions?	Why? Do you have any other suggestions?

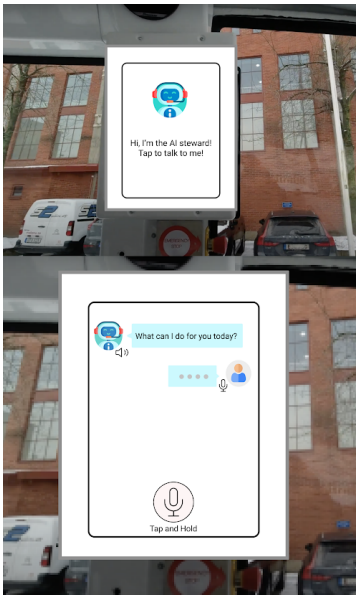
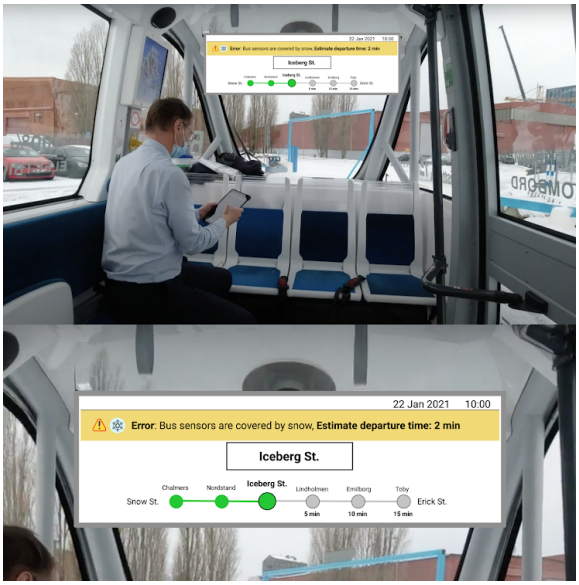
Please choose the method you like(you can choose more than 1 approach)

- Showing the route on the map
- Showing the route as a script

Q3 On the bus

Now you know the route to your destination and get on the bus. There is NO BUS DRIVER ON BOARD!!!. The bus brakes suddenly and the error happened. You want to know what happened. Below are two approaches that you can get the information you want:

First approach: The AI steward (ask a digital bus driver) (remember there is no bus driver on the AV bus) which you can ask any question with voice. How do you feel about this approach of talking to the AI steward?	Second approach: The digital signage shows the error with voice announcement. Also, the voice announces where you are and what is the next bus stop. How do you feel about this approach?

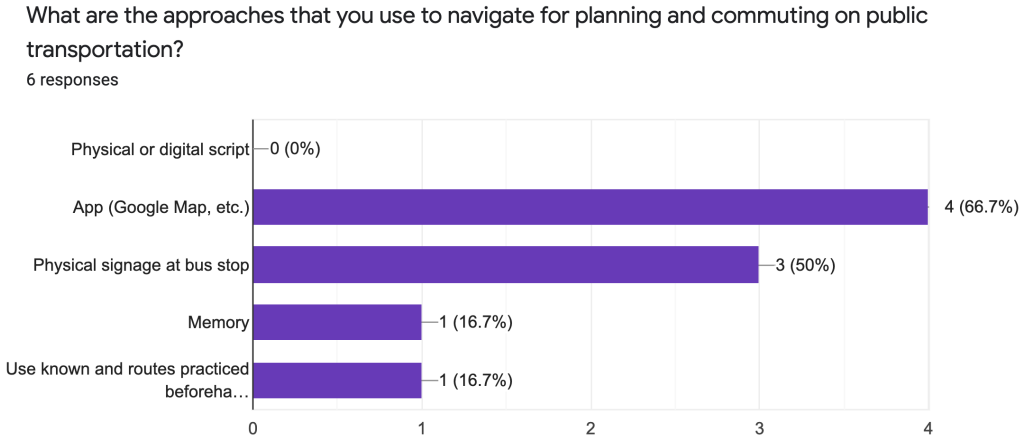
	
How do you feel about this approach of talking to the AI steward?	How do you feel about this approach of digital signage with voice announcement?
Not useful - Useful	Not useful - Useful
Why? Do you have any other suggestions?	Why? Do you have any other suggestions?

Please choose the method you like(you can choose more than 1 approach)

- AI steward
- Signage on the bus with the announcement

3.1 Survey Responses (6)

1



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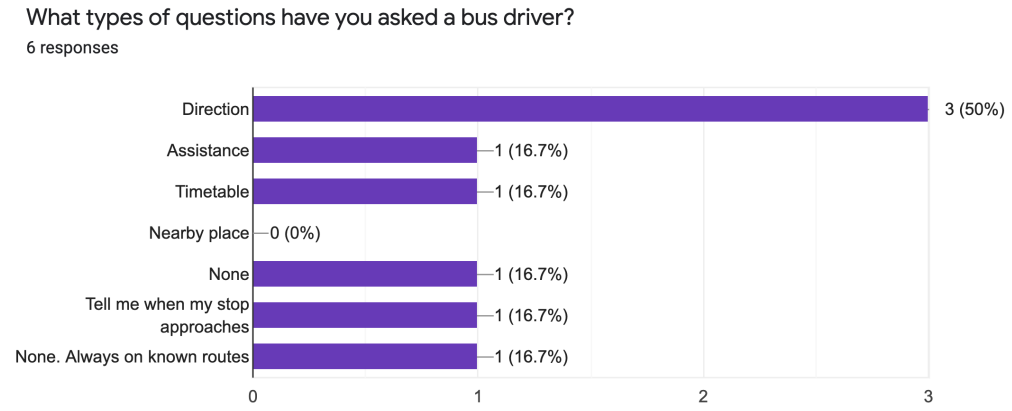

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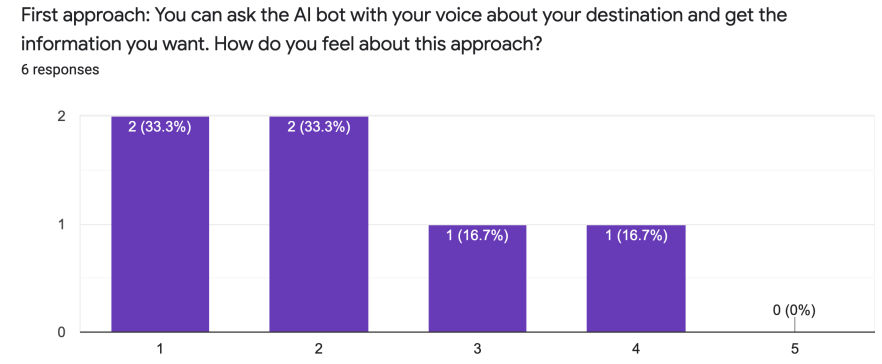


4 Please tell us Why?/Do you have other suggestion?

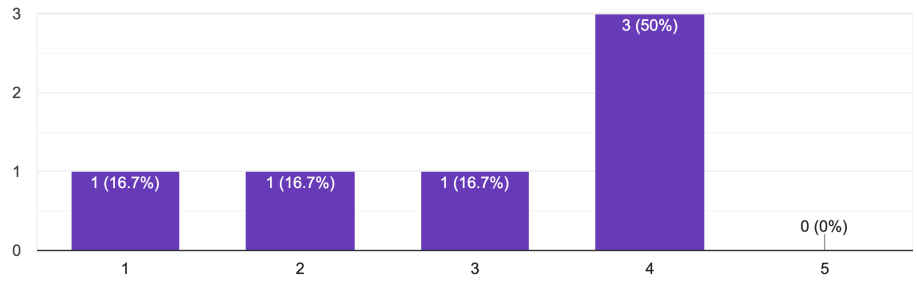
- Make sure the voice recognition is good with different accents/ speech impediments

- Dislike speaking in public places and wouldn't know what to say
- People with Down Syndrome can be difficult to understand
- I can only see an ai making the process much worse. Any problems I jave experienced with public transportation have been more about the need for expanded service, both space and time wise.
- Use Uber/Lyft frequently, familiar with that interface
- I don’t like talking in public

5

Second approach: You can select the destination by the first alphabet (you can swipe for viewing more alphabet in the screen) and get the information you want. How do you feel about this approach?

6 responses



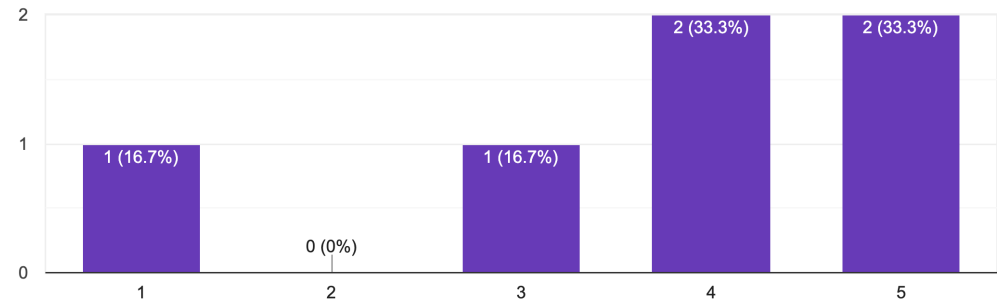
6 Please tell us Why?/Do you have other suggestion?

- First letter of the alphabet may be confusing for those who are not well versed with the english language
- Seems complicated to swipe so much
- Same as above.
- more similar to uber/lyft
- A smaller keyboard to fit all of them would probably be okay

7

Third approach: You can type the destination and get the information you want. And it will suggest a destination that you can choose. You don't have t...all the text. How do you feel about this approach?

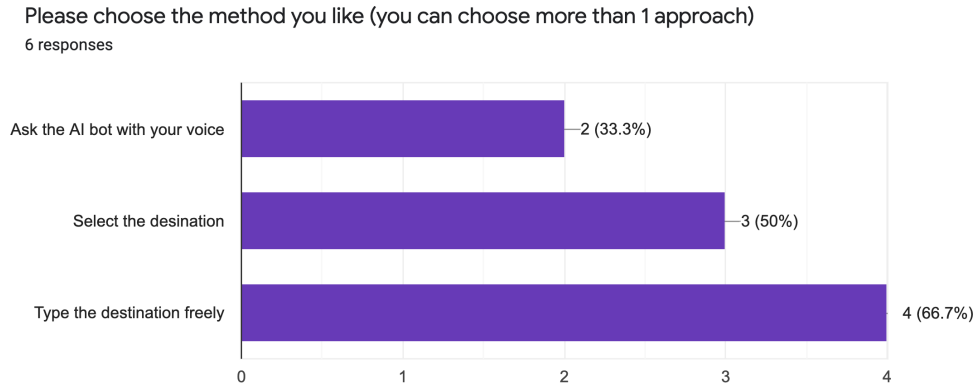
6 responses



8 Please tell us Why?/Do you have other suggestion?

- This may be the best for the average person, but again could cause issues for those with cognitive delays, or others with things like dyslexia
- Easiest and straightforward
- Same as above.
- Like Uber/lyft. A list of suggestions would be helpful
- I'd be worried about taking too long and typos

9



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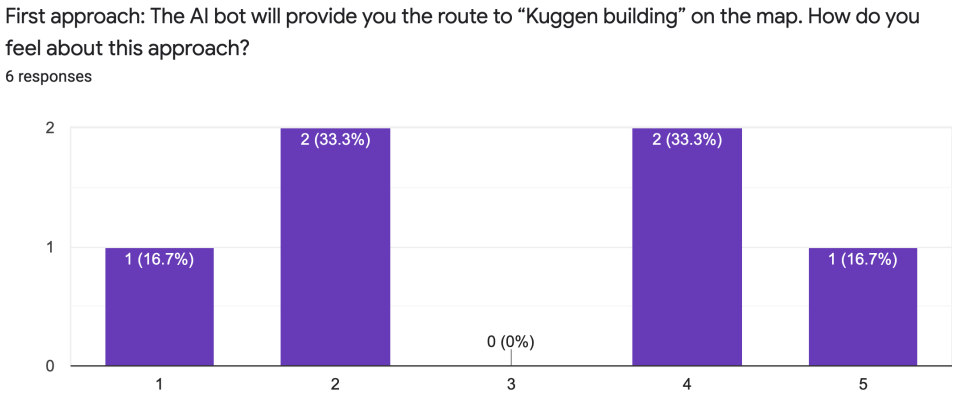
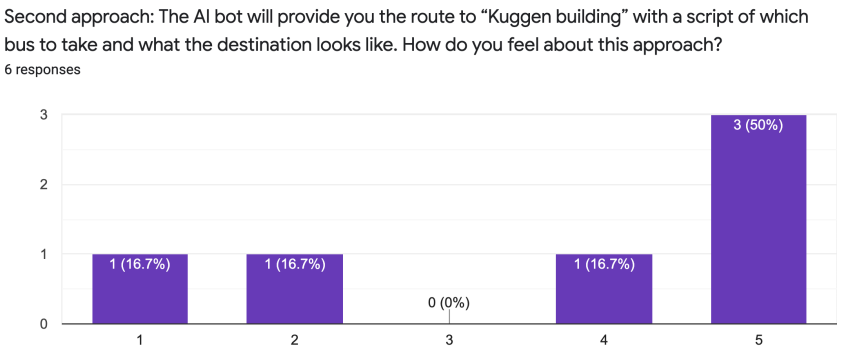


11 Please tell us Why?/Do you have other suggestion?

- A bit overwhelming
- Concise and clear
- My phone already does this. These are just screenshots of google maps, which I already have access to, and its more accessible through my phone
- Need something that can be on my phone to follow directions
- Maps are better for visualizing direction

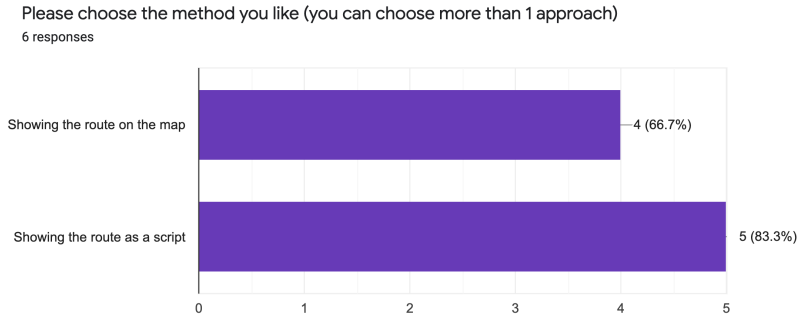
12



13 Please tell us Why?/Do you have other suggestion?

- This is the best option in my opinion. Not overwhelming, and easy to view pictures.
- Pictures are helpful and step by step is good
- Google maps and other such apps already do this. I doubt the pictures will keep up with how the environment looks each day to really be much help.
- Helpful if it can be on my phone
- It’s harder to memorize words than a picture of a route

14



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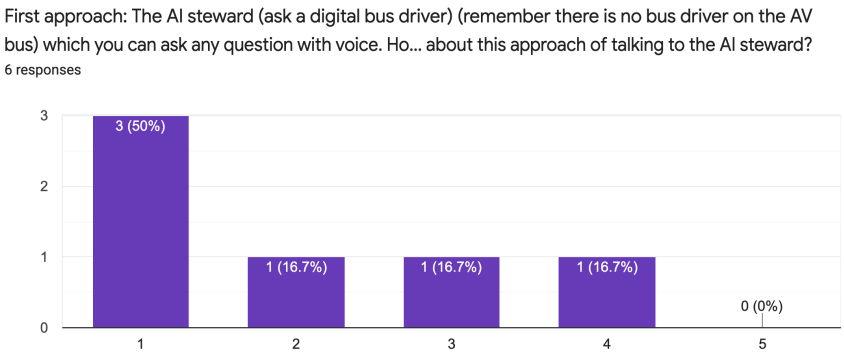
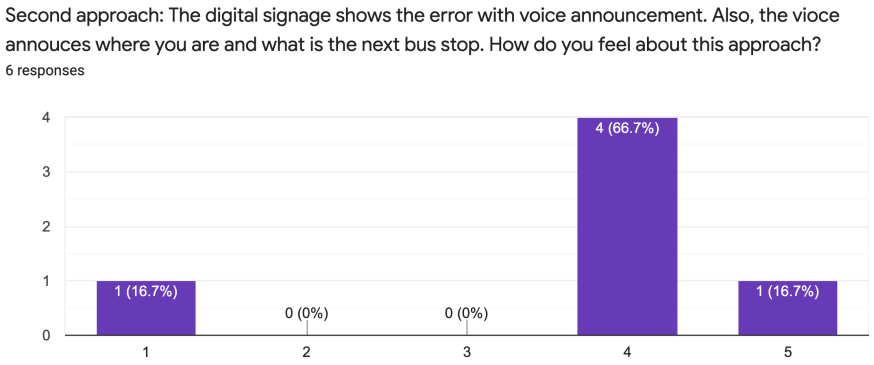


16 Please tell us Why?/Do you have other suggestion?

- Seems very approachable
- Not sure that is obvious enough
- I don’t like talking in public, and if this is an option I’m worried other people on the bus will start yelling
- Dislike speaking, wouldn't know what to say
- I would rather deal with a bus with a bus driver in this situation. If there is an error with buses with drivers you can just hop on the next bus.

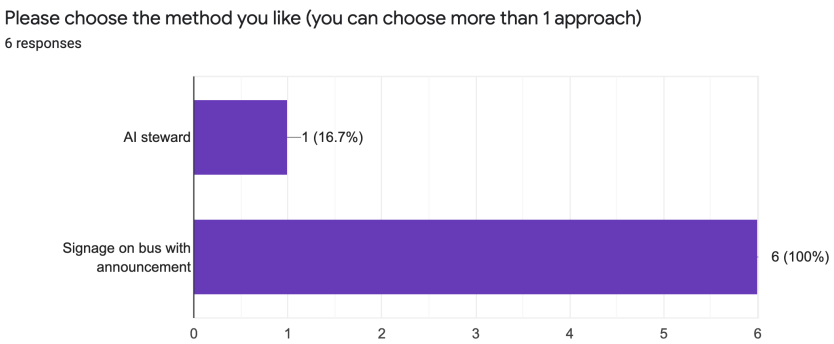
17



18 Please tell us Why ?/Do you have other suggestion?

- This is better for those who might be unfamiliar with the route, such as people visiting or those who don't take mass transit on the reg.
- Seems better
- As long as it’s visible from most seats
- Clear and unobtrusive
- Same as above

19



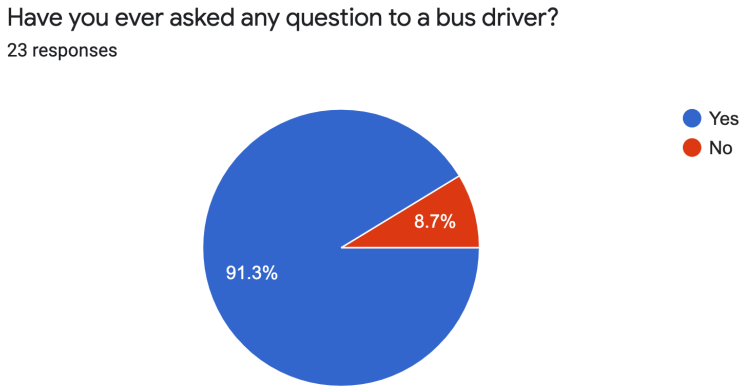
4. Conversation between Passenger and Bus Driver Survey

4.1 Survey Questions

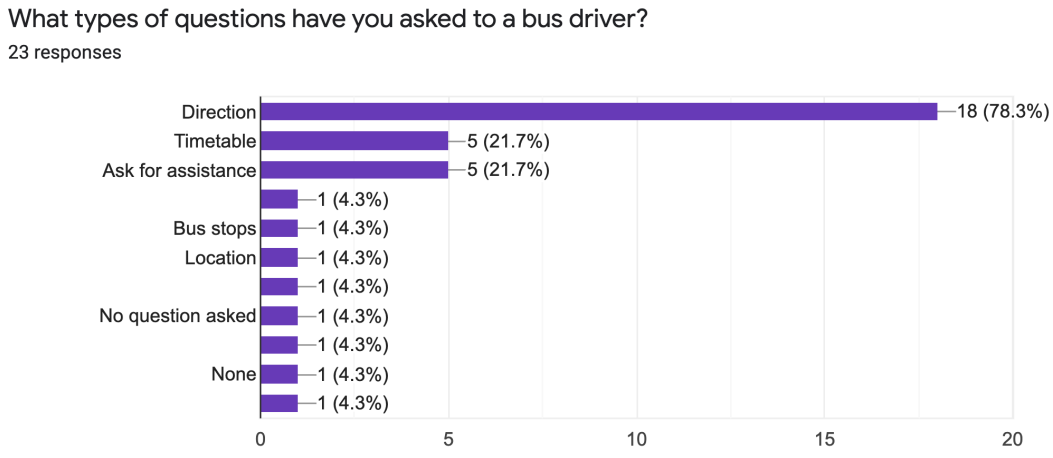
1. Have you ever asked any questions to a bus driver?
2. What types of questions have you asked to a bus driver?
3. What are the questions that you asked? Places listed at least 3 questions, if possible.

4.2 Survey Responses (23)

1



2



3 Can you tell us what are questions that you have asked the bus driver? Please list at least 3 questions, if possible.

- Is this bus going to X?

- Asked about why the bus is not moving, for example when an accident has occurred and stopped the traffic
- Does this bus stop at this station
- Does this bus stop at this location?
- Does this bus pass through a specific mall?
- When do I get off this bus if I want to go to this place?
- Does this bus go to *this* bus stop?
- Is this the bus which leaves at *this* time?
- Is this the bus line *number*?
- "Does this bus stop at X?", "Are you X bus, I didn't see?", "Can you open the door, I entered the wrong bus", "Someone forgot their wallet/bag in the back", "there's an uncomfortable person in the back, can you do something about this"
- Does this buss go to X?
- Are you stopping at this.. stop?
- How do I get to that place?
- How much is the ticket?
- Do I need to show you my ticket? Does this bus go to x? Can I pay with card?
- Is this bus going to destination X? Is this bus number X?
- "Is this bus [X]?" - for when the number indicator on the outside of the bus has been broken.
- I have not asked any other questions to the bus driver. They are not to be disturbed for information such as directions or timetables.
- No question asked
- Are you stopping the nextstop? Does this bus goto x? Is there another bus coming soon after you?
- I have asked if the bus stops at a certain stop, or which other bus I should take. I have also asked if they can tell me when the bus stop is approaching (when phones didn't exist) so I could hop off at the right place.
- "How many stops before [This Stop]?"
- Dont remember it was some years ago. Probably the direction of if being the right bus when being abroad
- No, I haven't asked any questions to the bus driver
- Does this bus go to "X"? (In case the display is broken or something)
- "Does this line go to X station?" "Is this the Y line?" (The signs outside the bus hadn't updated from its previous assignment and listed a line that typically didn't run this route, but the bus showed up at my stop at the time that was expected of the "Y" line) and finally "Are we departing soon?" (After 10 minutes delay at the bus hub)

- Does this bus go to *location*?
- When will you leave the station? (If I have entered the bus but it hasn’t moved)
- Are you heading to Växjö Central?
- Does this bus go to redbergspaltsen?
- Can you take us close to ... ? Our bus doesn't seem to be running today today some reason and we have been waiting for 40 minutes.
- Direction: Does this bus/tram stop at XXX? Timetable: How often does this bus/tram go? If there has been an unexpected stop, I have asked what has happened and why we arent moving. etc
- Does this bus go to.....? Where can I find bus.....? I want to pay for both of us, can you help me?

5. Users Error in Transportation Survey

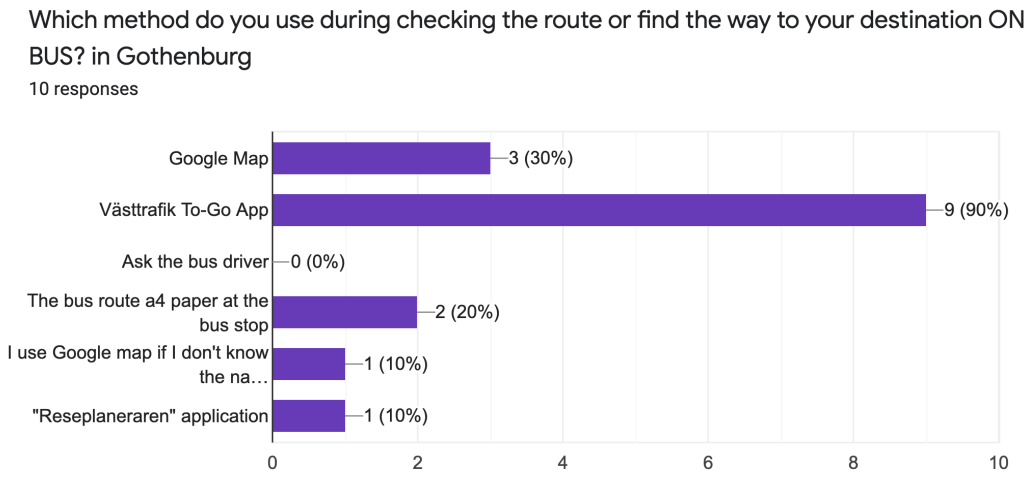
5.1 Survey Questions

This survey aims to understand the passenger decision during the commuting journey by public transportation in Gothenburg.

1. Which method do you use during checking the route or find the way to your destination ON THE BUS? in Gothenburg
    - Google Map
    - TO GOApp
    - Ask the bus driver
    - The bus route a4 paper at the bus stop
    - Othre
2. If you ask the bus driver, why did you choose to ask the driver instead of using Google Map/ The TO-GO App / The route map at the bus stop?
3. Have you ever get on the wrong bus?
    - Yes
    - No
4. Why did you get on the wrong bus? And how did you solve it?
5. Have you ever get off at the wrong bus stop?
    - Yes
    - No
6. Why did you get off the wrong bus stop? And how did you solve it?

5.2 Survey Responses (10)

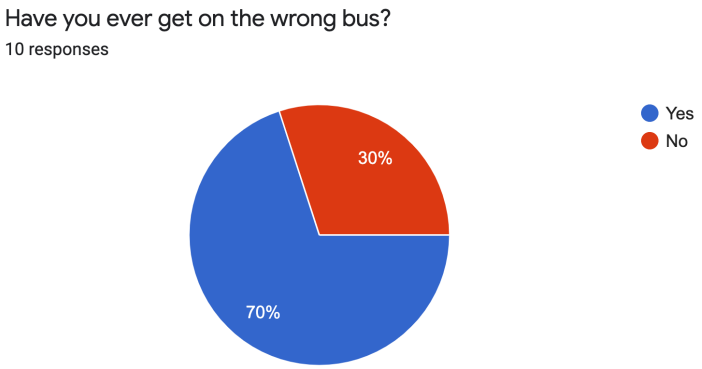
1



2 If you ask the bus driver, why did you choose to ask the driver instead of using Google Map/ The TO-GO App / The route map at the bus stop?

- -
- I don't ask the bus driver
- Was mandatory...
- I don't ask the driver.
- i dont
- I have not asked the bus driver
- If my internet connection was down.
- I never ask the bus driver
- If I'd ever ask the bus driver it is because I don't have the time to check myself in the app. I'd ask whether the bus stopped at a particular stop.

3

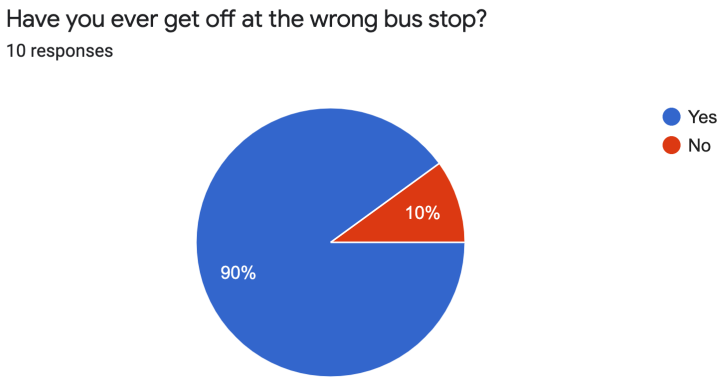


4 Why did you get on the wrong bus? And how did you solve it?

- -
- Probably in a stressed situation and where i think i might miss the bus/tram and hurry to catch i and jump on the wrong bus. Or if I'm distracted by my phone. Or if im very tired. Or drunk haha. Usually solve the situation by quickly getting off the bus at the next stop and either go back or hopefully the right bus stop at that station as well.
- Got off the next stop.
- I got on the right bus number, but in the wrong direction. I noticed that it drove in the wrong direction so I got off at the next bus stop.
- Jumped of at next larger station where i know there is a lot of other buses. Or just jumping of at a stop and taking the same line back to where i began.
- I got on the right tram number but the wrong way, this was when I was new in Gothenburg. Just jumped off at the next bus stop.
- Mistook the sign, got off at the next stop.

- No I did not
- (Happend to me rarely but) Usually due to stress in the moment, could be that I am not paying attention to which direction I should travel (resulting in stepping on the right number but going in the wrong direction)

5



6 Why did you get off the wrong bus stop? And how did you solve it?

- Sometimes I miss the right stop and realize my mistake exactly WHEN the bus leaves the right stop. Then I go off the next stop. I it is not too far I walk from there. If its too far away I wait for a bus yo take me back.
- By mistake. I was not looking at the stop. I went to the opposite station and got on the next bus that was coming
- The name on the app for the stop was different to the name of the stop. Luckily I asked the bus driver since the app said it should be this stop, and he said yes this is the stop and they stopped for me a few km down the road.
- I did not press the stop button, so it drove by the stop. I had to get off at the next stop instead and walk back.
- Waited for the next bus to continue my journey.
- I have not got off the wrong bus stop
- Because I was on the wrong line, so I had to get off to get back to where I was going
- I looked at my phone and missed the stop. I walked back, it was only one stop :)
- Unclear/non existent feedback in buss/tram (lacking/missing audio/visuals telling me which stop the bus is currently at/which stop is next)
- Happens only if I’m not familiar with the surrondings/the particular route
- If I’ve been distracted and focused on something else. Solved it by either walking back or getting another bus/tram/tube

Appendix F - Physical Evaluation

1. Evaluation Script

Footprint

Context description: You get off the bus at Regnbågsgatan platform B and you need to take the AV bus to your office. Now you have a task:
Task: find the AV bus stop
Think aloud procedure: You can say whatever comes into your mind as you perform the tasks. This might include what you are looking at, thinking, doing, and feeling while finding your way to the AV bus stop.
Evaluation: Rate the factors from 1-5

- What do you think of the visibility of the footprint on the ground? (Not visible-Visible)
- What do you think of the difficulty to recognize and understand the meaning of footprint? (Not easy-Easy)
- What do you think of the footprint design while assisting you to navigate to the destination? (Not helpful-Helpful)
- What do you think of the aesthetic of the footprint design? (Not good-Good)
- What do you think of the efficiency of using footprint to navigate to the AV bus stop? (Inefficient-Efficient)

Basic information signage

Context description: You arrive at the AV bus stop, and ready to take the AV bus, this is the first time you take the AV bus. You see this signage and hope to get information about the journey.
Task: What can you tell from the screen? Can you describe how you perceive this bus stop signage?
Think aloud procedure: You can say whatever comes into your mind as you perform the tasks. This might include what you are looking at, thinking, doing, and feeling.
Evaluation: Rate the factors from 1-5

- What do you think of the visibility of the information on the signage? (Not visible-Visible)
- What do you think of the difficulty to recognize and understand the information provided in the signage? (Not easy-Easy)
- What do you think of the signage design while assisting you find the information you want about the bus? (Not helpful-Helpful)
- What do you think of the aesthetic of the signage design? (Not good-Good)

- What do you think of the efficiency of finding information from the signage? (Inefficient-Efficient)

2. Evaluation Result

Experiment Group - Test with prototype

Participant A

1. The participant was led to Platform B and given the task to find Platform E.
    a. He tried to check that he was at Platform B, and looked around to find Platform E. He saw Platform A and D, but there was no Platform E. He walked around and found our signage and footprint. He found “Platform E” on the signage with an arrow pointing. Then he thought he might not need to follow the arrow, since the footprint showed the direction. He followed the footstep and crossed the street. He was confident that he would find the way to the destination. He got to Platform E.
2. The participant was given the second task of perceiving the information from the signage at the bus stop.
    a. He thought there was a lot of information. Firstly, he saw the bus stop name. It matched with the original bus station. Then he saw the next bus and the arrival time. He was not sure what the time means. He saw the schedule and notice it was 9:15, he would take the bus at 9:20. He was not sure the direction, he thought the top one might be the previous station, and then-current station and then next station. He saw the information about how to buy the ticket, he was confused “where to buy ticket” and “how to buy ticket”. He thought it was a problem for people to know where to buy the ticket.
3. Evaluation part
    a. Footprint & signage
        i. Visibility - 2 (The footprint was hard to see at first. People might not care about if it is AV bus or normal bus. Better to adapt the Vastraffik signs. Foot print is safe than the arrow.)
        ii. Recognize and understand - 5
        iii. Assistance - 5 (Don’t need to always look at it)
        iv. Efficiency - 5
        v. Aesthetic - 3
    b. Bus stop signage
        i. Visibility - 2 (Confused about the two columns, what is the time? What do the green ones mean? The direction could be a bit bigger.)
        ii. Recognize and understand - 3 (Not sure if the normal ticket can be used in AV)
        iii. Assistance - 3

iv. Aesthetic - 3
v. Efficiency - 2

4. Other feedback
    a. Confused that there is no Platform E. The signage was not so visible, it was hidden. People will look to the opposite of the road firstly. It is better to have both the footprint and signage. Dangerous to only have arrows that people will lose.

Participant B

1. The participant was given the task to find the Platform E
    a. She looked around and did not see the platform. She first tried to open Google Map. She didn't find anything. Then she walked around and saw our signage. Then she saw the footprint and followed it. Then she saw another signage cross the road. She was happy that she was not lost. Then she just follows the footprint. She was wondering why the footprint was gray XD. Finally, she found the signage.
2. The participant was given the task to search for information on the signage.
    a. Firstly, she saw the next bus will come 5 minutes later. And she knew the status of the bus (late or not). The direction is clear. She assumed the top stop was the previous stop and then the next stop. The schedule was clear as well. Then she noticed how to buy a ticket. She thought it was clear. The ticket price and ticket time were good for the foreigners.
3. Evaluation part
    a. Footprint & signage
        i. Visibility - 4
        ii. Recognize and understand - 4 (Firstly confused since it was first seen, then it was useful)
        iii. Assistance - 5
        iv. Aesthetic - 4 (Blue pops out, good.)
        v. Efficiency - 5
    b. Bus stop signage
        i. Visibility - 4
        ii. Recognize and understand - 4 (Not understand how late is the bus)
        iii. Assistance - 5
        iv. Aesthetic - 5
        v. Efficiency - 4 (Better to have how long it takes to the destination, dout about the late)

Control Group - Test without a prototype

Task: We want you to go to Hugo Hamma kej from your place by bus. You can plan your trip beforehand. It depends on you.

Participant C

Result:
She got off the bus from platform B. She started by searching the place on google map but google map suggested her to walk. (We think google map doesn't have a bus 56 info). Then she checked it with a to go app because we told her to go by bus. Now she knew she needed to go to platform E to take bus 56. She looked around and she couldn't see platform E from where she was standing. THen she checked on the app again and the show where platform E is. She followed the app by matching the surrounding landmark and the app(e.g renting a bicycle or offices). And then she recognized the road because this is where she studied her Swedish class, so she knew that she needed to go at the right corner. However, she said that if she did not visit this road before she surely will go in the opposite direction. She suggested we should place the direction sign so she will quickly know where she should go.

Participant D

Result:
He was introduced to the task of finding bus 56 and Platform E. He didn’t use his phone to search the bus stop. He tried to look around and saw Platform ABCD. He planned to walk around in four directions to find Platform E. Then he walked to the left corner and luckily find Platform E in 2 minutes. He explained that he didn’t use a mobile phone to navigate too much. Usually, he tried to walk around. And he tried to search Platform E on Google Map but there was no result. He said if he tried with a mobile phone first, he might not be able to find the bus stop.

Summary:

From our test, the participants use mobile phones and navigation ability. The first participant uses a map and bus applications as well as her memory and recognition of the road and symbols to navigate. However, the second participant didn’t use any assistant but rely on himself to search for the bus stop by walking around. We should support the information in many forms which can be beneficial for each individual.

Appendix G - Digital Evaluation

1. Evaluation Script

Shelter signage

Context description: This is your first day in Gothenburg. And you need to go to company A to meet your friend.
You are a person who is bad at finding a direction and remembering the route. You always rely on a google map. On halfway to the destination, **your mobile data runs out** but you successfully arrive at the **regbonsgatan bus stop platform E**. Now you are under the **shelter** at the bus stop. Here you can see interactive digital signage in the shelter
Task: Go to company A and get off the correct bus stop
What is your plan of how to know where Hamma kej is?
How will you perceive the information?
When will the bus arrive?
Do you know why the next bus is late?
Note ***Don't have to ask if they mention during the test***

--Show the bus signage during the question--
Evaluation: Rate the factors from 1-5

- What do you think of the visibility of the information on the signage? (Not visible-Visible)
- What do you think of the difficulty to recognize and understand the information on the signage? (Not easy-Easy)
- What do you think of the signage design while finding the information to company A? (Not helpful-Helpful) how helpful it is?
- *What do you think of the aesthetic of the signage design? (Not good-Good)*
- What do you think of the efficiency of finding information from the signage? (Inefficient-Efficient)

Announcement signage (and voice) on the bus

Context description: Now, you are on the bus and t**here is no bus driver.** Then you arrive at Chalsson gata bus stop and the bus starts to take off from the bus stop but suddenly, the shuttle bus stops!!.

Announcement - "Sorry for the inconvenience. The bus sensors are covered by the snow at the moment. Please wait inside the bus. The bus will depart in 2 min "

What is the next step you are going to do?
Do you know what causes the bus to stop?
Do you know where you are right now?
Do you know how long you need to wait?
- Don't have to ask if they mention during the test

(Difference in the seriousness of errors)
Is it enough info for you to handle the situation when the error happened?
Didn't know that 2 mins are added up to 10 mins to Hugo…

Additional questions:

- Have you ever met the occasion when you are on the bus, and it crashes into another car? If yes, how did you solve this or how did the bus driver solve this?
- The normal car accidentally crashed the AV bus on the way. The sensor and AI create an error sound and announce that there is an accident and suggest you evacuate.
- What do you think about this situation? What is your expectation? What will you do in this situation? How do you feel? DO you trust the AI in this situation?

2. Evaluation Result

Participant E

Shelter signage

The participant was introduced to the context and task. The participant was asked to roleplay as a person bad at finding direction and remembering the route.

Think-aloud :
Firstly, he checked the map, to see where he is and where Hugo Hammars Kaj is. He noticed the current time, and he thought it would better to have a bigger clock. The word "AV" was a bit confused. He knew that his bus will arrive at 18:00. "Arrive" and "Next" was a bit confused. He tried to click on commuting instruction and ticket instruction. He didn't know where is the Vasttrafik store, and there was a problem he cannot buy a ticket using a mobile phone. It would be good to have the ticket store shown on the map. The question "how does AV work?" was confusing that he thought it was the instruction of the AV bus. He thought the two instructions could be better to just open and don't need to click. "Press button" was confused, stop or open the door? Then, he opened the chatbot. The "search" button was better to be chat button. He liked the script that shown the picture of the destination. Better to have

the input bar on the bottom to input again if the type wrong. (Create a prototype more like a messenger!)

Question:

- Do you know why the next bus is late?
    - He knew the reason for the bus being late. Could be nice to make the error information larger.
- What do you think of the AI assistant?
    - It was useful. Better to have instruction on what can be asked by an AI assistant. Ie. it can help to guide to the destination. The script was really nice. (Comment: user another keyword like: Where are you going? Are u lost? Tap to ask the direction)
- Evaluation
    - Visibility - 3 (The path is really visible. The instruction should be open. Better to have other bus information on the map.)
    - Understand information - 3 (Icon in instruction is straightforward. Instead of use “search”, maybe use the chat. Have more interaction with the bot. Add follow-up questions to make it a chat.)
    - Efficiency - 4

Announcement signage

The participant was introduced to the context.

Think-aloud:

The error message was clear and he thought he would just wait for 2 minutes. He didn’t like the word error, it seems a problem in software. He preferred it to be more human, such as “sorry...”. He knew that he was one bus stop from the destination. He wanted to know how cold outside since it snow. The time should be a bit bigger since he needed to know if he will arrive on time.

Questions:

- Does it have enough information for you to handle the situation?
    - Yes. It should be better to have direction on the signage.

Additional questions:

- If a car crashes into the AV bus, what do you think of this situation?
    - Better to show the information both on screen and with an announcement. Should have a big message on the screen that said get off. It should have two levels. The serious one and not serious ones.
- Have you ever might any accidents on the normal bus?
    - Yes. the bus driver parked and announced to get off and everybody gets off.
- Do you trust AI?

    - Yes. He trusts AI drivers. AI can detect errors, but human always makes mistakes.

Participant F

Shelter signage

The participant was introduced to the context and task. The participant was asked to roleplay as a person bad at finding direction and remembering the route.

Think-aloud process:
She ensured she was at Platform E, which is the correct bus stop. She was confused about the "Hugo Hammars Kaj" on the map, is it a bus stop or just a place. The "arrive" was confusing, the bus arrives or the passenger arrives? She didn't know the meaning of the warning sign. The warning information was too small. Then she knew. She tapped the AI assistant. Click search. She thought the script was nice for her. She noticed the instruction part. The "ticket" information was crucial to her. The information was clear just hard to read.

Question:

- Which platform would you take off?
    - She didn't know which bus stop, but only the destination.
- Evaluation
    - Visibility - 3 (The text was too small.)
    - Understand information - 3
    - Efficiency - 3 (It took her a while to figure out the meaning of the map.)

Announcement signage

The participant was introduced to the context on the bus and the hard stop scenario.

Question:

- What is the next step you want to do?
    - She cannot understand whether she needs to get off or just stay. (Here the question we asked is ambiguous.)
    - So she waits for 2 minutes.
- Do you know what is the reason makes the bus stop?
    - She knew it is the sensors covered by snow.
- Do you know where you are?
    - At Carlssons Gata.
- Is it enough information you need?
    - Yes, but should clarify if the passenger needs to wait for 2 minutes or not?

Additional questions:

- Have you ever might any accidents on the normal bus?
    - Yes. The bus cannot work. The driver explains the situation. Passengers wait for the next bus and change the bus.
- If a car crashes into the AV bus, what do you think of this situation?
    - It is scary, but she would follow the instruction of AI to evacuation. She trusts the AI. She needs clear and calm instruction.
- Do you trust AI in this situation?
    - Yes. She trusts the AI. She would panic at that situation and not trust herself. She would see the AI as a bus driver.

Participant G

Shelter signage

The participant was introduced to the context and task. The participant was asked to roleplay as a person bad at finding direction and remembering the route.

Think-aloud process:

He can see the "Hugo Hammars Kaj" bus stop on the map. He tried to click on the map. He can see that he was at Platform E on the map. He thought he needs to follow the blue route on the map. He was afraid he cannot find the direction after getting off the bus. He thought he needed to go there by bus. He tried to find the information about buying a ticket. He knew he needs to go to the store to buy the ticket. And he thought maybe he needs to download the ticketing App. He tried to see the information about how to commute the bus. He thought he would wait at the bus stop for 9 minutes and get on the bus, show the ticket, and travel on the bus. He was not sure whether "Hugo" is a bus stop or not. He noticed the AI assistance, he thought it was a custom service. Since he already gets enough information so he doesn't need to use AI assistance.

Question:

- Do you know why the second bus is late?
    - He didn't notice first. He was firstly confused about the error icon. Then he saw the error information
- Evaluation
    - Visibility - 4 (The most important information is the path, he thought the map was clear. The position of the bus was clear.)
    - Recognize and Understand information - 4
    - Efficiency - 4 (The destination information was clear.)
- Do you want to try with AI assistance?
    - He was not sure about the function of the AI assistant. In this task, he thought he doesn't need it. The picture of the destination was really good.

- Before using the AI do you know you need to take the bus to 2 stops and get off at "Hugo.."?
    - He didn't know how many stops he needs to ride, but he knew that he need to get off at the "Hugo.."

Announcement signage

The participant was introduced to the context on the bus and the hard stop scenario.

Question:

- What is the next step you want to do?
    - He noticed the estimated departure time was 2 minutes, he thought he would wait for 2 minutes. If the bus didn't depart, he would get off and walk to the destination.
- Do you know where you are?
    - Carlssons Gata
- Is it enough information for you to handle the situation when the error happens?
    - Yes. he knew why the bus stop and the estimated time. He thought this are the information he needed. It would be better to have some alternative routes, such as nearby bus stops, etc.

Additional questions:

- Have you ever might any accidents on the normal bus?
    - Yes. he had an experience that many bus stops in the queue, and he walked back home. The bus driver suggested passengers to change another bus.
- If a car crashes into the AV bus, what do you think of this situation?
    - The first thing is to make sure the passengers' safety. The Av bus should open the door and let passengers get off the bus. In normal bus drivers would handle the situation. But in the AV bus, how do the AV bus talk to the other car drivers?
- Do you trust AI in this situation?
    - Yes. if the AI can have the correct action.

Participant H

Shelter signage

The participant was introduced to the context and task. The participant was asked to roleplay as a person bad at finding direction and remembering the route.

Think-aloud:

She saw the current time was 18:00. She was confused about the error symbol. She can see the path on the map. She interacted with the AI assistant. It showed the picture. She thought the script was nice to see. She noticed the late information. “Next” means next bus or next stop?

Question:

- Which bus stop you would get off?
    - Hugo Hammars Kaj
- Evaluation
    - Visibility - 4 (The blue box about where to buy a ticket was too small)
    - Recognize and Understand information - 4 (What the bot would help was unclear. And the “Next” was unclear)
    - Assistance - 4 (If there were a lot of people, the situation would be complicated)
    - Efficiency - 5

Announcement signage

The participants were introduced to the context on the bus and the hard stop scenario.

Question:

- What is the next step you want to do?
    - She will sit inside and wait for 2 minutes. If it took more than 2 minutes, she would look for help.
- Is it enough information for you to handle the situation when the error happens?
    - It would be better to have a help number to look for support.
- Do you know where you are now?
    - Carlssons Gata.

Additional questions:

- Have you ever met an accident on a normal bus? How did the bus driver handle this?
    - She met the bus stop in the center of the road. The driver got off the bus and talked with other drivers. But the driver didn’t announce to the passengers.
- If a car crashes into the AV bus, what do you think of this situation? What do you expect from the AI?
    - She would try to keep herself safe first. She expected safety protocols and instructions on what to do. The language should be both English and Swedish.
- Do you trust AI in this situation?
    - Not 100%. Since she didn’t have experience commuted on AV bus before. If this was an everyday routine to travel on an AV bus, she will trust it. AI was designed by human and human-made mistakes.

Participant I and J

Shelter signage

We invited two people to interview together at this time. Participants were introduced to the context and task. Participants were asked to roleplay as a person bad at finding direction and remembering the route.

Think-aloud:

Firstly, both of them notice the red dot where they were on the map. And they tried to interact with the signage. Participant A tried to follow the blue route and walk. There was no scale on the map, so he didn't know if the distance was far or not. Participant B wondered the direction of the bus. Participant A tried to tap the robot and input the destination. He wondered if he can talk with the bot since it was under the Corona pandemic. Participant B wondered what was AV bus. "Ride for 2 stops" was ambiguous. They had different opinions on this sentence. The information of the destination's picture was clear. They were wondering whether the picture would change in real-time. The two methods of buying tickets seemed to need to do both. Maybe add an "or". "Show ticket" was confused. Participant B wondered whether they should buy a ticket on the phone since there was no data on the phone. They discussed how to buy a physical ticket in Gothenburg. Participant A thought about it would be nice to have both the Swedish and English versions. Maybe have a flag on the screen to change the language. Participant B wondered whether the chat would be kept after he left. Their plan was to buy a ticket and wait for the bus, and travel according to the suggested route.

Question:

- Did you notice the warning sign? Do you know why it was late?
    - No. Participant A only wanted to know what time would the bus come, he didn't care about the reason.
- Evaluation
    - Visibility - 3/4 (Participant A wondered whether the map could zoom in/out or move. The map was too full now. It was nice to have the current position in the center.)
    - Understand information - 3/3 (The information on the map didn't stand out. The two red dots had different meanings which were confusing.)
    - Efficiency - 3/4 (To get to Company A was good, but to get to other places was bad. The information about buying a ticket should be more clear. "Where to buy a ticket" was more important, maybe switch the position.)

Announcement signage

The participants were introduced to the context on the bus and the hard stop scenario.

Question:

- What is the next step you want to do?
    - Participant A saw it took 10 minutes to the destination so he knew cannot walk, so he would wait inside. Participant B would go to pick a coffee.
- Is it enough information for you to handle the situation when the error happens?
    - Yes.
- Do you have any suggestions?
    - Have the "2 min" more clear. Such as estimate departure time. "Please wait inside" was not friendly. Is it possible to get off? Two warning signs were a bit scary. Multiple signs made people stressed. Maybe have a box on the green box, like a drop.

Additional questions:

- Have you ever met an accident on a normal bus? How did the bus driver handle this?
    - The bus driver stopped at the bus stop, and let the passengers get off. The bus driver didn't provide instructions on what to do. For travelers not to understand the local language, they would lose under this situation. Participant B met a time when a car crashed into a scooter. He was scared at that time. All passengers were worried and there was a mess on the bus. He would follow other passengers to change a bus.
- If a car crashes into the AV bus, what do you think of this situation? What do you expect from the AI?
    - Stop and let people leave, and have someone fix the situation.
- Do you trust humans more than AI?
    - Yes.

Participant K

Shelter signage

The participant was introduced to the context and task. The participant was asked to roleplay as a person bad at finding direction and remembering the route.

Think-aloud:

She saw the blue route on the map, and she saw the bus could take her to "Hugo Hammars Kaj", and she would walk to "Company A". She was wondering whether there would be another bus route on the map. So she would just wait for 9 minutes and get on the bus and get off at "Hugo Hammars Kaj". On the top, there was the AV bus time information. It was clear enough. And then she noticed the error icon and the information of the late bus. She knew the reason why the bus was late. She was not sure about the location mark on the map, she cannot read the text, it was too small. She was wondering whether the AV bus was different from the

normal bus. Maybe change the “show ticket”, since there was nowhere to show the ticket. It will be convenient to have the QR code of the App on the signage. She tried to interact with the AI assistant. The function of showing the picture of the destination was good. It would be nice to have a function to download the script into her phone.

Question:

- Evaluation
    - Visibility - 4 (Information on the top was clear. The information in the map is too small.)
    - Understand information - 4 (Her main focus was on the map and AI assistant. The chat bot and map should be bigger and other information should be smaller.)
    - Efficiency - 5

Announcement signage

The participant was introduced to the context on the bus and the hard stop scenario.

Question:

- What is the next step you want to do?
    - If the distance was not far, she would get off and take a walk. If the distance was far, she would wait inside the bus.
- Is it enough information for you to handle the situation when the error happens?
    - Yes. it was nice to have the reason for the error.

Additional questions:

- Have you ever met an accident on a normal bus? How did the bus driver handle this?
    - No.
- If a car crashes into the AV bus, what do you think of this situation? What do you expect from the AI?
    - She would more concerned about the product itself. Maybe the car displays the nearby hospital.
- Do you trust humans more than AI?
    - She would trust AI in this situation.

Participant L

Shelter signage

The participant was introduced to the context and task. The participant was asked to roleplay as a person bad at finding direction and remembering the route.

Think-aloud:
She assumed she was under the shelter. And she tried to interact with the AI assistant. She got the result from the assistant. She matched the result from AI with the map. She noticed the error information. And then she saw the information about commuting AV bus and buying a ticket. She wondered whether she could use a mobile phone to buy a ticket or not. But actually, in this situation, she cannot use mobile data. So she changed her plan to go to the service point and buy the bus ticket. Her overall plan was to go to the ticket store to buy the ticket and wait for the AV bus. She would commute on the AV bus and get off at "Hugo Hammars Kaj". After she got off the bus, she would check the screen at the bus stop again to find "Company A".

Question:

- Did you notice there is a late bus?
    - She didn't notice it before, she felt it was not a problem for her journey.
- Do you plan your route using the map or only the AI assistant?
    - When she looked at the screen, the first thing she noticed was the map and saw the blue route. Then she noticed there was an AI assistant, so she tried to interact with it.
- Do you have any feedback?
    - She was confused about the information about where to buy a ticket. Since the icon's color was different from the one in the map. It was not matched. So it took some time for her to realize where the ticket service store was. Overall it was clear.

Announcement signage

The participant was introduced to the context on the bus and the hard stop scenario.

Question:

- What is the next step you want to do?
    - She would wait for 2 minutes and change to the next bus. (Here the information we said might not clear enough for her, so she misunderstood the notification.) if the bus didn't come in 2 minutes, she would re-plan the route.
- Do you know where you are?
    - She knew that she was at Carlssons Gata. But she was not clear where exactly the position she was. She was not sure about whether she needed to walk back to the bus station to take the next bus or not. She would just follow other people.
- Is it enough information for you to handle the situation when the error happens?
    - Yes. She knew the reason for the situation.
- Do you have any suggestions for this design?
    - It would be good to see where the exact position she was on the whole route (ie. have a position on the map).

Additional questions:

- Have you ever met an accident on a normal bus? How did the bus driver handle this?
    - Yes, it was on the bridge and the bus stopped. The bus driver calmed the passengers to not be worried. And passengers got off and took the next bus.
- If a car crashes into the AV bus, what do you think of this situation? What do you expect from the AI?
    - It would be good that the announcement told the passengers how to react. And it would be nice the announcement to have both the English version and the Swedish version.

- Do you trust AI in this situation that AI guides you to evacuate?
    - She cannot trust the AI 100 percent. She would listen to the AI instruction and make judgments herself.
- Do you trust humans more than AI?
    - Yes. because she can communicate with humans but AI just provides instruction. AI just provide a decision by program, sometimes the decisions are not according to the real situation.

Appendix H - Figures

Figure 6.8 User Journey Map 1 - Kevin

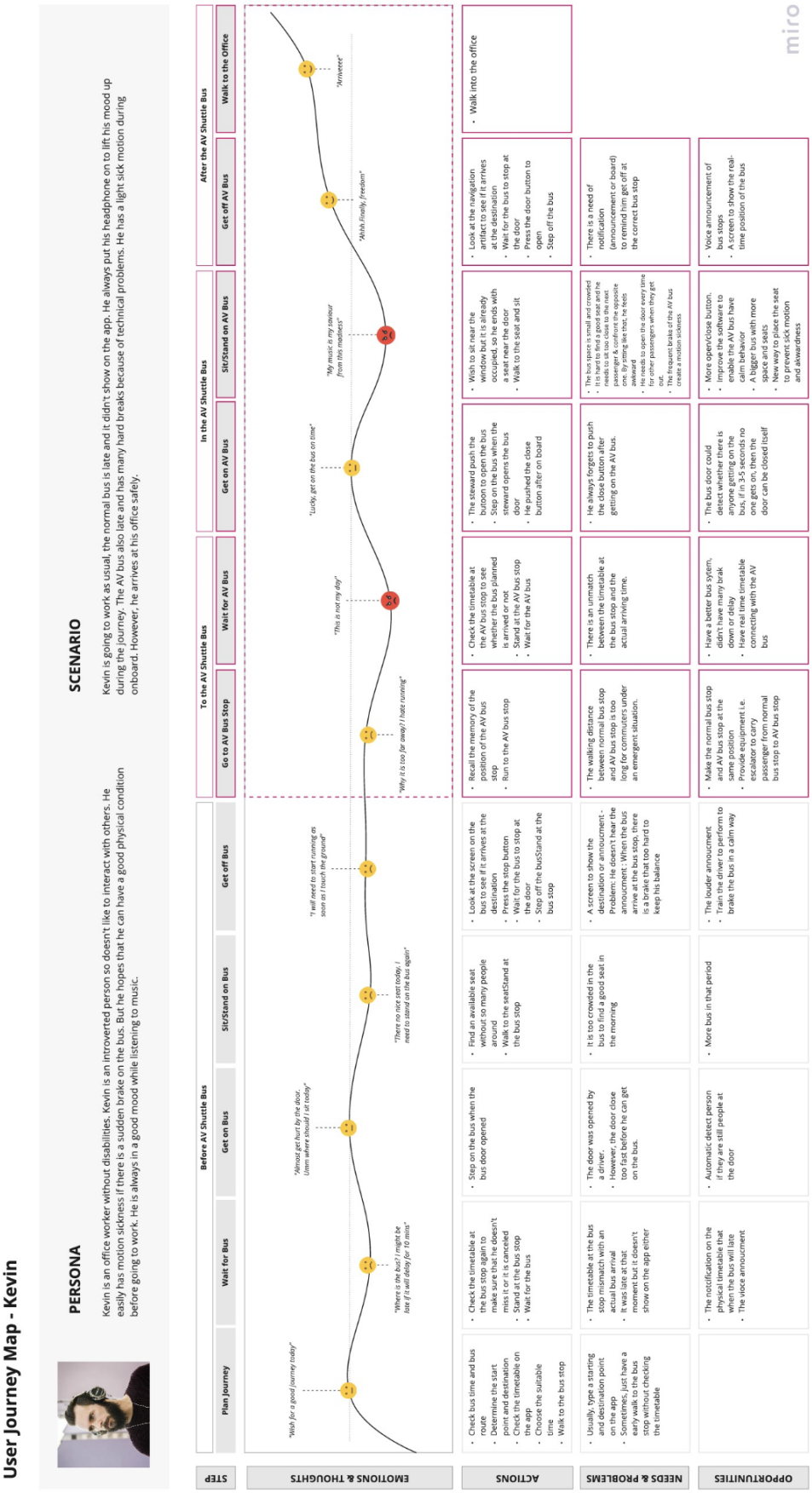


Figure 6.9 User Journey Map 2 - Emma and Emily

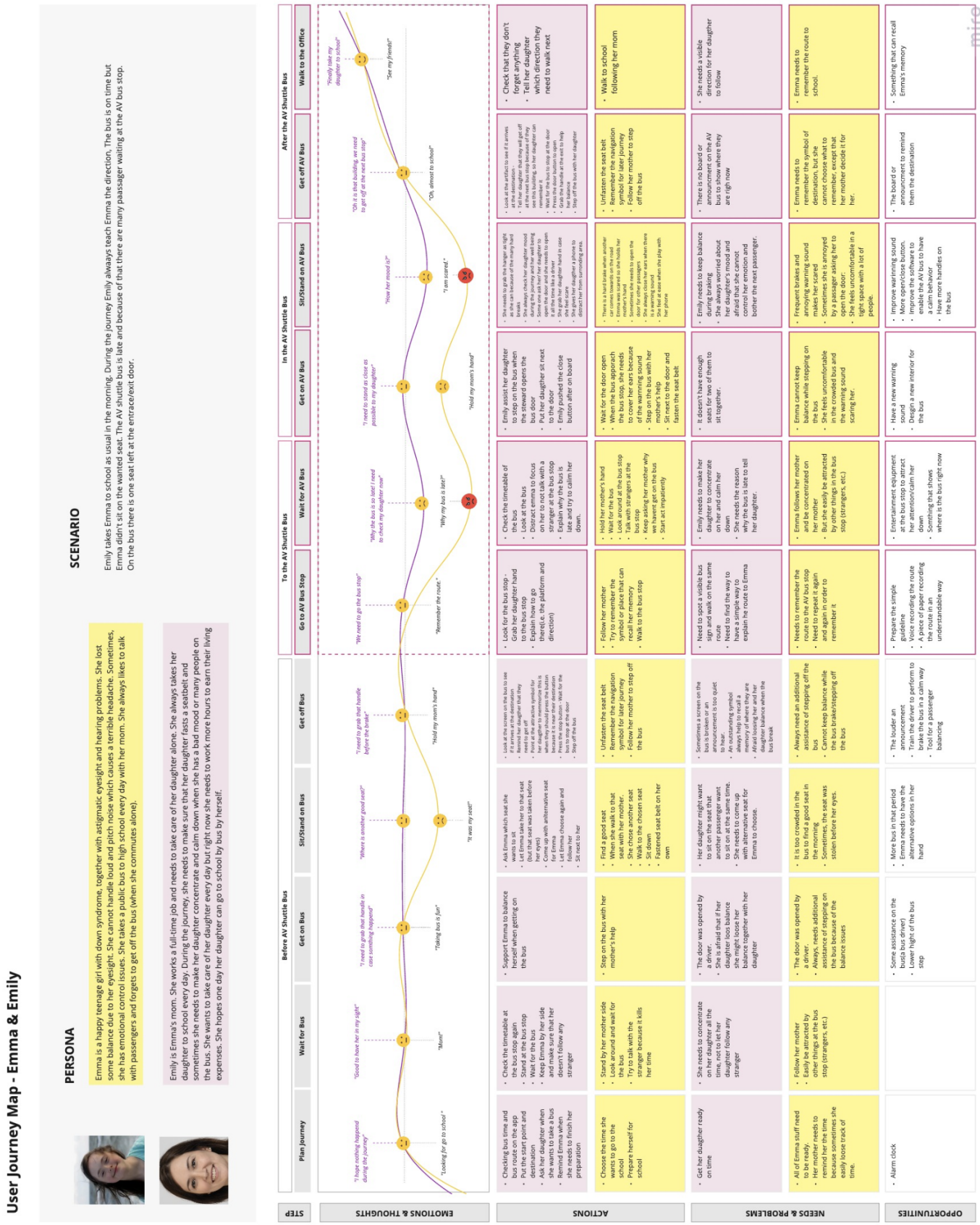


Figure 6.10 User Journey Map 3 - John

User Journey Map - John

PERSONA

John is a boy with Autism and living with his parents at home every day. John is a hyperactive guy and socially awkward, so he doesn't like to be near people and requires some activities to calm him down during the journey. Sometimes, he cannot control himself and his hands. And he would feel panic and stress when there are a lot of people on the bus. He always follows the instructions created by his family or the school to follow in his everyday life.

SCENARIO

John lives one bus stop away from the AV bus stop, so he always walks to the AV bus stop, and takes the AV bus to his special school. Today is his third time go to his school. When he is following his script on his phone, it ran out of the battery. So he is stressed with the journey. And on the AV bus, he mistakenly pushes the emergency button, result in the hard stop of the bus. What a terrible morning for John.

STEP	To the AV Shuttle Bus			In the AV Shuttle Bus		After the AV Shuttle Bus	
	Plan Journey	Go to AV Bus Stop	Wait for AV Bus	Get on AV Bus	Sit/Stand on AV Bus	Get Off AV Bus	Go to School
EMOTIONS & THOUGHTS	"Wish for a good journey today"	"Oh no my phone die!!"	"Oh it is crowded, and where can I charge my phone"	"Too annoying"	"Sh*t im screwed, what happend to me"	"Finally, Im out	"Wish to meet my friends soon"
ACTIONS	• Follow a physical script of how to go to school step by step. • Put the start point and destination and check a bus time on the app • Plan alternative routes if unexpected thing happen • Choose the suitable time and when to walk to the bus stop	• Follow the direction from the map on his phone • His phone ran out off battery on the way • He recalls where is the bus stop • Spot the bus platform • Walk to the bus stop	• Stand far away from other people at the bus stop area because it is crowded • Keep checking the bus arrival • Try not to clap his hand in public • Look for a way to charge his phone	• The warning sound notify him that the bus arrive • The steward push the button to open the bus • Follow other passengers and Step on the bus • Look around to check which seat he can sit	• Walk to the corner of the bus • Sit down on the seat and look for the charger on the bus • Try to keep distance from other passengers, but there are a passengers next to him and in front of him • He cannot help himself to not to push emergency button next to him. • The car stop immediately, he apologised and the bus driver fix it.	• Look at the navigation artifact to see if it arrives at the destination • Wait for the bus to stop at the door • Asking other passengers to press the door button for him • Step off the bus	• Ask for the direction to school • Walk to the school
NEEDS & PROBLEMS	• His families made a script of how to go to the school for him, and he just follow it.	• Sometimes, his battery run out and it takes some time to recall where is the bus stop. • The bus stop is hardly to spot, so he needs more extra time to look for it • Stress increase because he is afraid about missing a bus and charging his battery	• He has difficulties controlling his behaviour, emotion and his hand, he is afraid that his hyperactive behaviours would bother other people. • If people stand close to him he will feel upset.	• The warning sound in the bus increase his stress. • Because of the stress, make him forget the sequence of taking the bus	• It is crowded on the bus and he needs to sit close to each other also no charger on the bus to charge his phone, these increase his stress and anxiety. • His hyperactive actions would result in problematically push some buttons on the bus.	• He needs to ask someone to open the door for him , but it increasse his stress by talking with a stranger	• He needs to ask someone for direction, but it increases his stress by talking with a stranger
OPPORTUNITIES	• Illustration on the app.	• Visible bus stop • Power bank	• Separated waiting area • Charge phone area at the bus stop • A familiar object on his hand claim him down	• Redesign the warning sound • The instruction of how to commute the bus, inside the bus or at the bus stop	• Have relax music, or some video on the bus • Placed the emergency button out of the hand length • Redesign seat to keep distance from each other • Add a warning sign for not push a emergency button • The charger on the bus	• Add a open button close to him	• Add a map at the bus stop to introduce the landmarks, important traffic informations, etc. nearby.

Figure 6.11 Problem Defined from User Journey Maps

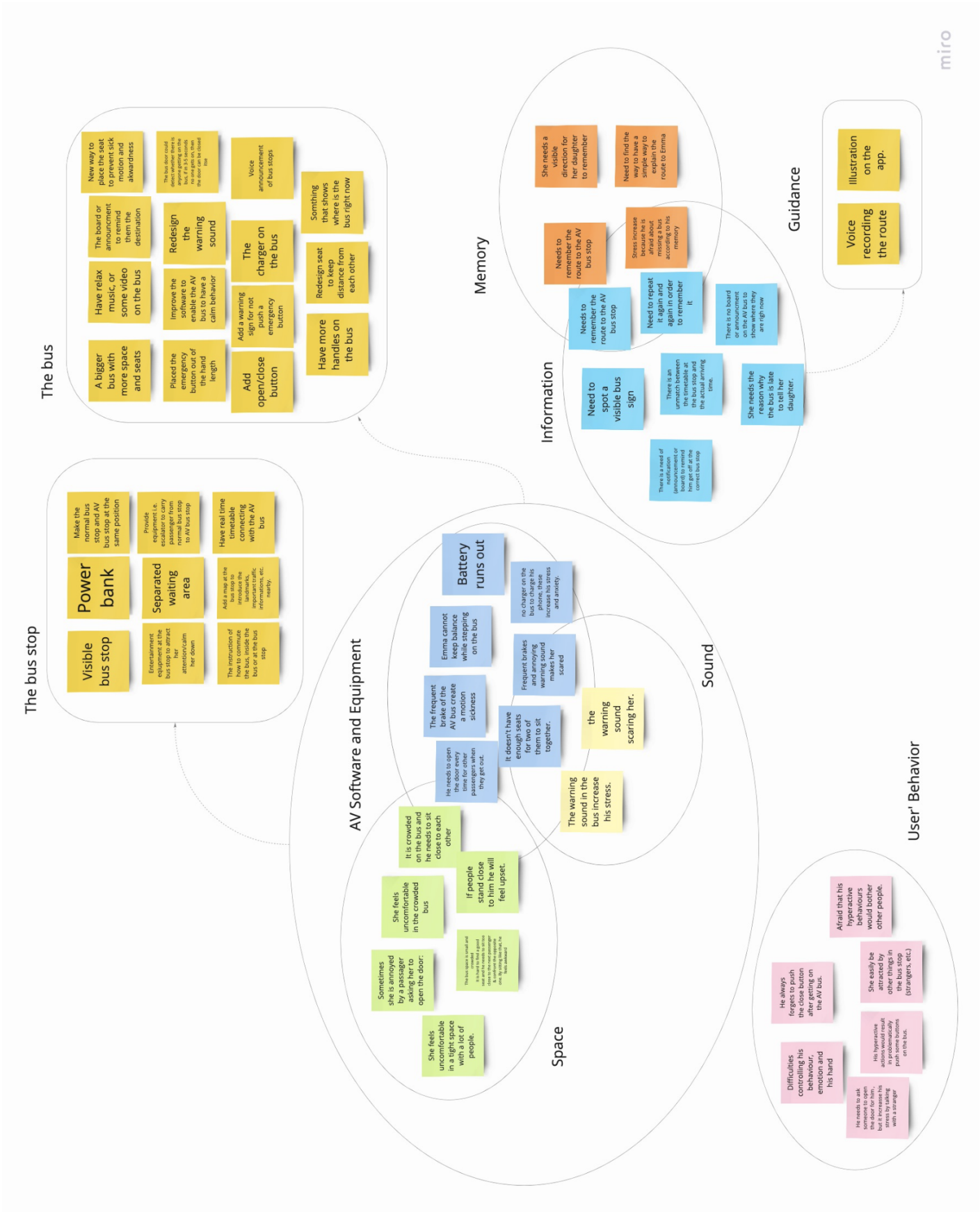


Figure 6.16 Ideation Results in Second Week