



WPI



Dansk Blindesamfund

Improving Accessibility of Public Transport Information for the Blind

An Interactive Qualifying Project submitted to the faculty of Worcester
Polytechnic Institute in partial fulfillment of the requirements
for the Degree of Bachelor of Science on April 30, 2018.

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This report represents the work of four WPI undergraduate students submitted to the faculty as evidence of completion of a degree requirement. WPI routinely publishes these reports on its web site without editorial or peer review.

Abstract

Information that sighted commuters take for granted in Copenhagen's public transportation network is often inaccessible to people who are blind or partially sighted. We identified potential improvements to the accessibility of transit information to recommend to the Danish Association of the Blind. We determined the main challenges blind and partially sighted people face when accessing transit information; observed the current accessibility of the system; and evaluated accessible solutions to identify the best potential improvements. Based on our findings, we recommend expanded use of audio announcements, stricter regulation for bus operators, increasing the accessibility of mobile phone applications, and the implementation of beacon technology in the bus system.

Executive Summary

Introduction

The United Nations' Universal Declaration of Human Rights (1948) affirms that all people have a right to participate in society; but people who are blind or partially sighted often face obstacles that obstruct that right (American Foundation for the Blind, n.d.; Blind find difficulties accessing public transport, 1999; Demmitt, 2014). One important obstacle is the limited accessibility of information in public transportation that is available to blind and partially sighted commuters. People who are blind or partially sighted are reliant on public transportation to travel independently since they are unable to operate vehicles (Casas, 2007). Social exclusion and inequality that those who are blind or partially sighted face can be exacerbated without accessible public transportation (Kenyon, Lyons, & Rafferty, 2002).

Generally, blind and partially sighted commuters do not have equal access to information regarding public transportation, including details about arrivals, departures, and schedule irregularities. People who are blind or partially sighted often have to depend on audio announcements, mobile phone applications, or advice from other commuters to get up-to-date information regarding public transportation (American Foundation for the Blind, n.d.). However, audio announcements are not always audible or available and mobile phone applications are not always accessible or consistently up-to-date. Additionally, asking other commuters for help deprives blind or partially sighted commuters of their independence.

Other cities around the world have implemented solutions that have aided in alleviating these problems. For example, San Francisco's Bay Area Rapid Transportation system went above and beyond the Americans with Disabilities Act and included extra accessibility features, including universal, comprehensive audio features in ticketing machines and public transit vehicles. In Chile, a local university developed an audio-accessible version of the mobile phone application developed for their public transportation. In Bucharest, an advocacy organization installed beacon technology into all its buses, train stations and bus stops—the beacons would transmit information to a mobile phone application when the mobile phone user passed the beacon.

Solutions like these do not yet exist in Copenhagen for a variety of reasons. Copenhagen's public transportation system is vast and complex, with three main modes of transportation covering over 72,000 kilometers of roads and rails. Further complicating the matter, these three main modes of transit

are each controlled by a different company, and each company contracts out to other companies to maintain their system. Additionally, Denmark does not have a strict disability policy that would aid in enforcing the implementation of large accessibility changes throughout the entire public transportation system.

Our project suggests ways to overcome these challenges in order to increase the accessibility of information about public transportation for the blind and partially sighted. We also hope to contribute to solving the larger problem of the inequality people who are blind or partially sighted face in society.

Methodology

To achieve our goals, we first addressed the various barriers faced by blind or partially sighted commuters trying to access information about public transportation. We investigated the accessibility of information about public transportation schedules, arrivals, and departures, focusing on Copenhagen's public transit system. We used a survey and interviews to assess the information needs of people who are blind or partially sighted. Using these data, we identified technologies that may address the needs of the community. To determine potential obstacles to those solutions, we communicated with public transportation companies, such as DSB, Banedanmark, and Movia. We familiarized ourselves with the public transportation system by systematically observing train stations and bus stops. We also corresponded with various technology companies, such as Kontakt.io Beacons and the developers of the Rejseplanen and Afgange mobile phone applications, to identify opportunities for implementing various solutions in Copenhagen's transit system. Considering this information, we determined which solutions were most viable and recommended steps that could be taken to improve information access to public transportation for people in Copenhagen who are blind or partially sighted.

Findings

Through our interviews and our survey, we found three main challenges that our blind and partially sighted research participants faced while accessing information about public transportation. We found that identifying the line and destination of public transportation vehicles can be difficult for those who are blind and partially sighted. We also found that information about delays and schedule changes is frequently inaccessible, and this can cause confusion for blind and partially sighted commuters. Additionally, we found that blind and partially sighted commuters find it difficult to travel without updated information about their locations.

Through our interviews and surveys, we also identified various solutions that blind and partially sighted commuters prefer. All of our survey respondents and interview participants mentioned audio

announcements as being helpful. Right now, audio announcements are used to announce the identity of an S-train as it arrives at the station, the stop or station the transit vehicle is approaching, and announcements are made for major track changes or delays on the platform and in the station. While audio announcements are helpful for blind and partially sighted commuters, our observations allowed us to learn about several shortcomings. Audio announcements can be hard to hear—during our observations, we noted that we generally could not hear audio announcements because of the noise from other trains or other commuters. Audio announcements are not consistently available in all modes of public transportation. Based on our observations, the announcements of the next stop or station happen after the vehicle passes that stop or station about 8 percent of the time, and the announcements do not play at all about 2 percent of the time. Additionally, while the S-train announces its line and destination, these announcements are not always consistent. Regional trains and buses do not make these announcements at all.

About half of our research participants used mobile phone applications to both plan and follow their routes. However, mobile phone applications are sometimes difficult to learn and cumbersome to use. One of our interview subjects described how difficult it can be to hold a mobile phone, a white cane, or other belongings while navigating through a train station. Even when our research participants used mobile phone applications, they found that the features of the applications are not always fully accessible to people who are blind and partially sighted. However, we also found that the application developers at Rejseplanen and Afgange were willing to make improvements to their applications' accessibility.

From our interviews with various public transportation companies, we learned about the roles these companies play in the public transit system, how information is distributed through the public transit system, and what these companies do to provide information about schedule irregularities. DSB controls the trains themselves, Banedanmark controls the train tracks, and Movia controls the bus system. The entire Metro system is controlled by the Metro company, but since most of our blind or partially sighted research participants lauded the accessibility of information in the Metro system, we focused our research on the bus and train systems.

Normally, information is directly transmitted from the GPS systems on buses and trains to control centers, then the information on boards and signs in bus stops and train stations is automatically updated. Public transportation companies also automatically send their information to Rejseplanen, which then sends the information to applications like DSB, Moovit, and Afgange. If there are any extenuating circumstances that would cause a schedule change or a track change in the train system,

Banedanmark manually announces these changes from the control center. In such circumstances, the control center employees manually change the information on boards and signs at bus stops and in train stations. The information is then distributed to Rejseplanen, and then subsequently to the other mobile phone applications and websites that use Rejseplanen's services.

Through our background research, we learned that Bluetooth Low Energy Beacon Technology was being used by the Tandem Association in Bucharest, Romania to make the public transportation system there more accessible. We interviewed a representative of the Tandem Association, the advocacy organization that orchestrated this project, which they call Smart Public Transportation. With the help of Vodafone and other private sponsors, the Tandem Association deployed over 3,000 beacons throughout the public transit system and launched a complementary app. Beacons placed on buses could alert app users standing at bus stops which bus is approaching. While app users are on the bus, the app notifies users of their current location as the bus passes beacons at bus stops. We contacted a beacon company in Poland called Kontakt.io to learn more about the pricing of beacons in such a large project. We found that beacons are generally around 12-13 USD (74-80 DKK), with an additional cost for software integration and maintenance. In our interview with Movia, we learned that Movia is currently investigating potential uses for beacons in Copenhagen's bus network.

Recommendations

Based on our findings, we compiled a list of recommendations. We provided the Danish Association of the Blind with a list of the company representatives we corresponded with throughout this project. The Danish Association of the Blind can maintain a dialogue with these representatives and move forward with implementing our recommendations.

We recommend that the Danish Association of the Blind work with the Tandem Association and Movia to consider a Bluetooth Low Energy beacon system for use in Copenhagen's bus network.

The use of BLE beacons in buses and bus stops could combat the problem of identifying buses. In Bucharest, the Tandem Association successfully implemented a BLE beacon system and a corresponding mobile phone application through their Smart Public Transportation project. Additionally, Movia is currently in the early stages of evaluating the use of beacons in the Copenhagen bus system. The Danish Association of the Blind could correspond with both the Tandem Association and Movia to gain insight into the process of implementing a BLE beacon system. The Tandem Association could give the Danish Association of the Blind a more comprehensive idea of how they were able to receive sponsorship for this project. The Tandem Association could also discuss their vision for the future of their Smart Public Transportation project, including upgrades they hope to make to add audio features to beacons.

We recommend further research into the feasibility of a system for external announcements for buses. Should Movia not move forward with the implementation of beacons for identifying buses and bus stops, external announcements would aid blind and partially sighted commuters in identifying the correct lines and destinations of buses. Implementing loudspeakers on buses to make external announcements could assist with the ambiguity of bus identity. However, this could prove extremely expensive and slow to implement, because Movia contracts bus operation out to various companies and these contracts start and end at varying times. Loudspeakers could also be installed at bus stops to aid in identifying the line and destination of buses. However, our interviewee from Movia believes that these loudspeaker announcements would be poorly received by residents in the surrounding areas, and Movia has never tested or implemented announcements outside buses. Despite these challenges, we believe that audio announcements are an ideal solution for commuters who prefer to not use mobile phone applications, so they are a solution that cannot be disregarded. Therefore, we recommend further research be done to see if various announcement systems are feasible in the Copenhagen transit system. This research should consider possibilities besides automated system-wide announcements, such as on-demand announcements played at the push of a button, or announcements only at the most-problematic bus terminals.

We recommend that Movia require buses to pull up to their designated signposts. About half of our interviewees said that they have trouble identifying the right bus at bus stops. When multiple buses stop in a line, the buses behind the first usually will not pull up to the signpost before leaving, which usually does not allow blind and partially sighted individuals time to identify the bus lines and destinations. We recognize that Movia does not directly control bus driver training, but Movia does control their contracts. Therefore, we recommend Movia update their contract standards to ensure all bus drivers always stop at every signpost when there are passengers at the signpost.

We recommend that DSB and Banedanmark improve their audio announcements. We recommend that announcements on train platforms and in train stations be repeated. Banedanmark controls the platform and station announcements for the regional trains and DSB controls the platform announcements for the S-trains. During our observations of Nørreport and central station platforms, we observed that when we could not hear announcements, it was because the announcements were drowned out by the noise from other trains or other commuters. Therefore, we recommend that Banedanmark and DSB repeat their announcements of track changes and delays twice on platforms. Additionally, we noticed during our observations at Nørreport and Central Station that the S-trains announce their identity as they arrive at the station, but regional trains do not. Therefore, we also

recommend that DSB ensure that all of their trains announce their identities as they arrive at the station.

We recommend DSB, Rejseplanen, and Afgange’s developers take steps to improve the accessibility of their applications. Oftentimes applications are not designed with accessibility in mind, which can leave the information they present unreadable by screen readers. Rejseplanen and DSB, two of the applications most-used by our research participants, have significant accessibility problems. We recommend that they take steps to improve their applications’ accessibility. Rejseplanen and DSB should comprehensively evaluate their applications’ current accessibility to determine what they need to change. Currently, Rejseplanen is working with an accessibility consulting firm, Diversa, to increase the accessibility of their website. Consulting firms like Diversa can be extremely helpful when improving the accessibility of mobile phone applications, but Afgange and other independently-developed applications may not have the funds to hire consulting firms to increase accessibility. Therefore, we recommend the developers of Afgange and other independently-developed apps work with the Danish Association of the Blind to fix their accessibility problems.

From our focus group and interviews, we found that five of our blind and partially sighted research participants do not use mobile phone applications because they have not learned how to use them. As of right now, blind and partially sighted commuters can navigate through public transportation without the use of mobile phone applications. However, DSB is moving towards a ticketless system, which would rely heavily on mobile phone applications. Therefore, we recommend that the Danish Association of the Blind work with the Institute for the Blind and Partially Sighted to develop and implement a curriculum teaching people who are blind or partially sighted to use relevant applications as these applications become more accessible.

Acknowledgements

Our team would like to thank the following individuals and organizations for their contributions to and influence on the outcome and success of our project.

Our faculty advisors, Professor Holly Ault and Professor Constance Clark, for their continual guidance and support throughout our project, during the preparation period and our time in Denmark.

Our sponsors, John Heilbrunn and Jesper Holten, for their extensive support, guidance, and availability during our time working with Danish Association of the Blind and for their assistance on making this paper and project fully accessible for blind and partially sighted readers.

Danish Association of the Blind and Institute for the Blind and Partially Sighted staff members, for welcoming us into their workspace, for their encouragement, and their effort to provide us with more contacts for our research.

Our blind and partially sighted research participants, for their willingness to share their opinions and experiences.

Our stakeholder representative research participants, for their investment in the success of our project and continual correspondence.

Worcester Polytechnic Institute's research librarians for helping us make correct citations.

Our team would like to thank **Worcester Polytechnic Institute** for providing us with this opportunity to travel and extend our project experience.

This project would not have been possible without the assistance and participation of those mentioned above.

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Chapter 1: Introduction

The United Nations' Universal Declaration of Human Rights (1948) affirms that all people have a right to participate in society, but people who are blind or partially sighted are often faced with obstacles that obstruct that right (American Foundation for the Blind, n.d.; Blind find difficulties accessing public transport, 1999; Demmitt, 2014). One important obstacle is the limited accommodations that are available for public transportation. People who are blind or partially sighted are unable to operate vehicles and must rely on public transportation to access much of society independently (Casas, 2007). The inaccessibility of public transportation exacerbates the social exclusion and inequality faced by people who are blind or partially sighted (Kenyon, Lyons, & Rafferty, 2002).

Generally, blind and partially sighted commuters do not have equal access to information regarding public transportation, including details about arrivals, departures, and schedule irregularities. People who are blind or partially sighted often have to rely on audio announcements, specialized technologies, mobile phone applications, or advice from other commuters to get up-to-date information regarding public transportation (American Foundation for the Blind, n.d.). While these solutions can be somewhat effective information aids for blind and partially sighted commuters, they have their drawbacks. Audio announcements can be difficult to hear, and it can become complicated for blind and partially sighted commuters to listen to both audio announcements and directions from their mobile phone applications while also navigating the public transit system (Bennett, 2014). Specialized technologies need to be implemented throughout the entire public transit system to work effectively, requiring cooperation across the public transit infrastructure (Noor, Ismail, & Saaid, 2009). Mobile phone applications can be difficult for blind or partially sighted commuters to learn how to use, and applications can be inconsistent with current schedule changes or irregularities. Additionally, applications that are not designed to be completely accessible can become inaccessible with application updates. Being forced to depend on other commuters deprives the blind or partially sighted commuter of their independence while traveling (Holten & Heilbrunn, personal communication, February 5, 2018).

In order to provide current information regarding public transportation to blind or partially sighted commuters, several countries have made infrastructural improvements. For example, in Great Britain, the Disability Discrimination Act prompted Britain's Royal National Institute of Blind People (RNIB) to pair with React Technologies (Fielding, 2005). The partnership worked to ensure that all entrances, exits, and electronic displays are accessible to the blind or partially sighted. RNIB React's

initiative included a system that allows blind or partially sighted commuters to give feedback, so they can enact changes in the system to ensure that public transportation meets every commuter's needs (Fielding, 2005). Similarly, in San Francisco's Bay Area Rapid Transit (BART) system, blind or partially sighted commuters can submit modification requests and ideas they have that would allow the transit system to better accommodate travelers. BART consistently shows dedication and economic commitment to accessibility by increasing the volume of train announcements and transfer information, making numerous other changes to aid people with physical disabilities (San Francisco Bay Area Rapid Transit District, n.d.-a). Chile's transportation system, Transantiago, is accompanied by a completely accessible mobile phone application, AudioTransantiago, that reads all the transit schedules out loud and can aid the blind or partially sighted person in planning their excursions (Sánchez & Oyarzún, 2011). In Bucharest, the Tandem Association, a nonprofit organization that works to improve the lives of people who are blind and partially sighted, implemented beacons throughout their train stations, bus stops, and inside buses. Beacons are devices that transmit information from a central system to a mobile phone application when the user comes into range. The Tandem Association uses beacons to provide a description of the bus as it arrives at the stop, among other things (Tandem Association, n.d.).

Changing infrastructure and utilizing legislative power may have been effective in ensuring accessibility in other regions, but accommodation strategies have not been implemented in Denmark. This is in part due to the fact that Denmark has not passed any laws to accommodate people with disabilities. Rather than creating a disability act, various organizations in Denmark cooperate with the government through forums discussing how society should develop (Wiederholt, Bendixen, Dybkjær, & Bonfils, 2002). Without solid legal protection and advocacy, the accessibility of public facilities and municipalities is up to those who own or run the specific line of transportation.

Further complicating the matter, the public transportation system in Copenhagen is vast and complex, including several train lines and an extensive bus network (Ministry of Foreign Affairs of Denmark, n.d.). A large number of stations and stops means commuters need to receive a lot of information regarding arrivals, departures, schedule irregularities, and the identity or line of the arriving mode of transportation. Additionally, different aspects of the Danish public transportation system are controlled by different municipalities, and construction and operations are contracted out to different companies (Holten & Heilbrunn, personal communication, February 5, 2018). The use of different operators and subcontractors makes it difficult to track when there are delays or when there is planned construction.

To address the various barriers faced by blind or partially sighted commuters, we investigated the accessibility of information about public transportation schedules, arrivals, and departures, focusing on Copenhagen's public transit system. We used surveys, interviews, and observations to assess the information needs of people who are blind or partially sighted. Using these data, we identified technologies that may address the needs of the community. To determine potential obstacles to those solutions, we communicated with public transportation companies, such as DSB, Banedanmark, and Movia. We also corresponded with various technology companies, like Kontakt Beacons and the developers of the Rejseplanen and Afgange mobile phone applications to identify opportunities for implementing various solutions in Copenhagen's transit system. With this information, decided solutions are most viable and recommend steps that could be taken to improve information access to public transportation for people in Copenhagen who are blind or partially sighted.

Chapter 2: Background

This chapter discusses the motivation and context for our research. First, we provide an overview of the social problems faced by people who are blind or partially sighted, as well as the current state of public transportation in Copenhagen. We then examine various existing solutions to those problems, particularly assistive technologies for navigation and infrastructure-based solutions used around the world.

2.1. Accessibility and Social Exclusion

Danish society highly values social interaction and much of Danish culture revolves around social activities (Russel, 2016). In order to get to social events or jobs, blind and partially sighted individuals are dependent on public transportation since they cannot ride bicycles or drive (Casas, 2007). This dependency, however, is not matched by reasonable accessibility features for blind and partially sighted commuters. Without accessible public transportation, they cannot access social events or work opportunities, and “when social rights are not secured and a population is at a disadvantage, social exclusion occurs” (Casas, 2007). Social exclusion, especially stemming from lack of access to society, means missing a large part of Danish culture.

The problem of social exclusion due to a lack of access to society can be solved by taking measures to make public utilities and services accessible to those who are blind and partially sighted. According to the W3C Web Accessibility Initiative, “the purpose of accessibility is to provide equal access for people with disabilities” (Henry, Abou-Zahra, & Brewer, 2014). In the case of Danish public transportation, people who are blind and partially sighted do not have the same access to information about public transportation, thus public transportation is inaccessible to them. Inaccessibility in public transportation can be attributed to a variety of different factors. Equal access to information about public transportation is the ultimate goal of our project, but we quickly found many barriers to achieving this goal, including the public transit network itself.

2.2. Copenhagen Public Transit Network

The current framework of the Danish public transportation system may act as a barrier to improving accessibility. The transportation network is vast and complex, to match the size and

population of the city. Different parts of transportation infrastructure are controlled by different companies, which complicates the sources of information regarding schedule irregularities. Each company displays and distributes their information in various ways. Because the modes of transportation in Copenhagen are operated by different companies, information about them is not always coordinated effectively.

2.2.1. Description of the System: Buses, Trains, and Metro

The three main forms of public transportation in Copenhagen are buses, trains, and the Metro, covering over 72,000 km of roads and rails. Figure 1 shows the complexity of all the intersecting bus, train and metro lines in Copenhagen. Copenhagen's three modes of public transit each include multiple lines, and each mode of transit is operated by a different company independently from the other modes of transit (Ministry of Foreign Affairs of Denmark, n.d.).

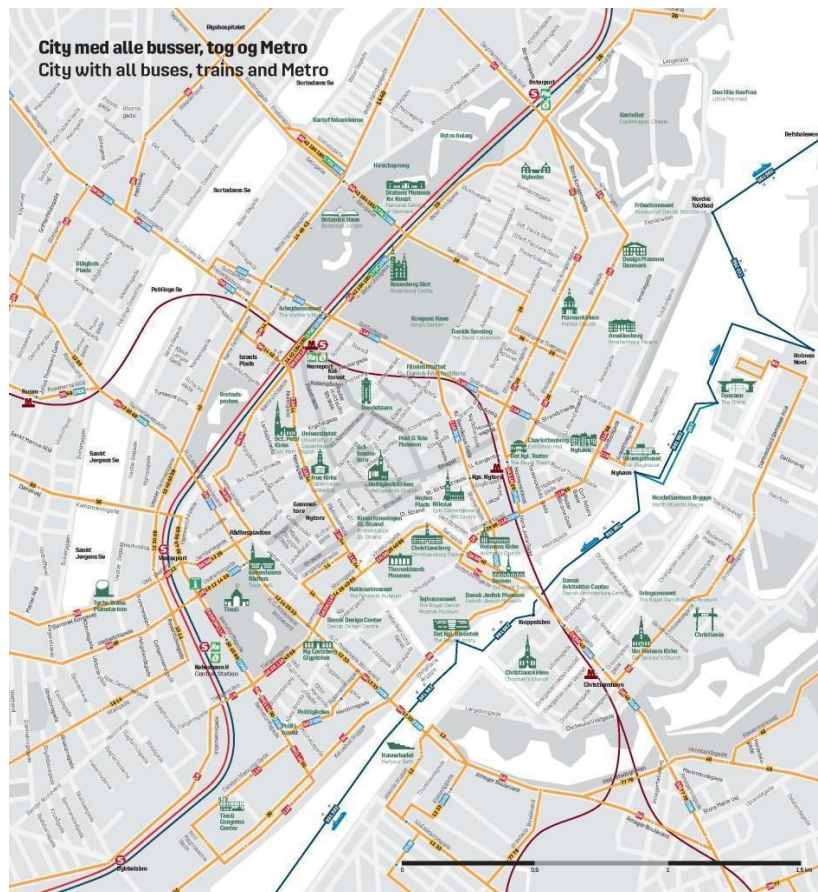


Figure 1. Map of Copenhagen with all bus, train, and metro routes (Din Offentlige Transport, n.d.-a).

Copenhagen's bus system consists of several lines servicing different routes. Regional buses

connect distant locations such as Odense, Aarhus, and Aalborg. In the Copenhagen area, the A-bus stops frequently, the S-bus has fewer stops but services a wider region, and local buses are less frequent but service a smaller area (Mcomish & Norman, 2014).

Copenhagen has two train systems that service different areas: the regional train and the S-train (commuter rail/rapid transit). The S-train has 84 stations in the city and the suburbs, averaging about 360,000 travelers every day with seven lines that arrive at different time increments. See Appendix 2.1 for a map of the S-train, highlighting the multitude of stations that serve more than one line. Regional trains run from the inner parts of Copenhagen to the outskirts of the city, around Denmark, extending beyond the lines of the S-train (Mcomish & Norman, 2014). See Appendix 2.2 for a map of the train lines as they extend beyond Copenhagen.

The Copenhagen Metro services the central parts of the city. It has 22 stations, and a total of one million people using the Metro every week (Ministry of Foreign Affairs of Denmark, n.d.). Currently, construction is underway to extend the Metro to a city ring line, which is projected to be completed in July of 2019. This upgrade will include 17 new stations in central Copenhagen (Metroselskabet, n.d.-a), and provides an opportunity to improve accessibility. See Appendix 2.3.1 and Appendix 2.3.2 for maps of the current and planned metro systems in Copenhagen. The Copenhagen Metro runs all hours of the day, every day of the week (Metroselskabet, n.d.-a). Unlike the buses and trains, the Metro is fully automated and normally operates without human input (Metroselskabet, n.d.-a).

Considering all of the public transit lines, people who are blind or partially sighted need updated information in order to reach their destinations. When a bus or train arrives at a station, commuters need to know both the identity and destination of the vehicle. Currently, information regarding schedules and routes is available in stations and on platforms through electronic display boards. Audio announcements are present inside of most buses, in the Metro stations, and on S-train platforms. However, most up-to-date and detailed information regarding schedule irregularities is primarily available through visual displays. If a blind or partially sighted commuter cannot read the schedule displayed in the station, hear the audio announcements, or access updated information regarding the vehicle's arrival, they could board the wrong vehicle and end up in an unfamiliar and potentially dangerous environment.

2.2.2. Administration of Copenhagen's Public Transportation

Public transit in Copenhagen is controlled by the Ministry of Transport, Building, and Housing. The Ministry oversees the system and regulates many of the companies that operate different parts of

the system (Transport-, Bygnings- og Boligministeriet, 2017; Transportministeriet, n.d.). One of those companies is DSB, the company that operates the S-train and regional trains. DSB operates the ticket booths and sets the regular schedule for the trains. Another company under the Ministry's control is Banedanmark, which regulates the train tracks. DSB and Banedanmark are separate companies, yet share the operation of the same system (DSB, n.d.-a). There is a fine line between which aspects are controlled by which company, but Banedanmark and DSB work well together to control the train tracks and stations simultaneously, collaborating to regulate traffic on the tracks and control the platforms at each station (European Commission, n.d.). Movia operates similarly to DSB—Movia sets the regular schedule for buses across Zealand and oversees contracts with bus suppliers and operators (Movia, n.d.).

Accessing up-to-date information in such a complex system can be difficult. Departures and arrivals are typically displayed on signs and digital displays, which are already inaccessible to blind or partially sighted travelers. This difficulty is compounded by changes in scheduled commuter traffic throughout the day. All of these factors make it difficult for those who are blind or partially sighted to get updated information about schedule irregularities. Getting updates regarding public transport can be challenging for blind or partially sighted commuters, as many updates are visually displayed on schedule boards or announced over loudspeakers, and can be difficult to hear during rush hours.

2.3. Accessibility Policy and Advocacy

Worldwide, various standards regulate public services and internet platforms to provide a framework in which these services are accessible to all; but countries are not required to comply with these voluntary standards. Similarly, instead of being regulated by strong legislation, the accessibility of information in Denmark is governed by a more general parliamentary resolution calling for the fair treatment of people with disabilities. Advocacy organizations, such as the Danish Association of the Blind, lobby for fair treatment of people with disabilities.

2.3.1. Worldwide Standards

Worldwide, there is motivation to push for equal rights for people with disabilities. In 2006, the UN adopted the Convention on the Rights of Persons with Disabilities (CRPD), a treaty aiming “to promote, protect and ensure the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities” (CRPD, 2006, art. 1, para. 1). The CRPD provides broad

definitions for disabilities and clarifies areas where accommodations are needed to allow people with disabilities to exercise their rights (United Nations, n.d.). The CRPD has been ratified by 177 countries and regional integration organizations, including Denmark and the European Union (United Nations, n.d.).

One international organization working to implement the CRPD is the European Association of Service Providers for Persons with Disabilities (EASPD). Over 80 million people in Europe live with a disability, and the EASPD operates on the principles of “openness, participation, accountability, effectiveness, and coherence” (EASPD, n.d.-a, Our Principles section) to allow them all to be included in European society. The EASPD’s objectives include implementation of the CRPD’s recommendations, user-centered services, and fair working conditions (EASPD, n.d.-a). Although not specific to Denmark, the EASPD works to advance the EU’s policy regarding people with disabilities. The EASPD cooperates with several EU networks, political institutions, universities, and organizations, to develop project ideas and propagate the positive outcomes of those projects (EASPD, n.d.-b).

A standard relevant to public transportation in the European Union, in particular, is the “technical specification for interoperability” regarding accessibility for persons with disabilities (Commission Regulation (EU) No 1300/2014). This specification was written by the European Railway Agency (now the European Union Agency for Railways) and outlines requirements for the international rail networks in Europe. For example, train tracks cannot be more than a meter below the platform, a regulation that was put in place so that if a commuter with a physical disability accidentally fell on the tracks they could easily get up from the tracks. DSB, the Danish national railway company, ensures that the Danish rail networks comply with these standards, though only trains and stations that service international lines have to comply.

The European Union also requires that websites comply with accessibility standards. The European Union recommends compliance with Web Content Accessibility Guidelines (WCAG) 2.0, a widely recognized list of guidelines for accessibility written by the World Wide Web Consortium (W3C). According to the W3C website, WCAG provides guidelines that all organizations, government agencies, and educational institutions should follow. Additionally, anyone can use WCAG as a guide for web accessibility. The WCAG guidelines include suggestions for labeling and methods to improve screen readability. Following these standards increases website accessibility (World Wide Web Consortium, 2017).

If the Proposal for Public Procurement Websites and Mobile Applications, a proposed Danish bill meant to implement a European Parliament directive, is passed, all public sector websites throughout

Denmark will need to comply with WCAG guidelines by September 2019 (Folketing [Danish Parliament], 2018). If the public sector website has any inaccessible features, the website will need to include a web page detailing the areas in which accessibility is lacking and listing the reasons these accessibility features have not been fixed. However, this bill does not define any financial or administrative consequences enforcing compliance (L 126, 2018).

2.3.2. Other Countries' Accessibility Policies

Many countries have created their own accessibility policies to create an equal society. The United States enforces country-wide accessibility with the Americans with Disabilities Act of 1990 (ADA). The ADA specifies requirements that must be met by public and private employers, organizations, and services. These requirements are enforced by various departments of the federal government (Americans with Disabilities Act, 1990; United States Department of Justice, 2013).

Similarly, Australia has the Disability Discrimination Act 1992 (DDA), which obligates that employers in Australia must take measures to prevent discrimination against people with disabilities (Australian Human Rights Commission, n.d.). The DDA also requires that all Australian Government agencies make their information and services accessible. To achieve this, the Australian Government website is compliant with the first level of WCAG 2.0 and is in the process of becoming compliant with the second level (Australian Government, n.d.). Any refusal to make website information completely accessible to someone with a disability is viewed as discrimination (Australian Government, n.d.).

Sweden, a nearby Scandinavian country, has a strong disability policy. Sweden firmly believes that tearing down barriers to people's participation in society "is a matter of equality and justice" (Government Offices of Sweden, 2015, People with disabilities section). Sweden is invested in improving the accessibility of the justice system, transportation, IT, housing, funding for job hunting, etc. The Swedish Government has worked towards making bus and tram stops more accessible while reviewing The Disability and Public Transportation Act (Government Offices of Sweden, n.d.).

The European Union has a disability strategy (Publications Office of the European Union, 2015) that follows the Convention on the Right of People with Disabilities. There are eight areas of priority that make up these guidelines, including accessibility, equality, participation, employment, education and training, health, external action and social protection. In 2015, the European Parliament adopted the proposal for the European Accessibility Act (Lecerf, 2017). The Act would define accessibility requirements for products and services and would clarify existing European law regarding accessibility. The Parliament has voted on this act, but has yet to move forward towards adopting the European

Accessibility Act (Lecerf, 2017). A legislation such as this may create a framework for accessibility standards in countries such as Denmark that do not have strict accessibility laws.

2.3.3. Danish Accessibility Policy

Denmark has a different perspective on disability laws than the strict legislation found in many other countries, and this must be taken into account when considering possible solutions. Rather than having separate laws to accommodate people with disabilities, Denmark's national government provides more general requirements, allowing local governments to establish their own levels of accommodation (Wiederholt, Bendixen, Dybkjær, & Bonfils, 2002).

When the Americans with Disabilities Act was passed in the United States, Denmark briefly discussed the possibility of passing similar legislation. According to Wiederholt et al. (2002), it gained little support, both in the government and among advocacy organizations because Danish society prizes the cooperative atmosphere surrounding its politics. Wiederholt et al. claim lawmakers and advocacy groups were concerned that introducing laws that give certain people special treatment would cause a divide in society. Instead of passing a law, the Danish Parliament (Folketing) passed a resolution, at the urging of the Danish Disability Council, calling for the country to treat people with disabilities fairly. In particular, they asked both public and private organizations to "create possibilities for expedient solutions in consideration of disabled citizens' needs". At all levels, various organizations cooperate with the government through committees and less formal contact to help determine how society should develop, including the implementation of new accommodations (Wiederholt, Bendixen, Dybkjær, & Bonfils, 2002).

2.3.4. Advocacy for People who are Blind or Partially Sighted in Denmark

Much of the general population worldwide do not understand the difficulties faced by people who are blind or partially sighted (Iowa Department for the Blind, n.d.) and Denmark is no exception. People who are blind or partially sighted make up about 3% of the population in Europe (Pascolini & Mariotti, 2011), so their wants and needs may not be considered by much of society (Holten & Heilbrunn, personal communication, February 26, 2018). Additionally, some accommodations made to public services, such as loud audio announcements or loud clicking noises made by ticket stand indicators, can be seen as disruptive to the general public, making changes difficult to implement and maintain (Holten & Heilbrunn, personal communication, February 5, 2018). As a result, people who are

blind or partially sighted can feel underrepresented, necessitating further efforts by advocacy organizations.

The Danish Association of the Blind (Dansk Blindesamfund; DAB) is an organization that supports people who are blind or partially sighted. The association is led primarily by people who have 10 percent or less vision, and they represent the blind and partially sighted population in Denmark. The main goal of the DAB is to take care of the interests of the blind and partially sighted people and to work towards an equal society (Dansk Blindesamfund, 2009). The DAB and other advocacy groups support and empower the blind and partially sighted community, trying to create a society that is inclusive of all.

The Danish government does not legislate equal opportunity, but the cooperative atmosphere around Danish policy attempts to give underrepresented populations more input in the government's policy creation process (Wiederholt, Bendixen, Dybkjær, & Bonfils, 2002). For example, the Danish Association of the Blind meets with DSB twice a year to provide their feedback on the accessibility of the railways. The opportunity to have direct contact with Danish transportation companies can be very beneficial in pushing for changes to make the system more accessible.

2.4. Advocacy and Policy in Action

Around the world, governments and advocacy organizations have made great strides towards improving accessibility in public transportation. Overarching disability legislation forces accommodations throughout public services. The best user-centered accommodations result from cooperation between government and advocacy organizations.

2.4.1. London Transportation: RNIB REACT

An example of a policy change and an advocacy organization working to improve information accessibility can be found in London. Various factors can make accommodating disabilities difficult, but advocacy organizations have been able to improve accessibility by cooperating with other organizations. After the United Kingdom's Disability Discrimination Act was passed in 1995, the Royal National Institute of Blind People (RNIB) partnered with REACT technologies to ensure accessibility in London's public transportation system in a collaboration called RNIB REACT (Fielding, 2005).

RNIB REACT focuses on making all information regarding public transportation as accessible as possible. It can be difficult to plan a trip without knowing all of the information about transportation, and for those who are disabled, "transport is the largest concern" (Clayton, Parkin, & Billington, 2017, p.

453). The React System uses trigger and fob technology to relay real-time information to users. The triggering fobs used in the React System are small devices with only two buttons that are small enough to carry in a pocket or in hand. For this system to work, commuters travel with either a triggering fob or the React System's mobile phone application. Signs at bus stops and train or tram stations are fitted with trigger boards that allow them to detect the signals generated by the fobs and phones running the application (REACT Technologies Limited, n.d.). When users with a fob or the application approach these signs, the signs announce their location. Then, when the user presses a button on the fob or application, the signs provide additional information, such as upcoming arrivals at the stop (REACT Technologies Limited, n.d.).

2.4.2. Bay Area Rapid Transit Accessibility Services

Bay Area Rapid Transit (BART) is a system that was constructed in the 1960s in the San Francisco Bay area to prevent congestion during prime travel times on the Bay Bridge. The basic idea was to create an underwater "tube" for high-speed, automatic electric trains (San Francisco Bay Area Rapid Transit District, 2018, n.d.-b). BART is dedicated to complying with ADA regulations and the State of California accessibility requirements. Due to this strong passion to assist persons with a variety of disabilities, BART offers services to travelers who are blind, partially sighted, or physically disabled (San Francisco Bay Area Rapid Transit District, n.d.-a).

Accessibility services offered for travelers who are blind or partially sighted span from additional tactile signs to courtesy phones. When adding accessible features, the creators of BART considered the process of arriving at a train station, getting on the train, waiting for the next stop, and then getting off the train safely. Train operators announce the name of the approaching station as well as transfer information. Accessible features such as these in the BART system help blind or partially sighted commuters obtain information about their trip. Service animals are allowed to accompany the traveler as well (San Francisco Bay Area Rapid Transit District, n.d.-a). BART is a great example of a transportation system that has successfully implemented accessible features. BART is one of the many examples throughout the world that combine dedication and economic commitment to creating a public transportation system inclusive to all.

2.5. Information Aids for the Blind and Partially Sighted

Several technologies have been developed and applied to improve information accessibility. Several of these are discussed in the following sections. Location-indicating systems are a class of technology that has been created for people who are blind and partially sighted. Bluetooth Low Energy beacons and Radio Frequency Identification (RFID) systems can help people who are blind or partially sighted use public transportation systems by indicating the locations of important elements of the system. These technologies, paired with the use of mobile phone applications, can assist blind or partially sighted commuters in identifying buses or trains. Technologies such as these do not just provide the user with location aids, they help the commuter access the information that is provided by these apps.

2.5.1. Bluetooth Low Energy Beacon Technology

Bluetooth Low Energy (BLE) beacon technology is relatively new but has already been applied to public transportation accessibility (Supeala, 2015). Using BLE, mobile phone applications can interface with external devices (“beacons”) to generate and distribute location information. Beacon-based mobile phone applications receive location information transmitted by the beacons, small computers with Bluetooth transmitters. The applications use this information to determine the user’s location relative to the beacons. This information can also include the direction the user is facing, an unprecedented detail for a mobile navigation technology that can allow the user to navigate indoors. In addition to stationary beacons, devices such as smartphones may also transmit signals, allowing information about a user’s position to be included in navigation. Besides the benefits of such detailed information, Bluetooth Low Energy allows data to be transmitted at a minimal cost (Newman, 2014). Together, the low cost and high potential accuracy of BLE beacon technology make it an excellent candidate for communicating information to people who are blind and partially sighted.

The Tandem Association, a Romanian advocacy organization, has implemented a beacon-based system in Bucharest, Romania (Tandem Association, n.d.). As part of their Smart Public Transport project (SPT), a fleet of buses and stations were outfitted with BLE devices (Vodafone, 2017). These beacons continuously transmit identifying signals, which can be received by smartphones. Blind or partially sighted commuters can use applications to plan their route, and their phone will alert them when their bus is approaching (Tandem Association, n.d.). SPT is a pioneer of BLE beacon technology in public transportation and demonstrates how beacons can be used to share crucial information with

commuters.

2.5.2. Radio Frequency Identification Systems

Radio Frequency Identification (RFID) systems, the wireless equivalent to a bar code system, use wireless radio frequency transmissions to identify a specific object, item, or person. RFID tags and sensors are relatively cheap and easy to use, making them ideal for a variety of applications. The RFID tag or transponder responds to the reader's electromagnetic signal, identifying a specific object, item, or person. An RFID device reads tag data and compares it to an external database, then relays the message to a reader that can read the data aloud. RFID systems vary in both range and frequency (Noor, Ismail, & Saaid, 2009).

Noor, Ismail, and Saaid's study (2009) on RFID explored the feasibility of using RFID tags to aid people who are blind or partially sighted in gaining information about the public bus system. The study looked into what information blind and partially sighted individuals lack when using the bus systems. Generally, those who are blind and partially sighted can find it difficult to determine the origin of the bus, the bus's destination, and the identity of the bus. Noor et al. also looked into how powerful the tag needed to be in order for a reader inside a white cane to read it from a safe distance (Noor, Ismail, & Saaid, 2009). The study gave insight into how an RFID system could be effective to provide more information about public transit for those who are blind or partially sighted. However, there were no pilot studies done, nor any actions taken to implement an RFID system in Malaysia where this study was conducted.

2.5.3. Braille Signs and Tactile Indication

According to the American Federation of the Blind, braille and tactile signage throughout public transportation can greatly increase the accessibility of information. Public transit systems can make their ticket vending machines accessible with braille and large-print markings, along with audible output devices. Additionally, public transport systems can make braille and tactile information available throughout the system at consistent locations such as entrances and platforms (Accessible Mass Transit, 2018). Throughout the BART system, braille and tactile signs are present at station entrances, restrooms, station exits, the beginning of each staircase, emergency exits, elevators, escalators and periodically along the station platforms. There are several tactile indicators throughout the system, which can guide a commuter to their platform. Similarly, Braille Literacy Canada, an organization

dedicated to promoting the use of braille, has published guidelines for braille and tactile signs (Braille Literacy Canada, 2016). The guidelines specify letter size and spacing, as well as preferred sans serif fonts that should be used for tactile wording. These guidelines suggest plain, contrasting backgrounds on signs that use universally accepted pictograms (Braille Literacy Canada, 2016).

2.5.4. Mobile phone and website applications

People who are blind or partially sighted utilize websites and mobile phone applications to gain information about public transportation. Websites and applications generally present information in a visual, inaccessible format. On iPhones, VoiceOver, the built-in screen reader, can be used to access information displayed on the screen. VoiceOver utilizes simple commands that read the contents of the screen, allow users to navigate the screen and select items on the screen (Chapter 1. Introducing voiceover, 2018). According to the American Federation of the Blind, users generally take a little over a week to become proficient in using VoiceOver and VoiceOver is generally simple to use (Brian M Celusnak, 2016).

Some mobile phone applications are specifically designed to be accessible. An example of an accessible public transportation app is Chile's AudioTransantiago. Chile's public transportation system, called Transantiago, accompanied their new transportation system with an inaccessible application that displays route information and aids users in planning trips. The University of Chile wanted to improve the accessibility of information on Transantiago's app for the blind and partially sighted. People who are blind or partially sighted were originally unable to use the app, as it only displays information graphically. AudioTransantiago was created as an application to present the information in the form of synthesized voices. This app provides text-to-speech conversion and helps the users plan their trips (Sánchez & Oyarzún, 2011).

2.6. Public Transportation Aids for the Blind and Partially Sighted in Denmark

In Denmark's public transportation system, there are several services already in place to aid blind and partially sighted commuters in their travels. Afgange and Rejesplanen are two web-based solutions that are useful for journey planning and receiving updated information about public transit. Public transportation companies also provide their own services to aid blind and partially sighted commuters, including complimentary personal assistants, door to door bus service, and hotline

telephone and SMS services. All of Denmark's existing solutions can be useful to blind or partially sighted commuters, but we found that they have their shortcomings.

2.6.1. Web and Mobile Phone Applications for Public Transportation in Denmark

In Denmark, various web and mobile phone applications are useful for navigating public transit. Three of these applications are Rejseplanen (Danish for "journey planner"), the DSB applications, and Afgange (Danish for "departures").

Rejseplanen is one of the most-used transit services in Denmark (Rejseplanen A/S, n.d.-b). The Rejseplanen website and mobile applications allow users to plan their trips using updated transit schedules. DSB provides similar services through its website and mobile applications and allows its users to purchase tickets for their planned journeys. Afgange shows the locations of nearby stations and stops, and it allows users to view upcoming departures from those locations.

All of these applications use up-to-date information provided by Rejseplanen about arrivals, departures, and stations, including service problems such as elevator breakdowns. Rejseplanen gets this information from the transit companies it is owned by (Rejseplanen A/S, n.d.-a) (see Appendix 4.13).

While web and mobile phone applications are not accessibility technologies, they may be usable through screen readers, making them a potentially valuable tool for blind or partially sighted commuters.

2.6.2. Assistive Services

In Denmark, there are assistive services available that allow a person with disabilities to request a guide, who can assist passengers in transferring from train to train (DSB, n.d.-b). Movia has a similar service called Flextrafik where customers can call ahead 24 hours in advance and get picked up at their residence and then dropped off at their destination. These services are helpful but can be inconvenient due to the fact that these services require all trips to be planned in advance.

A service that is accessible to all travelers is the DSB customer service hotline. The hotline lists arrivals and departures at a given station and can assist travelers in buying tickets or requesting other information about DSB's services (DSB, n.d.-c). Any traveler can call the hotline for help, but blind and partially sighted commuters particularly benefit from the audio information (Holten & Heilbrunn, personal communication, February 26, 2018). Similarly, there is an SMS hotline for buses—commuters can send the code for a bus stop, which is printed on the signpost, to the hotline to get updated

schedule information sent to them (Din Offentlige Transport, n.d.-b), messages that can then be read aloud with VoiceOver. However, if a blind or partially sighted commuter wished to use this service, they would have to memorize or ask another commuter for the stop's code, as it is only displayed visually.

2.7. Our Project

Our research focused on providing people who are blind or partially sighted with information about the identity and destination of public transportation vehicles, as well as any delays and route changes that may occur. Although people who are blind or partially sighted can obtain this information via loudspeaker on the platform and mobile devices, these sources are often inconsistent with one another or difficult to access. Travelers that rely on accessible forms of information have limited resources that are currently available to them. Economic constraints and government policies are at the root of this inconsistency; therefore, they are important considerations we took into account as we completed our analysis. We worked alongside advocates for the blind and partially sighted community to generate feasible solutions that satisfy their needs.

Chapter 3: Research Methods

The goal of this project was to investigate the accessibility of public transportation schedules, arrivals, and departures in Copenhagen in order to support the Danish Association of the Blind in addressing the inequalities faced by people who are blind or partially sighted.

In order to achieve our goal, we focused on the following objectives:

1. Assess the information needs of people who are blind or partially sighted regarding public transportation in Copenhagen.
2. Examine the current accessibility of information regarding public transportation for people in Copenhagen who are blind or partially sighted, particularly regarding route information and irregularities in scheduling.
3. Determine what systems might improve the accessibility of information regarding public transportation in Copenhagen for people who are blind or partially sighted.

To accomplish these goals, we gathered information from people who are blind or partially sighted, as well as other stakeholders in the public transportation system. We also investigated potential solutions. Throughout this process, we focused on maintaining a dialogue with people who are blind or partially sighted to ensure that our research is beneficial. The methods we used to carry out our objectives are presented in the following sections.

3.1. Ethical Considerations for Our Project

Ethics are an essential part of social science research, and our team was sure to prioritize moral principles while conducting our project. As our project is centered around people who are blind and partially sighted, we made sure to consider terminology in our survey and interview questions. To ensure that the participants were fully informed about the survey, we included an informed consent form as the first question of the survey and required an affirmative response to submit. Additionally, the survey was completely anonymous.

During interviews, we were careful to treat our subjects ethically and respectfully. To ensure that our subjects were able to give informed consent to participate in an interview, we created an informed consent form that described the project and the interview procedures, emphasizing that the entire process is voluntary. As included in our informed consent form, we were sure to remind the

participant that they were welcome to leave at any point they felt necessary. We requested that our sponsor would convey the same assurances to anybody that they reached out to on our behalf. Additionally, we took measures to ensure the confidentiality of our interview subjects: we removed all identifying information from our records and referred to participants exclusively by code outside of their respective interviews. Each interview was administered by one member of our team. With permission from the interviewee, the interview was audio recorded and transcribed at a later time. To ensure confidentiality of our focus group participants, the two note takers assigned code names for each participant prior to the session.

Our team was sure to practice good ethics and research processes in every aspect of our research. Above all, we treated our participants with the utmost respect in all parts of our research.

3.2 Assessing the Information Needs of the Blind and Partially Sighted Community

We dedicated the initial steps in our research to determine the needs of people who are blind or partially sighted regarding the public transportation system in Copenhagen. We surveyed and interviewed people who are blind or partially sighted to build an understanding of their needs relating to the accessibility of information in public transportation. We analyzed the gathered data to determine the underlying problems that we needed to address. This analysis allowed us to determine what types of solutions to search for and provided the context in which to evaluate potential solutions.

This portion of our research aimed to answer these questions:

- How do people who are blind or partially sighted currently get information about public transportation?
- What aspects of the current public transportation system in Copenhagen cause difficulties for people who are blind or partially sighted?
- What methods of information distribution in the current public transit system do people who are blind and partially sighted find helpful?
- What methods of information distribution in the current public transit system are not useful for people who are blind and partially sighted?
- What types of changes would people who are blind or partially sighted like to see in how information is distributed in the public transit system?

- What types of information aids are people who are blind or partially sighted willing or able to use? (e.g. audio announcements or mobile phone applications)
- What types of solutions might address the information needs of the blind or partially sighted community?

Our primary source of information on Copenhagen's community of people who are blind or partially sighted was our sponsor, the Danish Association of the Blind. By consulting with our sponsor, we identified potential research participants in the community.

3.2.1. Survey of the Blind and Partially Sighted Community

In order to build a broad understanding of how the blind and partially sighted community interacts with public transit, we conducted a survey of blind and partially sighted commuters online. To make the survey as accessible as possible, we set up the survey using three online survey services (Google Forms, SurveyMonkey, and Qualtrics) and asked our sponsor which was most accessible. Based on their advice, we distributed our survey via SurveyMonkey—SurveyMonkey has options that make accessible to screen readers (SurveyMonkey, n.d.), and the Danish Association of the Blind (DAB) has used SurveyMonkey successfully before. The Danish translations for the survey were provided by our sponsor. We initially distributed our survey through the DAB's email list consisting of 90 members of the DAB. Our sponsors got feedback about the survey being slightly inaccessible after we received seven responses. We fixed these minor changes before the survey was distributed through the DAB's Facebook page, which had 2,935 followers at the time of posting. Because of the channels we distributed our survey through, our sample was mainly members of the Danish Association of the Blind.

Through our survey, we hoped to gain information about blind and partially sighted commuters' tendencies in the greater Copenhagen area—what modes of transit they generally use, what apps they use to help navigation, and whether or not they ask for assistance while traveling. We also wanted to hear survey respondents' opinions on the current accessibility of the public transit system and accessibility features that were useful to them. We asked ten questions in multiple choice and short response format. We have included our actual questions, in English and in Danish, in Appendix 3.1.

Although we recognize that electronic surveys are subject to multiple types of bias (especially selection biases), we wanted a way to assess the general opinions of members of the Danish Association of the Blind. Since our sample size was relatively small and mainly consisted of members of the Danish Association of the Blind, we used the data to support some of the claims made by our interview

subjects. We also used the survey results to focus our background research and interviews with companies on modes of transport and solutions that were mentioned more often.

3.2.2. In-depth Interviews with Members of the Community

To build a deeper understanding of the challenges faced by people who are blind or partially sighted, we conducted a series of in-depth interviews of members of the blind and partially sighted community. While we used the data gathered by our surveys to understand general trends in the needs of the blind and partially sighted community, these interviews allowed us to better understand the individuals' needs. The interviews of community members helped us see the “human face to [our] research problem” (Mack, Woodsong, MacQueen, Guest, & Namey, 2005, page 29)—the interviews allowed us to engage in a dialogue with members of the blind and partially sighted community and allowed members to express their individual opinions.

We interviewed six employees of the Danish Association of the Blind and one employee of the Danish Institute for the Blind. All of our interview subjects used public transportation regularly to commute to work and other engagements, and all subjects felt relatively comfortable using public transportation. This sample was good for gaining insight into the methods blind and partially sighted commuters use and the problems they regularly face. However, although we reached out to a variety of organizations, we did not interview anyone who did not regularly use public transit or was deterred from using public transit because of its inaccessibility. Thus, our findings are skewed towards problems and solutions that people who regularly commute face, and subsequently our recommendations work to mitigate those problems and implement those solutions.

Our interviews were semi-formal because we wanted them to be conversational rather than a question/response format. Having a less strict interview format allowed us to ask follow up questions. The team member leading the interviews attempted to draw extended responses from the interviewee to gain a comprehensive understanding of the interviewee's opinion on different aspects of public transit. We asked interview subjects about their opinion of the accessibility of public transit as it is right now. We inquired about their tendencies while using public transit—how often they use public transit and where they go using public transport. We then asked about the aspects of public transit that they liked and disliked and any methods they use to aid them in public transit. We also asked interview subjects about what they would change about the transit system. Our interview questions can be found in Appendix 3.2.

After each interview, we transcribed the audio recording and destroyed the recording after validating the accuracy of the transcription. We then read through our transcriptions and categorized the interview responses; the categories were activities interviewees use public transit to attend, feelings about the current accessibility of public transit, problems with public transit, preferred existing solutions, and suggestions for improvement. We analyzed the content of the interviews to identify specific information-related needs and challenges frequently faced by people who are blind or partially sighted in public transportation. As we continued our research, we used the transcribed recordings and interview notes to update our interview questions for our focus group in order to gain different perspectives on points that we did not predict with our initial interview questions. We ultimately used our content analysis of interviews to identify types of solutions that might address those challenges and needs.

3.2.3. Focus Group with Members of the Community

Besides individual interviews, we conducted a focus group to continue to expand our understanding of the wants and needs of people who are blind and partially sighted. The benefit of a focus group is that it allows the participants' responses to build on one another, drawing out nuances that might otherwise be missed (Mack, Woodsong, MacQueen, Guest, & Namey, 2005). The focus group was conducted in a similar manner to the interviews but included multiple participants. Our focus group consisted of both blind and partially sighted students at the Danish Institute for the Blind, all of whom used public transportation regularly. Similar to our interviews, we recognized the skewed sample that this presented—the focus group findings were mainly problems and solutions faced by people who commuted regularly and therefore our recommendations are for this subset of the population.

Three members of our team oversaw the focus group: one moderator and two note-takers. The moderator facilitated conversation by posing questions to the group. We crafted our focus group questions to gain a more specific understanding of the public transit lines and the current solutions in place for blind and partially sighted commuters. We asked about the focus group members' feelings about the accessibility of information about public transit and what the focus group members liked and disliked about the bus, metro, S-train, and regional train systems. We also asked when and how they utilized mobile phone applications. We asked their opinions about audio announcements, braille, and tactile signs inside the stations. We asked them to describe the difference between traveling an unfamiliar route versus a familiar route. Finally, we asked them for suggestions to improve the accessibility of information in public transit. A complete list of our questions is in Appendix 3.3. The

moderator primarily guided the discussion, ensuring that the group did not stray too far from the intended topic of conversation and that the discussion continued to move forward productively. While each focus group was audio recorded, the note takers were present to keep track of key points, making the transcription easier to follow.

After the focus groups, we transcribed our audio recording and destroyed the audio recording after transcribing it. We performed a content analysis similar to the content analysis performed in our interviews. We sorted the focus group answers into categories, including the respondents' feelings about the current accessibility of public transit, preferred means of getting information about public transit, problems focus group members found with the system, mobile phone applications, audio announcements, braille and tactile indicators, and suggestions for improvements to the system. The results from the focus group were used to continue to identify information-related needs and challenges frequently faced by people who are blind or partially sighted in public transportation. We ultimately used our focus group analysis to identify types of solutions that might address those challenges and needs.

3.3. Examining the Accessibility of Information in the Current System

Understanding the needs of people who are blind or partially sighted allowed us to identify solutions with the potential to satisfy those needs. However, selecting technologies that are practical to implement required a closer look at the current accessibility of public transportation information and the systems that support it. In addition to considering how information can be accessed, we investigated solutions that have been previously attempted to understand why different types of solutions were not effective.

This portion of our research aims to help us answer these questions:

- How is information regarding public transit schedules reported to the public?
- What technologies have been considered or implemented to improve the accessibility of information in public transportation?
- If some technologies have been used in the past to improve the accessibility of information, why are they no longer used?
- What other factors prevent these technologies from solving the problems faced by the blind and partially sighted community?

We performed observations to understand how the public transportation system works. We completed these observations to see where the system was lacking, where companies could make improvements, and to witness some of the challenges that the blind and partially sighted commuters face while traveling via public transit. Our observations did have some limitations. We are not blind or partially sighted and therefore we do not know if bus drivers would pay special attention after seeing someone with a white cane or a guide dog. We did our best to observe stations in which there would be a larger presence of the blind and partially sighted population, but even so, we saw very few.

3.3.1. Infrastructure Survey of Stations

For qualitative evidence, we evaluated current accommodations for blind and partially sighted commuters in the busiest stations in the Copenhagen public transit system. We evaluated Copenhagen Central, Nørreport, and Valby stations. We created a detailed protocol to evaluate these stations properly (Appendix 3.4). We started by using a map of the area. We plotted where we stood in the station, which can be seen as the human figure on the maps (Appendix 3.5). Initially, we determined whether there were tactile indicators present in the stations. We noted where the bus or train stopped, whether it was by the post outside for buses, or whether it was aligned with the current tactile door indicators. These qualitative results aided us in determining other problems the blind and partially sighted may face in the stations, and which stations are most problematic.

3.3.2. Observation in Buses and Trains

In order to understand the amount of information that a commuter receives on a bus or a train while in transit, we created a protocol for observing buses and trains. We focused on the presence and content of audio announcements inside the vehicles, and if or when the vehicles announced each stop. The observation protocol for the inside of buses and trains is outlined in Appendix 3.6. The observation protocol specified the length of the observation, where the observer should sit, and which data to note. We recorded the time of any audio announcement and the time at which the bus and train stopped, including stops that were not announced. Our main goal of these observations was to keep track of any audio announcement inconsistencies. Data for the time and content of audio announcements relative to the bus or train route were recorded on data sheets. An example can be found in Appendix 3.7.

3.3.3. Observation of Announcements on Train Platforms

In order to evaluate the quality of audio announcements inside stations, we first outlined an observation protocol to ensure we collected the data in a consistent, organized manner (see Appendix 3.8). For each announcement on the platform, we noted the time and the content of the announcement. In order to keep track of when an audio announcement played relative to the time of a train arriving or departing, our team kept detailed records of audio announcements heard on the platform and in the vehicle. An example of how we recorded these data is in Appendix 3.7. When the bus or train arrived, we noted its identity, time of arrival and departure, the time at which the doors opened and closed, whether there were any audio indicators that the doors were opening, and what track that train was departing from. From these data, we wanted to conclude which stations or modes of transport have announcements that have inconsistent audibility or content.

3.3.4. Observation of Bus Stops

To fully understand how the bus system works in Copenhagen, our team created another set of guidelines in order to observe and obtain as much information as possible. These guidelines are given in Appendix 3.9. We made sure to observe during rush hour, which in our case was around 15:00 and 17:00h. In our observations, we noted the identity of the bus, the time the bus arrived, how many buses came by, how many buses stopped at their designated stop, and how many buses stopped behind another bus at their stop. From our observations, we gained a better understanding of how congested these stops can become, as well as how confusing it can be for someone who is blind or partially sighted to find the correct bus when it does not stop at the designated post.

3.3.4. Evaluation of Mobile Phone Applications

We also evaluated mobile phone applications commonly used by those who are blind or partially sighted. These applications were identified using the results of the survey discussed in Section 3.2.1, and the results of our interviews with members of the blind and partially sighted community. We compared the information available on accessible applications to the information available on applications created for sighted commuters, identifying any information lost when the applications were made accessible. In order to evaluate the accessibility of these mobile phone applications, we met with one of our sponsors and asked him to demonstrate how one would use each app with a screen reader on an iPhone. Our sponsor demonstrated how to use three out of four applications while we observed

and noted which of their features are accessible, and where features began to fail a blind or partially sighted user. The applications we asked our participant to evaluate were Afgang, Rejseplanen, and DSB. These qualifications and features can be found in Appendix 3.10. The qualitative evidence found in our evaluation of applications aided us in identifying the specifications for a useful mobile phone application. Also, we were able to determine which applications or accessible feature improvements we should recommend to the Danish Association of the Blind, as well as the creators and maintainers of these applications.

3.4. Assessing the Roles of Public Transportation Companies

Based on our prior research, we examined different aspects of the transit system that are controlled by a large number of organizations. To understand how these organizations cooperate and what steps they have taken to improve accessibility, we conducted interviews with representatives of companies involved in public transportation.

Before contacting companies, we researched the industry and consulted our sponsor to determine which companies play the most important roles in distributing information to commuters. Based on the information that our sponsors gave us and our background knowledge, we reached out to six companies covering a variety of niches in the industry: DSB, Rejseplanen, Banedanmark, Movia, Midttrafik, and Arriva. To ensure that we interviewed representatives that would be capable of providing us with information about the companies' accessibility policies, our sponsors reached out to their contacts at DSB on our behalf. One of our interviewees from the Danish Association of the Blind (DAB) provided us with a contact at Movia. For the other companies, we contacted them by email or contact forms on their websites. In our initial messages to the companies, we described our research and goals, including the ethical guidelines we follow in our research. The representatives that responded set us up with other representatives that they believed would be able to answer our questions.

When interviewing company representatives, we followed the same protocols outlined in Section 3.1. For company representatives that were open to discussion but unable or unwilling to meet with us in person, we maintained a remote dialogue, via email or telephone. We also maintained remote contact with company representatives after in-person interviews. In these emails, we modified and extended our questions, using the results from the earlier discussion to determine how to gain more information.

Our questions for these company representatives focused on understanding the role that their company plays regarding the distribution information about schedules, routes, or any irregularities. Additionally we wanted to learn about the companies' previous attempts to improve accessibility, and, more importantly, to identify the factors that prevented these attempts from satisfying the needs we identified in the blind and partially sighted community. We also asked about what types of technologies have been considered, but are not in use, to determine what factors prevent their use.

By comparing the information gathered from different companies, we identified common barriers to improving accessibility, and we used those data as we examined different technologies to determine which are most likely to be viable solutions.

3.4.1. DSB

Through prior research and communication with our sponsors, we understood that DSB controls a part of the railway system in Copenhagen. Our sponsor provided us with the information for a representative of DSB who works closely with the DAB and accessibility concerns. Initially, we contacted this representative via email and scheduled an in-person interview. In this interview (see Appendix 3.11 for DSB interview questions), we wanted to learn more about which aspects DSB controls in the public transportation system. We also wanted to understand how updated information in the S- and regional train systems is relayed from the train to the commuters in the station or on the platform. Through our interviews, we gained insight into the aspects of the public transit system that DSB controls, the accommodations that DSB makes, and DSB's policy regarding accessibility. This information helped us analyze the flow of information in the public transportation network and figure out which recommendations would apply best to DSB.

3.4.2. Banedanmark

Through prior research and communication with our sponsors and DSB, we understood that Banedanmark also controls a part of the railway system in Copenhagen. The representatives of DSB that we interviewed shared a contact from Banedanmark that we would be able to talk with. We contacted this representative via email and scheduled an in-person interview and tour. In this interview (see Appendix 3.12 for Banedanmark interview questions), we wanted to learn more about which elements of the transit network are operated by Banedanmark. In particular, we aimed to learn about how Banedanmark handles schedule irregularities and distributes information to travelers. We wanted to

learn about what role Banedanmark has in the audio announcements present inside of trains, stations, and on platforms. This information helped us understand the responsibilities of Banedanmark compared to DSB, and to construct recommendations that apply specifically to Banedanmark.

3.4.3. Movia

Through our background research and interviews with blind and partially sighted commuters, we were able to form questions to ask Movia (see Appendix 3.13 for Movia interview questions). We mainly wanted to know more about the audio announcements inside of buses, so we could address the problems that blind travelers face when using the bus system. We hoped to learn more about the role Movia has in driver training, regulation and timing of audio announcements inside the buses. Also, we asked questions about how Movia distributes updated information to commuters at bus stops and on the bus. Finally, we sought more information for any future projects or technology usage that Movia is considering. These results helped our team cater our recommendations to ensure that Movia would have the potential to implement them.

3.4.4. Midttrafik and Arriva

Our sponsors suggested that we contact Midttrafik, as they have implemented a light rail that accommodates for travelers with disabilities. However, our sponsors did not have a prior contact for Midttrafik, so our team sent an email to Midttrafik's general email that they provide on their website. We corresponded with a contact from Midttrafik via email. In this correspondence, we learned that during the construction of the Aarhus Letbane system, Midttrafik focused on the details regarding accessibility, as this is what they believe mattered most for people with disabilities. Unfortunately, Midttrafik responded very late in our research process, so we were unable to organize an interview to gain more details, and Midttrafik has been excluded from our findings. We also planned to interview a representative of Arriva to gather information about bus operation and its costs, but we received no response to our initial contact.

3.5. Researching Technologies as a Potential Solution

From our interviews with members of the blind and partially sighted community, we learned about mobile phone applications that blind and partially sighted commuters prefer. We reached out to Rejseplanen, the largest journey planning website and mobile phone application in Denmark, to learn

more about how they are working to improve the accessibility of their website and mobile phone application. We also corresponded with the developer of Afgange, a mobile phone app that lists the departures leaving from nearby bus stops or train stations, to learn more about the developer's intentions for the app.

From our interviews with public transportation companies, we learned about the possibility of using beacons in Copenhagen's bus system. We contacted a representative from Kontakt.io Beacons, a beacon company based in Poland. We also reached out to the Tandem Association, an advocacy organization for people who are blind and partially sighted in Bucharest. The Tandem Association has implemented beacons throughout their public transportation system with a large degree of success.

3.5.1. Rejseplanen

We hoped that contacting Rejseplanen would help us understand how information is gathered from companies and distributed to commuters electronically. The DAB was not able to provide our group with a previous contact, so we used Rejseplanen's website helpline to contact a representative. We wanted to learn more about how Rejseplanen receives updated information from several public transportation companies and makes it available on the website and mobile phone application (see Appendix 3.14 for Rejseplanen interview questions). Also, we hoped to gain more information about how Rejseplanen evaluates the accessibility of their website and app. This information helped us evaluate the current steps that Rejseplanen is taking to accommodate people who are blind or partially sighted and how our recommendations may involve this company.

3.5.2. Afgange

We contacted the developer of Afgange through his LinkedIn page. We learned about why the developer created the app, what he did to make the app accessible, and if he would be willing to work with the Danish Association of the Blind to improve the accessibility of the app.

3.5.3. Kontakt.io Contact

While our team was considering solutions that could be successful in Copenhagen's public transportation system, we wanted to consider the cost of beacon technology. To do this, we contacted a salesperson at Kontakt.io, a company that creates and manufactures beacons. Through a series of questions (see Appendix 3.15 for Kontakt.io interview questions), we determined how much it would

cost to implement beacons throughout the city. These results helped us narrow down our recommendation regarding beacon technology.

3.5.4. Royal National Institute of Blind People and React Technologies

We reached out to the Royal National Institute of Blind People (RNIB) in London in an attempt to learn more about RNIB's collaboration with React Technologies in their triggering fob accessibility project. We contacted them through RNIB's hotline on their website. The hotline representative directed us to a representative of React Technologies and the React Technologies website, but all further contact was unsuccessful.

3.5.5. Interview with the Tandem Association

In order to further our understanding of how beacons can be used to make public transportation more accessible, we spoke with a representative of the Tandem Association, a nonprofit organization in Bucharest, Romania that works to improve the lives of people who are blind or partially sighted. The Tandem Association has taken on a massive beacons project that they call Smart Public Transportation. We wanted to know how many beacons were used in the project, how much these beacons cost to implement, who was in charge of maintaining the beacons, how the Tandem Association subsidized the cost of the beacons, and whether the project has been successful. Our questions are listed in Appendix 3.16.

3.6. Developing Recommendations

Through our background research, we identified various solutions that could potentially work well in Copenhagen. In our interviews with blind and partially sighted commuters, we identified solutions that the blind and partially sighted community preferred. We then compiled a list of potential solutions. When we interviewed representatives of companies, we asked about the feasibility of implementing these solutions in Copenhagen's public transportation system. Using our company interview results, we were able to compile our list of recommendations for the Danish Association of the Blind.

Chapter 4. Findings and Analysis

This chapter discusses our findings after conducting our interviews, observations, and surveys. First, we will describe the challenges people who are blind and partially sighted face when using the current public transit system, found from our interviews, observations, and survey. Next, we will describe how schedule change information moves through the public transportation system. Finally, we will discuss information aids that our research participants have found helpful when navigating the current public transportation system, first describing why they prefer those aids, then outlining the shortcomings of these solutions.

4.1. People who are blind or partially sighted face various challenges in the current public transportation system

Using Copenhagen's current public transportation system can be quite challenging for people who are blind or partially sighted. By interviewing and surveying individuals who are blind and partially sighted, we were able to build an understanding of the obstacles they face. Their difficulties mainly stem from the irregularities found throughout the system. The main challenges they face include identifying their desired bus or train, receiving updated information about changes in schedules, and their current location.

4.1.1. Identifying the line and destination of public transportation vehicles can be difficult for those who are blind and partially sighted

We interviewed members of the Danish Association of the Blind and students at the Danish Institute for the Blind. All of our interview subjects used public transportation regularly. About two-thirds of our interviewees stated that one of the biggest challenges they face is identifying the transit vehicle they need to take.

About half of our research participants said they particularly struggled with identifying buses. When a bus pulls up to a stop that services multiple lines, a commuter who is blind or partially sighted must ask another commuter or the bus driver to identify the bus, or they risk getting on the wrong bus. Three of our interviewees noted an additional problem: if the bus they intend to take pulls up behind

another, they may have trouble locating their desired bus, as buses in a line frequently leave without stopping at the signpost. In our observations, we saw a total of seven buses stop behind others, all of which left without stopping a second time at the stops' signpost (see Appendix 4.1).

Similarly, subjects encountered problems with identifying their intended train lines. Finding the correct platform at the train station can be difficult. The departure boards in the station are solely visual, and if this information is not announced, blind and partially sighted commuters will not receive this information. At busy train stations, tracks can service multiple train lines, making it hard to figure out the identity of the train that has just arrived. Half of our interview subjects said that regional trains do not announce their identity or destination (see Appendix 4.2), so they have no way of knowing which train is their desired train. Our observations from the outside of regional trains support this claim, as none of the regional trains we observed from the platform were accompanied by an announcement when they arrived (see Appendix 4.1). One-third of our interview subjects said they memorize the train schedules before they get to the station then closely monitor the time while they are on the platform to ensure they get on the right train. If they are unsure about the identity of the train, they have to ask fellow passengers.

4.1.2. Delays and schedule changes are frequently inaccessible and can cause confusion for partially sighted commuters

Most of our interviewees also mentioned that getting information about changes to schedules were a huge problem. Every train station we have observed, as well as some of the more frequently traveled bus stops, have screens that display when the trains or buses will arrive. At train stations with multiple lines, these signs also display what track the trains will be on. This information is kept up-to-date based on real-time data from Banedanmark and DSB. This updated information allows fully sighted commuters to adjust their plans as necessary. However, this information is not always included in audio announcements, leaving partially sighted commuters unaware of the changes. As one of our interviewees noted, even when the announcements are made, they generally do not contain enough detail for a person who is partially sighted to find the new track. Some of these problems can be solved by planning ahead, as some of our interviewees mentioned. However, making plans does not help with changes that are made after setting out. Blind and partially sighted commuters rely heavily on information aids while they are traveling.

4.1.3. Blind and partially sighted commuters find it difficult to travel without updated information about their location.

One interview subject described how anxious one can feel when they do not know their current location while using a public transportation vehicle. One interview subject travels unfamiliar routes with a companion to mitigate this problem, another interview subject asks the bus driver to alert them when they reach their bus stop, and about half ask fellow passengers for their location. However, all of these solutions do not allow the blind or partially sighted commuter to travel independently. Half of our research participants said they planned ahead using the Rejseplanen website to plot their journey. Planning ahead requires the blind or partially sighted commuter to memorize their route and then count stops while they are on their public transit vehicle to ensure they get off at the correct stop—these actions were described to be mentally taxing by one interview subject. Half of our research participants said they used mobile phone applications, such as Rejseplanen and Moovit, which would read out the stops along the journey. However, one interview subject said that this requires that they pay careful attention to their phone while also paying careful attention to their surroundings, which can be mentally draining.

4.2. Information Flow and Distribution from Companies to Commuters

We found that the flow of information regarding public transportation adds to the complexity of the system as it currently stands. Using information from our interviews with representatives of companies involved in Copenhagen's transit network, we were able to piece together the paths information takes to reach the public. The flow of information in Copenhagen's transit network is shown in Figure 2.

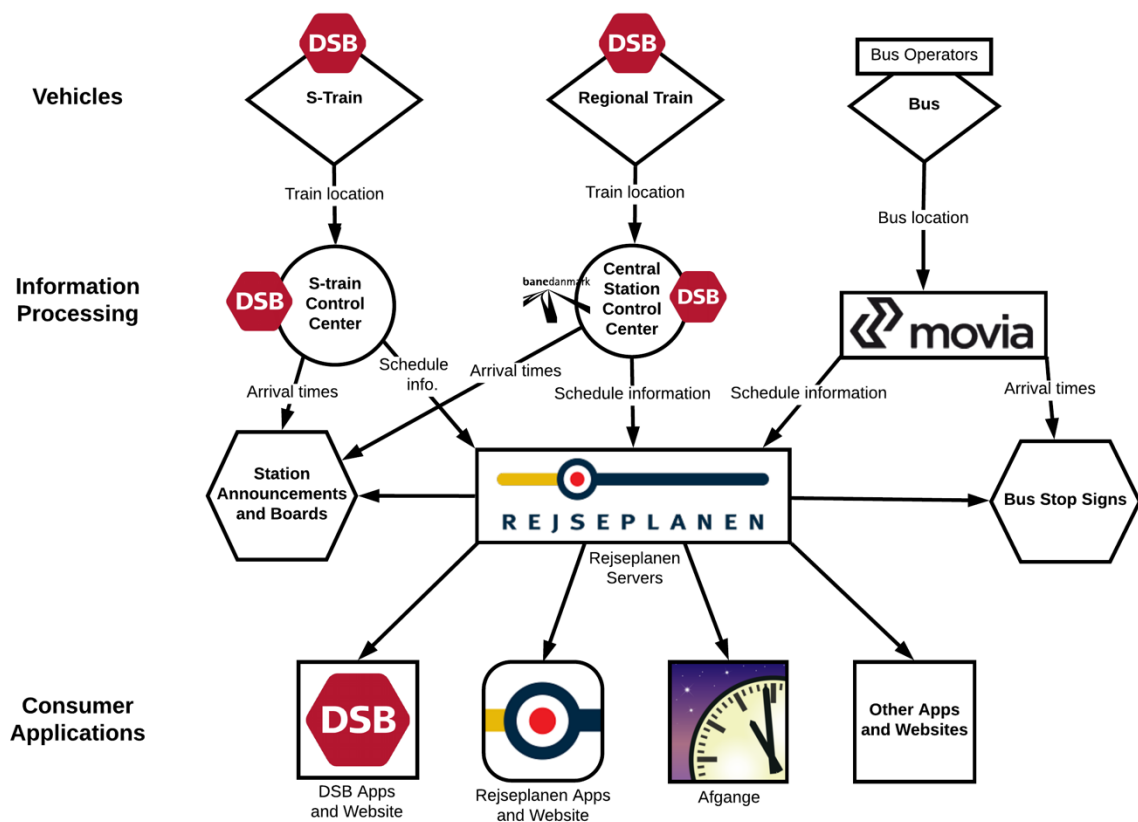


Figure 2. Flowchart of Information in Copenhagen's Transit System (logos used with permission)

DSB and Banedanmark, the two transit companies that control the trains, stations, and tracks in Copenhagen, track the trains using GPS and sensors placed on the rails and trains. Movia, the company that controls the bus network, tracks bus location via GPS receivers in the buses.

Information regarding schedules, delays, and schedules irregularities are sent by these companies to Rejseplanen. Regular schedules are updated daily, and real-time data are provided on a moment-by-moment basis. Since the transit companies share ownership of Rejseplanen (see Appendix 4.4), it is in their best interests to get their updated information for Rejseplanen to display, as quickly as they can.

Rejseplanen makes this data available for use by various transit applications, including Rejseplanen's applications, DSB's applications, and Afgange. This information is also used for the screens in stations that display information for upcoming S-trains and the large screens at some bus stops.

Information about regionals is centrally managed at a control center operated by DSB and Banedanmark. This control center monitors the regional trains for half of Denmark, though it can

manage the entire country's regional train network in emergencies. The center controls the information on regional train schedule boards in stations throughout the region, though most of that information is sent and displayed automatically. In the case of track changes or delays over 10 minutes, the control center operators will manually update the information being displayed. Announcements for the regionals trains, both in the trains and at the stations are managed similarly, with regular operation being announced automatically and special cases being announced manually. During our tour of the control center, we were told that manual announcements are repeated every seven minutes. In our observations of announcements in Central Station, we noted that when regional trains' departure times were announced, many were repeated at intervals under 7 minutes and that most of those trains had an additional announcement train about a minute before they left the station (see Appendix 4.1).

Announcements in the S-train system is managed from a separate control center operated by DSB. Unfortunately, we did not have the opportunity to visit the S-train control center. However, during our tour of the regional train control center, we learned that the S-train control center controls the announcements for the S-trains throughout the network, presumably in a similar manner.

4.3. Audio Announcements Help Commuters Access Information but are Inconsistent and can be Difficult to Hear

4.3.1. Audio announcements help commuters find their transport

Every single one of our interviewees mentioned audio announcements as a helpful feature of the transit system. Audio announcements at stations can help people who are blind and partially sighted find their trains and communicate information about delays and track changes. In trains, announcements can tell them which stop is next.

About half of our participants stated that the forms of transit in Copenhagen with the best audio announcements are the S-train and the Metro, which both make a beeping noise when the doors open and close and announce every stop inside the vehicles. Announcements about the identity of the train line are especially useful—speakers are present above the doors of all S-trains, that announce the train's identity and destination after the doors beep and open. Out of the 16 S-trains that we observed, they all announced their identity when their doors opened (see Appendix 4.1). These announcements were designed to be loud enough to hear from the platform. Even though the announcement is not broadcast from the platform, it is still accessible to a commuter on the platform.

Audio announcements in the train station or on the train platform can provide information about train delays and track changes. About half of our interviewees told us that they find these announcements very helpful.

In the bus system, the S-train system, and some of the regional trains, audio announcements announce the next stop, as long as the system is working well. Three interview participants claimed that the announcement system in buses is not as consistent as that in S-trains, but it is still helpful when it works properly (see Appendix 4.2).

Overall, audio announcements are a popular way for blind and partially sighted commuters to obtain information. However, every one of our interviewees identified shortcomings of audio announcements or suggested ways to improve or extend audio announcements in the transit system.

4.3.2. Audio announcements can be hard to hear

The most common complaint about audio announcements, both in our interviews and surveys, was that they can be hard to hear. We've noted this frequently during our observations, as well; the noises of other trains and the crowds at stations can make it hard to hear the announcements, much less understand them (see Appendix 4.1). In our observation of the S-train on platforms eleven and twelve in Central Station, ten out of the sixteen train announcements were difficult to hear due to other commuters or separate announcements for the station.

4.3.3. Audio announcements are not consistently available inside all transit vehicles

Though many of the transit vehicles have audio announcement systems, three of our interviewees noted that they are not always reliable and that they are not present in all modes of transit. Our observations of buses supported this to a limited degree; out of 170 times when we should have heard announcements before a stop, the announcement was played at the wrong time or not played at all a total of 14 times (about 8 percent).

Through our observations, we found that the S-train, the majority of buses, and a few regional trains announce the name of the next stop inside the vehicle. However, our observations show that these announcements are not always consistent—about 4 percent of the announcements we observed happened after their stop and about 4 percent of announcements were skipped (see Appendix 4.1). These inconsistencies, while uncommon, make it hard for commuters who are blind or partially sighted to rely on the audio announcements inside buses or trains. Many trains announce their stops as they move, but different types of trains and buses have different announcements. Some members of our

focus group mentioned that they still count stops to determine when they need to get off of some trains because they cannot trust the announcements to alert them of their stop. This problem is worse on buses. Buses do not always announce their next stop, and they only stop at passenger request, which can make it much more difficult for partially sighted commuters to know when to get off.

4.3.4. Audio announcements are not always provided on the platform

Announcements outside of transportation vehicles are not always available. S-trains announce their identity and destination as their doors open, but certain lines have inconsistent announcements, making some of our subjects feel as though they could not depend on the announcements (see Appendix 4.2). In our observations of Valby station, all of the B and Bx trains announce their identity and destination, but we only heard announcements from C trains half of the time. The only noise made by regional trains are the conductor's whistle before the doors close, and we noticed that there were no announcements of identity or destination at all. Bus identity and destination are not announced when the bus stops, which makes it difficult for people who are blind or partially sighted to identify their bus. The most frequent suggestion we have received is for audio announcements to provide the identity and destination of buses, especially at larger bus stations—our focus group and all but two of our interviewees made some form of this suggestion. Some of our interviewees specified cases where announcements would be especially useful: when there are many bus stops near each other, or when multiple buses arrive at the same stop, announcements could allow people who are blind or partially sighted to find the right stop or bus.

4.4. Applications can be useful to people who are blind or partially sighted, but they are not an ideal solution

4.4.1. Web and mobile phone applications can help commuters plan and follow their routes

About 60 percent of our 33 research participants mentioned that they use mobile phone or web applications to aid them in their travels. The applications most widely used by the 19 subjects who named any applications are Rejseplanen's website and mobile applications, with 14 users (74 percent). Besides Rejseplanen, the applications named most were DSB and Afgange, with 4 users (21 percent) each. The number of participants who named various applications is shown in Figure 3. These

applications provide a variety of services. Afgange shows the next buses or trains that should arrive at nearby stations. Although this does not identify the bus or train currently at the station or stop, it can provide partially sighted commuters with more confidence that the next bus or train will be the line that they need. DSB allows users to plan their journeys and purchase tickets and can show upcoming train departures nearby. Rejseplanen can be used for journey planning, checking ongoing delays and route changes, and listing upcoming arrivals and departures from any station at whatever time the user chooses. Rejseplanen is useful for planning trips and provides updated information about delays and other irregularities in the transit network, but many of our interviewees do not use the application, citing a lack of fully accessible features. All of these applications take traffic information into account, including delays and schedule changes. Of our interviewees, 8 (24 percent) stated that they use multiple applications, switching between them for different purposes, as different applications are more useful in certain situations.

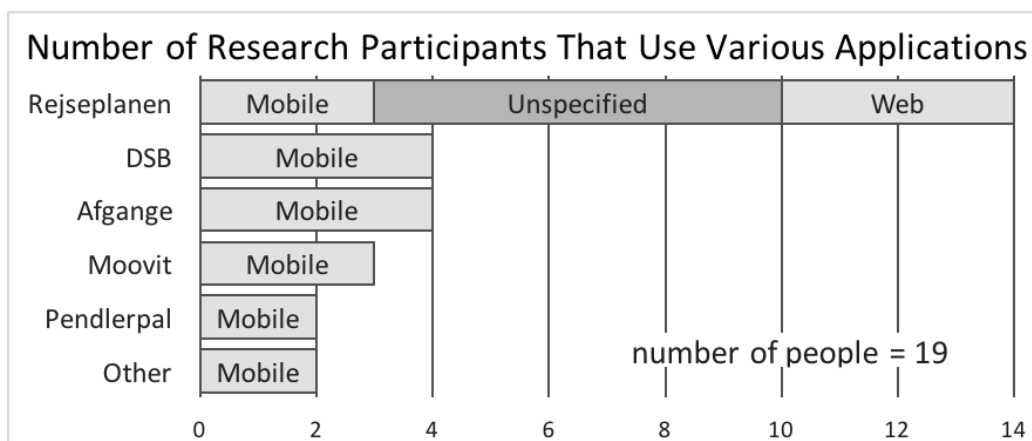


Figure 3. Chart of research participants' application use. Note that some participants named multiple applications, so the sum of the number of users each application has does not total 19.

4.4.2. Only around half of our research participants use mobile phone applications

Another major obstacle preventing applications from being the ideal solution is that many people prefer not to use them. In our survey, only around half of our respondents said that they use mobile phone applications (see Appendix 4.3). One research participant informed us that the use of mobile phone applications can sometimes complicate the situation rather than assist. Another participant stated it can be awkward to hold their phone near their ear and navigate applications, and it is even more difficult when carrying a white cane or other belongings. Several participants stated that they have not taken the time to learn how to use applications or simply do not want to. Two of our participants indicated that they are confident enough in their ability to navigate the transit network that

they do not feel the need to use applications, preferring to use other assistance like asking a passerby or audio announcements. Two of our interviewees and one focus group participant told us that rather than deal with the challenges of using applications while traveling, they limit their application use to web applications for planning their journey ahead of time.

Despite the resistance of blind and partially sighted commuters to using mobile phone applications, application use may become one of the only ways for commuters who are blind or partially sighted to maintain their independence in the future. In our interview with representatives of DSB, we learned that DSB is moving towards a paperless ticketing system, which may leave applications as the only way to purchase a ticket without the aid of a DSB employee. Additionally, representatives of both DSB and Movia indicated that their companies would prefer application-based solutions rather than solutions involving additional audio announcements. However, our sample was biased and relatively small, and may not have identified the main reasons for a lack of application use by people who are blind or partially sighted.

4.4.3. Applications are not always fully accessible to people who are blind and partially sighted

Although mobile phone and web applications can help with many of the challenges partially sighted commuters face, they are far from a perfect solution. Many people who are blind or partially sighted rely on screen readers to use computers, but many applications and websites do not present their contents properly for screen readers. For example, screen readers may skip or repeat information on some websites and applications, making navigation difficult or impossible. Even when applications are accessible, they may not remain accessible following future updates. For example, in the past, the DSB application had a button to load additional search results, but this button has been replaced by an inaccessible touch gesture. To understand the accessibility problems commonly faced by people who are blind or partially sighted, we briefly assessed the accessibility of Rejseplanen, DSB, and Afgange, the applications most used among our research participants.

Of the three applications we assessed, Afgange appeared to be the most accessible of the three, though it also has the fewest features. The application is relatively easy to navigate, with correctly-placed headers and easily navigable tables. However, the map-based route display, which shows the stops along a transit line, does not display the stops in a logical order to screen readers, which read the stops in an apparently random order. Additionally, some of the information given is not entirely clear.

For example, the number of minutes until departure is displayed only as a number, without any description.

Rejseplanen is generally usable, but the member of the Danish Association of the Blind that helped us with the assessment described it as “clunky.” Despite having multiple sections on the screen at a time (such as the search options and search results), there are few headings in the application, making it difficult to navigate between the sections.

DSB had the most accessibility problems. While the application’s main features are usable, many of them are difficult to navigate or present information poorly. When planning a journey, only three search results are shown and a swipe gesture is required to load more, but VoiceOver prevents the gesture from being detected. When viewing current traffic information, some information is skipped entirely, and attempting to navigate to the previous element instead jumps to a seemingly random position on the page.

4.4.4. Application developers are willing to take action to improve their applications’ accessibility

Applications may not always be accessible, but there are guidelines to make them more accessible. Web Content Accessibility Guidelines (WCAG) 2.0 sets standards for websites (World Wide Web Consortium, 2017), and Apple Inc. (2012) has accessibility guidelines for developing iPhone applications. These guidelines indicate how information can be presented so it is accessible via accessibility technologies such as screen readers. For example, WCAG 2.0 specifies that information should be labeled appropriately for screen readers and that relationships between visually presented information should be available to accessibility technologies. Application developers may follow these guidelines to improve their applications’ accessibility.

Rejseplanen is already taking steps to improve their web application’s accessibility. We observed a meeting between a Rejseplanen employee; the software developers at HaCon, the German company that develops Rejseplanen’s applications; and a representative of Diversa, an accessibility consulting firm. In this meeting, Diversa’s representative discussed Diversa’s assessment of Rejseplanen’s website and developers from HaCon took note of areas that could be improved. This will allow Rejseplanen’s web application to be made more accessible. Rejseplanen is planning to repeat this evaluation semiannually, to ensure that their web application remains accessible in future.

When we corresponded with the developer of Afgange, he informed us that he was unaware that Afgange is popular among people who are blind or partially sighted, and he had not developed it

with accessibility in mind beyond Apple’s guidelines for accessible application development. While he has no plans to develop the application beyond making sure it continues to work properly, he is open to working with the Danish Association of the Blind to improve it.

4.5. Bluetooth Low Energy beacon technology has the potential to provide information about public transportation to people who are blind or partially sighted

4.5.1. Tandem Association & Smart Public Transport

The Tandem Association representative we interviewed told us that the association learned about beacon technology and believed it was the perfect way to create a “sound corridor” for blind and partially sighted people who use public transportation. With the help of Vodafone and other private sponsors, the association started the Smart Public Transport (SPT) project throughout the city of Bucharest, Romania. This project consisted of deploying 3,000 beacons throughout the city—on buses, in stations, and on streets. These beacons are paired with a mobile phone application that is capable of recognizing which beacon the user is near, as well as patterns with which the user passes a line of beacons. A beacon in this system is programmed to hold the identity of the location it was placed. When a person using the iBeacon application approaches a beacon, it will play an announcement containing information. The first phase of SPT was to make it possible for a blind or partially sighted application user to be notified of which bus is approaching while he or she stands at a bus stop. The beacon inside of the bus is recognized by the mobile phone application, and the application then plays an audio announcement regarding which bus is arriving. The second phase of SPT was aimed to help a blind or partially sighted user riding on a bus, recognize which stop they are approaching. The application uses GPS coordinates, and while communicating with the iBeacon placed at the bus stop, it tells the user exactly which stop he or she is approaching.

Beacons can not only help identify stations and bus lines—they are currently being used in different projects in the underground transportation system in Bucharest. The beacons in the underground identify the station and identity of the line, but they also provide directional cues throughout the station. When implementing beacons in the underground system, Tandem considered the orientation of a blind person in the station and the best locations for the beacons. They decided to assign numbers to the beacon that the application could recognize. The number of the beacon would

increase as the user moved from the entrance of the station to the platform. Similarly, the beacon number would decrease as the user moved from the platform to the exit of the station. The mobile phone application is able to recognize the pattern in which beacons pass, and translate that into an audio announcement that will notify the user of the direction they are moving in. In addition to the directional assistance, there are beacons present throughout the station that provide the user with two options as they approach an intersection. For example, once the user reaches the beacon, the application will announce the destinations that they would reach if they were to turn left or right. This part of beacon implementation in Bucharest is more successful than the use of beacons on buses, as it is not subject to weather conditions or physical barriers that could be harmful to the beacon.

The Tandem Association wanted the beacons used for Smart Public Transport to be able to output a buzzing sound, allowing a blind or partially sighted commuter to detect the beacon's location precisely. The noise output was not included in the original design of the iBeacon that Onyx Beacon created and manufactured, and the addition of speakers to the beacons significantly increased the maintenance required by the system. The Tandem Association is looking into getting audio beacons from another company or working with a local technical university to develop these beacons. Their beacons projects are ongoing and have found reasonable success with using beacons for multiple purposes.

4.5.2. Kontakt.io beacons are relatively cheap, but beacon software and maintenance may be expensive

The Danish Association of the Blind is headquartered in the House of Organizations of Persons with Disabilities. This building has accessibility measures in place for people with all kinds of disabilities, including helpful aids for people who are blind or partially sighted. The building is equipped with several aids for blind or partially sighted visitors and employees, like Kontakt.io beacons. This company sells and manufactures beacons, and we wanted to learn more about the cost of implementation of beacons for the public transportation system. It would cost 12–13 USD (about 74–80 DKK) per beacon to apply them to buses, trains, and stations in Copenhagen. A representative of Kontakt.io stated that the main fees are found in software integration and maintenance, which could make beacon technology an expensive solution.

4.5.3. Movia is currently investigating the potential uses of beacons in Copenhagen's bus network

A representative from Movia stated that Movia is in the early stages of investigating a beacon project in Copenhagen. He indicated that Movia is extremely interested in learning from the success of Tandem's Smart Public Transport. Movia has planned to place beacons at bus stops to increase the accessibility of information. To pilot test beacon technology, Movia has placed beacons throughout their office to mock the implementation of beacons at stations. The beacons in the office work with an application, similar to SPT, which announces updated information about stations in Copenhagen.

Chapter 5: Recommendations and Conclusions

In this chapter, we first reiterate the goal of our project, summarize our methods to achieving our goal, and review what we found from these methods. We then provide a list of recommendations for the Danish Association of the Blind, suggesting ways to improve the accessibility of information in public transportation. The list is based on our findings, and our recommendations consider both the needs of commuters who are blind or partially sighted and the context of Copenhagen's transit system to identify which solutions are most feasible. We also provide recommendations for future projects, noting areas that would benefit from further research.

5.1 Summary of Findings

The goal of our project was to assist the Danish Association of the Blind in addressing the inequalities faced by people who are blind or partially sighted by investigating the accessibility of public transportation schedules, arrivals, and departures, focusing on the Copenhagen transit network. We worked to achieve this goal by balancing the wants and needs of blind and partially sighted commuters with the ability of public transportation companies to make changes to the system. By interviewing and surveying people who are blind and partially sighted, we built an understanding of the difficulties they face in using public transportation. We also talked to representatives from public transportation and technology companies to understand how information is communicated in the Copenhagen transit system and where improvements could be made.

From our communication with members of the Danish Association of the Blind and the Danish Institute for the Blind, we identified a number of problems that blind and partially sighted commuters face. Three major obstacles stood out among the responses we received. First, many of our subjects stated that they have a hard time identifying the correct transit vehicle, especially buses. Particularly, they have trouble identifying which bus at a stop is their desired bus, especially if there are several buses lined up in a queue along the curb. Second, some of our research participants find it difficult to obtain updated information about track changes, schedule changes, and delays. Third, the blind and partially sighted commuters we interviewed find it difficult to travel without updated information about their location.

All of our research participants stated that they use audio announcements to obtain information about public transportation. However, we found through observations and input from blind and partially sighted commuters that audio announcements are not consistently available in all modes of transit in Copenhagen. The buses and regional trains do not announce the identity of the line as the vehicle arrives at each station, and the announcements are sometimes skipped or may play at the wrong time. In train stations, audio announcements can be hard to hear, preventing updated information from reaching blind or partially sighted commuters.

Over half of our interviewees and about half of our survey respondents use mobile phone applications to obtain travel information (see Appendix 4.3). But mobile phone applications are often not fully accessible to blind or partially sighted users. From the interviewees who do not use mobile phone applications, we identified a few reasons why many blind and partially sighted commuters do not use them; they do not want to take the time to learn how to use the applications and they may find it difficult to use their phone while holding other objects and navigating a station, among other reasons.

Public transportation companies in Denmark comply with certain standards to ensure accessibility for people with disabilities. Audio announcements in train stations are controlled by Banedanmark and DSB, and the announcements are required to meet the European Union Agency for Railways' technical specification for interoperability regarding persons with reduced mobility, which standardizes announcement clarity and volume. Similarly, a recent bill requires mobile phone applications and websites for Danish public utilities to comply with Web Content Accessibility Guidelines (WCAG) by September of 2019 (L 126, 2018). However, WCAG is not just for public utilities—other application developers can use WCAG standards to maximize web accessibility. Rejseplanen, a widely used journey-planning website, does not currently comply with Web Content Accessibility Guidelines (WCAG), but they are taking steps towards compliance. Following these standards provides reasonable accommodations for blind and partially sighted commuters, but that does not necessarily equate to equal access. For blind and partially sighted commuters to get the same information at the same time as sighted commuters, public transportation companies may need to go beyond the requirements of both mandatory and voluntary standards. Representatives from DSB and Rejseplanen mentioned that they would ideally make more accommodations, but making accommodations can be expensive or challenging to implement. It is difficult for these companies to justify costly accessibility features as a profitable choice, as the changes would affect such a small number of passengers. However, many changes are still feasible for the current system.

Our recommendations aim to minimize cost, increase feasibility, and benefit other subsets of the population as well. A few of our recommendations are changes we believe will be easy to implement. With our more complicated recommendations, we suggested methods for approaching these complex problems and included several opportunities for solving the problems we identified. In gathering our findings, we forged many connections with company representatives. We provided the Danish Association of the Blind with the names and contact information of the company representatives that we interviewed in the hopes that the Danish Association of the Blind could continue a dialogue with these companies to ensure these solutions are implemented.

5.2 Recommendations to the Danish Association of the Blind

Based on the results of our research, we have composed a list of six recommendations for the Danish Association of the Blind and various transit companies. These recommendations aim to increase the accessibility of information in public transportation, centered around the wants and needs of the blind and partially sighted community. The recommended changes would involve collaboration between the transit companies, who control the transit network, and the Danish Association of the Blind, who have the blind and partially sighted community's wants and needs in mind.

1. We recommend that the Danish Association of the Blind work with the Tandem Association and Movia to consider a Bluetooth Low Energy beacon system for use in Copenhagen's bus network.

As an alternative to external audio announcements, the use of Bluetooth Low Energy (BLE) beacons in buses and bus stops could combat the problem of identification of buses. Additionally, this solution would be less of a disturbance to people living in the surrounding area and would allow Movia to maintain quiet stops. BLE beacons could act as a basis for a system that allows blind or partially sighted commuters to identify buses more independently. Beacons and related technologies can be used in many ways; we recommend that the Danish Association for the Blind look into three of these potential solutions.

In Bucharest, the Tandem Association has implemented a system using BLE beacons and a mobile phone application. The system consists of BLE beacons placed on the city's buses-the beacon transmits information to users' smartphones, allowing them to identify the nearest bus. BLE beacons can also be used to aid with navigation by indicating the location of bus stops. A BLE beacon system could be useful to tourists as well because the information from the beacons could be translated into other languages by a mobile phone application.

While BLE beacons systems could be highly effective, they present a number of challenges that the Danish Association of the Blind and Movia should consider. Despite the relatively low cost of individual beacons, the cost of the software and maintaining the system could be high. Additionally, not all people who are blind or partially sighted use mobile phone applications, and an application is the most likely user interface for such a system. In our interview with a representative of the Tandem Association, we learned about a variety of other problems that the Tandem Association encountered with their beacons, including problems with beacon response time and the physical durability of beacons.

However, according to the Movia representative that we interviewed, Movia is currently looking into the possibility of using beacons to improve the bus network. The Tandem Association also expressed interest in working with other advocacy organizations, so we recommend that the Danish Association of the Blind contact the Tandem Association and Movia to assess the feasibility of using beacons to improve the accessibility of Copenhagen's bus network.

If the Danish Association of the Blind and Movia determine that BLE beacons are feasible for Copenhagen's bus system, there are multiple related technologies that can be used to make the system even more accessible. For example, the Tandem Association has also looked into BLE beacons with built-in loudspeakers. This type of beacon could be used to make external audio announcements for buses. Combining announcements and beacons into a single system would benefit both blind and partially sighted mobile phone application users and non-users. However, beacons with built-in loudspeakers are rare and face other technical difficulties, such as a short battery life. We recommend that the Danish Association of the Blind collaborate with Movia and the Tandem Association to investigate the feasibility of developing audio-capable beacons for use in Copenhagen's public transportation system.

While BLE beacons with built-in loudspeakers may require extensive research to implement, the Royal National Institute of Blind People (RNIB) has worked with REACT Technologies to implement a system in London's transit system that has similar capabilities. This system is potentially usable by all people who are blind or partially sighted, as it can be operated by a trigger fob, a small device, rather than requiring a mobile phone application. Unfortunately, RNIB and REACT Technologies did not respond to our requests for interviews, so we were unable to evaluate their system as a potential solution in Copenhagen. Therefore, we recommend that the Danish Association of the Blind and Movia reach out to RNIB and REACT Technologies to determine whether a similar system could fulfill their needs. Beacons and their supplemental technologies could be an ideal solution to aid not only in identifying bus lines and destinations but also in receiving updated location information while in transit.

2. We recommend further research into the feasibility of a system for external announcements for buses.

One of the most common challenges faced by our research subjects is identifying the correct bus at a bus stop. In five out of our seven interviews, the interviewees suggested that buses announce their identity as they arrive at each stop. The S-train's announcement system received praise from our interviewees, and similar announcements for buses would be useful to commuters who are blind or partially sighted. Alternatively, the same effect could be achieved by announcements made by loudspeakers at bus stops, identifying buses as they arrive.

However, these recommendations may prove difficult to implement. External audio announcements would require a significant economic commitment from Movia. Movia contracts bus operations to companies of varying size and buses are expensive to upgrade and maintain. Movia must carefully consider the limitations of the contractors before changing their requirements to include external loudspeakers. Similarly, installing loudspeakers on all of the bus stops in Copenhagen could be expensive. Additionally, the announcements could be considered a nuisance by nearby residents, so installing a loudspeaker system would involve extensive pilot testing. Additionally, the Movia representative we interviewed indicated that alternative solutions such as smartphone applications and Bluetooth beacons may be more in line with Movia's existing plans.

Despite these challenges, external announcements for buses would be invaluable in improving the accessibility of public transportation and especially useful for blind and partially sighted commuters who do not like to use mobile phone applications. Therefore, external announcements should be considered. We recommend further research into the feasibility of installing different types of announcement systems in Copenhagen's buses or bus stops. This research should consider other possibilities besides automated system-wide announcements, such as on-demand announcements played at the push of a button, or announcements only at the most problematic bus terminals.

3. We recommend that Movia require buses to pull up to their designated stops.

About half of our interviewees said that they have trouble identifying the right bus at bus stops that service multiple lines. At stops that service only one line, the identity of a bus at the stop is always clear. However, as our observations and interviews indicate, when multiple buses stop in a line, the buses behind the first usually will not pull up to the signpost before leaving. To solve this problem, we recommend that Movia specify and enforce in their contracts with the bus operators that bus drivers must pull up to the signpost with people at them, even if they stop before the signpost.

In addition to making sure each bus stops at the designated signpost, it would be beneficial for bus drivers to be trained to recognize when a blind or partially sighted individual is waiting for their bus, which can be indicated by a white cane or service animal. Awareness training combined with requirements for bus drivers to stop at the designated signpost would be helpful not only for blind and partially sighted commuters but for other commuters who may need additional assistance as well.

The largest obstacle to this solution is that bus driver training is not controlled directly by Movia—it is controlled by the contractors that operate the buses. However, Movia does make the rules for the bus operators, and they could create incentives to provide additional training for drivers. Therefore, while the bus operators would have the main responsibility in implementing these recommendations, Movia could update their standards to make the system more accessible overall.

4. We recommend that Banedanmark and DSB improve their audio announcements.

All but two of our survey respondents and every interviewee said that announcements are a helpful source of information, but over half of both groups noted that audio announcements can be hard to hear or understand. Our observations in train stations supported this; some announcements were difficult to hear, particularly when ambient noise obscured the announcements. Repeating announcements would give commuters a second opportunity to hear the information being played. For these reasons, we recommend that the Danish Association of the Blind encourage Banedanmark and DSB to require that all announcements be repeated each time they are made.

For announcements about the regional train, the infrastructure is already in place on train platforms and in train stations. The content and frequency of the announcements on the platforms and in the stations are controlled by Banedanmark. Additional announcements would only require changes to their announcement guidelines and an update to the software they use for automated announcements.

Similar changes could be made for announcements about the S-trains. Announcements about S-train schedule changes are controlled by DSB. Based on our observations of Nørreport and Central station, S-train announcements are only made on the train platform, not in the stations' buildings. The control center for the S-trains is in a separate location from the Banedanmark and DSB control center that makes the audio announcements for the regional trains, and the Banedanmark and DSB control center is in charge of the audio announcements in the train stations. Therefore, future research could look into the relationship between these control centers to determine if all S-train audio announcements could be made inside stations as well. This would allow for more flexibility for blind and

partially sighted passengers, as they would always get all of their information while they are in the station.

Our research participants also noted that audio announcements of train identity are inconsistent. Through our observations of Nørreport and Central station, every S-train we observed announced itself, but regional trains did not announce themselves. Therefore, we recommend that DSB ensures all of their trains announce themselves as they arrive at the station.

The S-trains already have the infrastructure for announcing their identities, so DSB would just need to ensure that these audio announcements are consistently made every time an S-train arrives at any station. If audio announcements are not being consistently made in the S-trains, DSB would only have to change their audio announcement software. DSB could implement the same announcement system as the S-train as they upgrade their regional trains. DSB should also look into other ways that regional trains ensure their identity is announced as the train arrives.

5. We recommend that the DSB, Afgange, and Rejseplanen mobile phone application developers take steps to improve the accessibility of their applications.

About half of the blind and partially sighted commuters that we interviewed use mobile phone applications to help plan their journey and get updated scheduling information. Mobile phone applications can provide significant aid, but the information they present can sometimes be unreadable to screen readers, and, by extension, inaccessible to people who are blind or partially sighted. The half of our blind and partially sighted research participants that do not use mobile phone applications say they are deterred from application use because they do not want to take the time to learn to use the applications. Therefore, we have three recommendations regarding mobile phone applications. We recommend that DSB, Afgange, and Rejseplanen mobile phone application developers take steps to improve the accessibility of their applications. We next recommend that the Danish Association of the Blind look into the organizations and individuals that develop the other widely used applications, and determine how they can best improve their accessibility. We finally recommend that as applications become more accessible, the Institute for the Blind and Partially Sighted develop and implement classes, teaching users about the accessibility features of these applications.

Rejseplanen and DSB, two of the most-used applications among our research participants, have significant accessibility problems, and we recommend that they take steps to improve their applications' accessibility. The details of the process the companies use to increase their applications accessibility may differ, but the first step is the same; they must comprehensively evaluate their applications' current

accessibility to determine what they need to change. This should be done with the help of an appropriate consulting firm, such as Diversa.

The other application frequently named in our research, Afgange, is developed by an independent developer. As a result, hiring a consulting firm such as Diversa for Afgange is infeasible. Additionally, major changes to Afgange may be infeasible, as the developer works on it as a personal project. However, the developer has expressed interest in improving accessibility, and the Danish Association of the Blind could give advice on what he could do to improve the application. When we evaluated Afgange's accessibility, we noted two specific points that could be improved. First, the time until a bus or train arrives is listed without any identification of what the number means. This information can be inferred from visual context but is unclear when read by VoiceOver. Second, the app currently displays bus routes on a visual map, and VoiceOver reads them in an apparently random order. We recommend that the developer of Afgange try to put the information available on this map in a table form, or make them available in a logical order.

We also recommend that the Danish Association of the Blind look into the organizations and individuals that develop the other widely used applications, and determine how they can best improve their accessibility. After Rejseplanen, DSB, and Afgange, we identified Moovit and Pendlerpal as the next two most popular mobile phone applications. However, because we gathered our data about commonly used mobile phone applications from a survey with a small sample size, a more in-depth survey could be used to gather more data about which applications blind and partially sighted commuters prefer before contacting those application developers.

From our focus group and interviews, we found that five of our blind and partially sighted research participants do not use mobile phone applications because they have not learned how to use them. As of right now, blind and partially sighted commuters can navigate through public transportation without the use of mobile phone applications. However, DSB is moving towards a ticketless system, which would rely heavily on mobile phone applications. Therefore, we recommend that the Danish Association of the Blind work with the Institute for the Blind and Partially Sighted to develop and implement a curriculum teaching people who are blind or partially sighted to use relevant applications as these applications become more accessible.

5. We recommend further research into the feasibility of implementing uniform tactile indicators and signs throughout the public transit system in the greater Copenhagen area.

Almost all of our research participants named tactile indicators and other means of physical accessibility as helpful in navigating the transit network. Copenhagen Central Station and Nørreport

Station have tactile indicators that help blind and partially sighted commuters in finding stairs, edges of platforms, ticket booths, and check-in and check-out points. However, these tactile indicators are not uniformly placed at all stations. As our observations supported, some stations have more tactile indicators than others. Additionally, tactile indicators are not consistently used to indicate the same things throughout all stops and stations, which can confuse blind or partially sighted commuters at new stations, according to one of our interview subjects. DSB, the main company that controls the platforms of stations has added more tactile indicators in recent years, and they explained that any infrastructure-based solution may be expensive to implement.

We recognize that although tactile indicators are a widely used aid for the blind and partially sighted, they are mainly navigational aids, so they are beyond the scope of our project. Therefore, we recommend further research into the feasibility of the addition of uniform tactile aids across all stations and stops. Additional research into the implementation of a uniform solution for tactile indicators would benefit the blind and partially sighted community in regards to the ease of navigating unfamiliar stops and stations.

Chapter 6: IQP Learning Objectives

In this chapter, we discuss the various lessons we learned while completing our IQP. We first examine elements of project design that we found especially important when developing our IQP. We then review important processes that we discovered while performing project work. We finally explain how the lessons we learned will affect our collaborative and independent work for the rest of our time at WPI and subsequently in our future careers.

6.1. Lessons in Project Design

Delegating tasks according to our team members' strengths

In designing our IQP proposal and then our IQP itself, our group feels that we have grown significantly as project designers. In the initial stages of our project, we split all work we encountered equally among the four of us. We quickly found this approach to be counterproductive. We were producing inconsistent work depending on the task at hand—for example, certain group members yielded higher-quality research, others were better at converting that research to writing, and others contributed the most by editing the content that was already written. We learned that in order to be successful, we must redistribute the work based on our group members' strengths. We were much more productive with this approach; each group member was working in an area they were better suited for and therefore much more interested in.

The iterative nature of project design

Project design requires a lot of trial and error—something that we saw firsthand in our IQP. When we started our project, we all had extensive ideas for solutions that would solve our huge problem. As we worked on our proposal, we realized that with limited time and other constraints, our project might not be able to live up to our initial expectations. We consequently limited what we thought we could achieve. When we got to Denmark, we realized that so many organizations were willing to aid us in completing our project and so many people wanted to see our project realized; we then were able to expand our project into territories we did not think we could reach when completing our proposal. The iterative process we went through to figure out the scope of our project was frustrating. A lot of areas that we so meticulously researched and methodologies that we carefully

planned to carry out were no longer relevant. But we learned an important part of the research process—the cycle of acknowledging mistakes, making amends, and moving on.

6.2. Lessons in Technology and Society

Technologies for public services are generally designed with the majority of the population in mind

The majority of the problems that arose during our project were caused by the fact that public transportation was not designed with blind and partially sighted commuters in mind. The majority of information regarding public transportation schedules and identity is displayed on signs. Because blind and partially sighted commuters cannot see these visual cues, they miss a significant portion of the information that sighted commuters can easily access. The problems that blind and partially sighted face using public transportation parallel problems that various minority groups face when using products not designed specifically for their community.

Unequal access to technologies can equate to unequal access to the rest of society

Since public transit is not designed with blind and partially sighted commuters in mind, the challenges they face while commuting can discourage them from using public transportation. Blind and partially sighted commuters have limited options for transit in Copenhagen. They themselves cannot drive or ride bicycles, so their transit options are limited to being driven or walking. If public transportation is inaccessible, people who are blind and partially sighted cannot travel far independently, which could cause them to miss work opportunities or social events. When the designers of a new technology do not consider a holistic view of their users, they risk marginalizing large groups that may already be at a disadvantage.

It is economically difficult for companies to prioritize the needs of minorities.

Money is not in abundance in the transportation industry, and public transportation companies often have to prioritize more pressing infrastructural changes over accessibility improvements. Public transit companies need to be competitive in the market and generate revenue. Making accommodations would cost a large amount of money, and would not result in a direct return on investment, as the number of customers would not increase greatly. Our interview with DSB representatives confirms that viewpoint; they stated that making accommodations would generally only

affect customers who already frequently use public transit, not necessarily bring in new users. The returns on investment into accommodations often take the form of customer satisfaction, not increased revenue. Public transit companies have to make reasonable accommodations by various EU laws and regulations, but making any accommodations beyond that can be economically untenable.

Society is reliant on technology, but technology is not accessible to all members of society

Public transportation has become much easier to use because of new technologies. Display boards, announcements, and mobile phone applications make it easy for commuters to get updated information about schedule changes in public transit. But consequently, people have become dependent on these technologies. They rely on updated information from these sources to feel comfortable while using public transit. As these technologies have evolved to give more accurate updated information, accommodations for people who are blind and partially sighted have always been one step behind. As long as technology continues to evolve as an integral part of society, minority groups like the blind and partially sighted community will need to be accommodated for if there is ever to be equality for these groups.

References

- American Foundation for the Blind. (n.d.). Accessible mass transit. Retrieved from <https://www.afb.org/info/living-with-vision-loss/getting-around/accessible-mass-transit/235>
- Americans with Disabilities Act of 1990, 42 U.S.C. § 12101 (2018). Retrieved from [http://uscode.house.gov/view.xhtml?req=\(title:42%20section:12101%20edition:prelim\)%20OR%20\(granuleid:USC-prelim-title42-section12101\)&f=treesort&edition=prelim&num=0&jumpTo=true](http://uscode.house.gov/view.xhtml?req=(title:42%20section:12101%20edition:prelim)%20OR%20(granuleid:USC-prelim-title42-section12101)&f=treesort&edition=prelim&num=0&jumpTo=true)
- Apple Inc. (2018). Making your iOS app accessible. Retrieved from https://developer.apple.com/library/content/documentation/UserExperience/Conceptual/iPhoneAccessibility/Making_Application_Accessible/Making_Application_Accessible.html#//apple_ref/doc/uid/TP40008785-CH102-SW5
- Arriva. (n.d.). Countries: Denmark. Retrieved from <http://www.arriva.co.uk/countries/denmark>
- Australian Government. (n.d.). Accessibility. Retrieved from <https://www.australia.gov.au/accessibility>
- Australian Human Rights Commission. (n.d.). Disability discrimination. Retrieved from <https://www.humanrights.gov.au/employers/good-practice-good-business-factsheets/disability-discrimination>
- Bennett, M. (2014, February 14). A new app aims to assist blind people navigate Perth's public transport network. ABC News. Retrieved from <http://www.abc.net.au/news/2014-02-14/new-app-helps-blind-to-navigate-public-transport-feature/5258776>
- Blind find difficulties accessing public transport. (1999, May 23). BBC News. Retrieved from <https://news.bbc.co.uk/2/hi/health/349045.stm>
- Bologna Welcome. (2018, February 6). Tourism for disabled people in Bologna. Retrieved from <https://www.bolognawelcome.com/en/for-disabled-visitors/tourism-for-disabled-people-in-bologna/>
- Braille Literacy Canada. (2016). *Accessible signage guidelines*. Retrieved from <http://www.ft.dk/samling/20171/lovforslag/l126/index.htm>
- Casas, I. (2007). Social exclusion and the disabled: An accessibility approach. *The Professional Geographer*, 59(4), 463–477. <https://doi.org/10.1111/j.1467-9272.2007.00635.x>
- Clayton, W., Parkin, J., & Billington, C. (2017). Cycling and disability: A call for further research. *Journal of Transport & Health*, 6, 452–462. <https://doi.org/10.1016/j.jth.2017.01.013>

Commission Regulation (EU) No 1300/2014 of 18 November 2014 on the technical specifications for interoperability relating to accessibility of the Union's rail system for persons with disabilities and persons with reduced mobility. Retrieved from <https://eur-lex.europa.eu/eli/reg/2014/1300/oj>

Convention on the Rights of Persons with Disabilities, Dec. 13, 2006, 2515 U.N.T.C. 3. Retrieved from <https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html>

Dansk Blindesamfund. (2009, March 18). Mission, vision og værdier [Mission, vision, and values]. Retrieved from <https://blind.dk/om-os/mission-vision-og-vaerdier>

Demmitt, A. (2014). The transportation problem: Finding rides when you can't drive [Blog post]. Retrieved from <https://www.visionaware.org/blog/visually-impaired-now-what/the-transportation-problem-finding-rides-when-you-can%E2%80%99t-drive/12>

Din Offentlige Transport. (n.d.-a). City med alle busser, tog og metro [City with all buses, trains and metro] [Map]. Retrieved from <https://dinoffentligetransport.dk/media/2131/bustogmetrocity.pdf>

Din Offentlige Transport. (n.d.-b). SMS næste bus [SMS next bus]. Retrieved from <https://dinoffentligetransport.dk/trafikinformation/faa-besked/sms-naeste-bus/>

DSB. (2018, January 8). [Line map of the Copenhagen S-train] [Map]. Retrieved from <http://www.dsb.dk/globalassets/pdf/koereplaner/s-tog/2018/s-tog-8jan18.pdf>

DSB. (n.d.-a). Find billetter og services [Find tickets and services]. Retrieved from <https://www.dsb.dk/find-produkter-og-services/>

DSB. (n.d.-b). Handicapservice i DSB [DSB handicap service]. Retrieved from <https://www.dsb.dk/find-produkter-og-services/handicapservice-i-dsb/>

DSB. (n.d.-c). Contact DSB Customer Service. Retrieved from <https://www.dsb.dk/en/customer-service/>

European Association of Service Providers for Persons with Disabilities. (n.d.-a). Our philosophy. Retrieved from <http://easpd.all2all.org/en/content/our-philosophy>

European Association of Service Providers for Persons with Disabilities. (n.d.-b). Our strategy. Retrieved from <http://easpd.all2all.org/en/content/our-strategy>

European Commission. (n.d.). Mobility and transport: Denmark. Retrieved from https://ec.europa.eu/transport/modes/rail/ertms/countries/denmark_en

Fielding, C. (2005). Implementation of research-based UK regulations for public transport vehicles with particular reference to contrast in bus and rail vehicles. *International Congress Series, 1282*,

- 1007–1010. <https://doi.org/10.1016/j.ics.2005.05.059>
- Folketing [The Danish Parliament]. (2018). L 126 Forslag til lov om tilgængelighed af offentlige organers websteder og mobilapplikationer. [L 126 proposal for public procurement web sites and mobile applications: about the bill]. Retrieved from <http://www.ft.dk/samling/20171/lovforslag/l126/index.htm>
- General Assembly resolution 217, *Universal Declaration of Human Rights*, A/RES/217 (December, 10 1948). Retrieved from <https://www.un.org/en/universal-declaration-human-rights/>
- Google. (n.d.-a). [Google Maps: Copenhagen Central Station]. Retrieved April 30, 2018 from <https://goo.gl/maps/7TyczxeQVZC2>
- Google. (n.d.-b). [Google Maps:Nørreport metro station]. Retrieved April 30, 2018 from <https://goo.gl/maps/gWBcJLmi1h42>
- Google. (n.d.-c). [Google Maps: Nørreport S-train station]. Retrieved April 30, 2018 from <https://goo.gl/maps/1wYrwGPi39M2>
- Government Offices of Sweden. (2015, March 17). Goals and visions. Retrieved from <https://www.government.se/government-policy/social-care/goals-and-visions/>
- Government Offices of Sweden. (n.d.). Sweden's disability policy. Retrieved from <https://sweden.se/society/swedens-disability-policy/>
- Henry, S. L., Abou-Zahra, S., & Brewer, J. (2014). The role of accessibility in a universal web. In *Proceedings of the 11th Web for All Conference (W4A '14)*. New York, NY: ACM. <https://doi.org/10.1145/2596695.2596719>
- Hine, J., Swan, D., Scott, J., Binnie, D., & Sharp, J. (2000). Using technology to overcome the tyranny of space: Information provision and wayfinding. *Urban Studies*, 37(10), 1757–1770. <https://doi.org/10.1080/00420980020080381>
- Iowa Department for the Blind. (n.d.). Misconceptions. Retrieved from <https://blind.iowa.gov/family/misconceptions>
- Kenyon, S., Lyons, G., & Rafferty, J. (2002). Transport and social exclusion: Investigating the possibility of promoting inclusion through virtual mobility. *Journal of Transport Geography*, 10(3), 207-219. [https://doi.org/10.1016/S0966-6923\(02\)00012-1](https://doi.org/10.1016/S0966-6923(02)00012-1)
- Koch, M. (2014). Little Mermaid [Map]. Retrieved from <http://www.scandinaviastandard.com/wp-content/uploads/2014/01/Metro-K%C3%B8benhavn-2014.png>
- L 126 Forslag til lov om tilgængelighed af offentlige organers websteder og mobilapplikationer [L 126 Proposal for Public Procurement Web Sites and Mobile Applications]. (2018, January 11).

- Retrieved from http://www.ft.dk/samling/20171/lovforslag/l126/20171_l126_som_fremsat.htm
- Lecerf, M. (2017). European Accessibility Act. European Parliamentary Research Service. Retrieved from http://www.europarl.europa.eu/RegData/etudes/BRIE/2017/603973/EPRS_BRI%282017%29603973_EN.pdf
- Mack, N., Woodsong, C., & United States. (2005). *Qualitative research methods: A data collector's field guide*. North Carolina: FLI USAID. Retrieved from <https://www.fhi360.org/sites/default/files/media/documents/Qualitative%20Research%20Methods%20-%20A%20Data%20Collector%27s%20Field%20Guide.pdf>
- Mcomish, F., & Norman, R. T. (2014, January 19). How to use public transport in Copenhagen. *Scandinavia Standard*. Retrieved from <http://www.scandinaviastandard.com/public-transport-in-copenhagen/>
- Metroselskabet. (n.d.-a). Facts om metroen [Facts about the metro]. Retrieved from <http://m.dk/#!/om+metroen/facts+om+metroen>
- Metroselskabet. (n.d.-b). Metroens linjer [Metro lines] [Map]. Retrieved from <http://m.dk/~media/metro/nyheder/pressefotos/metroens%20linjer.jpg>
- Metroselskabet. (n.d.-c). [Line map of the planned Copenhagen metro] [Map]. Retrieved from http://intl.m.dk/~media/Metro/Metrobyggeriet/Grafik/Metrokort_basis_M1_M2_M3_M4.jpg
- Ministry of Foreign Affairs of Denmark. (n.d.). Transport infrastructure in Denmark. Retrieved from <https://denmark.dk/en/practical-info/work-in-denmark/transport-infrastructure-in-denmark>
- Movia. (n.d.). Om os [About us]. Retrieved from <https://www.moviatrafik.dk/om-os>
- Newman, N. (2014). Apple iBeacon technology briefing. *Journal of Direct, Data and Digital Marketing Practice*, 15(3), 222-225. <https://doi.org/10.1057/dddmp.2014.7>
- Noor, M. Z. H., Ismail, I., & Saaid, M. F. (2009). Bus detection device for the blind using RFID application. In *2009 5th International Colloquium on Signal Processing & Its Applications (CSPA 2009)* (pp. 247–249). Kuala Lumpur, Malaysia: IEEE. <https://doi.org/10.1109/CSPA.2009.5069226>
- Pascolini, D. & Mariotti, S. P. M. (2011). Global estimates of visual impairment: 2010. *British Journal of Ophthalmology Online*. <https://doi.org/10.1136/bjophthalmol-2011-300539>. Retrieved from http://www.who.int/blindness/VI_BJO_text.pdf
- Publications Office of the European Union. (2015). European disability strategy (2010-2020). *EUR-Lex*. Retrieved from Retrieved from <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=LEGISSUM:em0047>
- REACT Technologies Limited. (n.d.). The React System. Retrieved from <http://www.react->

tech.com/products/react-system/

Rejseplanen A/S. (n.d.-a). Ejere og ledelse [Owners and management]. Retrieved from

<https://help.rejseplanen.dk/hc/da/articles/115003285985-Ejere-og-ledelse>

Rejseplanen A/S. (n.d.-b). Mere om Rejseplanen [More about Rejseplanen]. Retrieved from

<https://help.rejseplanen.dk/hc/da/articles/115000127329-Mere-om-Rejseplanen>

Sánchez, J., & Oyarzún, C. (2011). Mobile audio assistance in bus transportation for the blind.

International Journal on Disability and Human Development, 10(4), 365–371.

<https://doi.org/10.1515/IJDHD.2011.053>

San Francisco Bay Area Rapid Transit District. (n.d.-a). Accessible services. Retrieved from

<https://www.bart.gov/guide/accessibility>

San Francisco Bay Area Rapid Transit District. (n.d.-b). A history of BART: The concept is born. Retrieved

from <https://www.bart.gov/about/history>

Supeala, D. (2015). World premiere: Large scale iBeacons network guides visually impaired people to use the public transportation service. Retrieved from [https://www.onyxbeacon.com/world-](https://www.onyxbeacon.com/world-premiere-large-scale-ibeacons-network-guides-visually-impaired-people-to-use-the-public-transportation-service/)

[premiere-large-scale-ibeacons-network-guides-visually-impaired-people-to-use-the-public-transportation-service/](https://www.onyxbeacon.com/world-premiere-large-scale-ibeacons-network-guides-visually-impaired-people-to-use-the-public-transportation-service/)

SurveyMonkey. (n.d.). Web Accessibility: 508 Compliance & WCAG2. Retrieved from

https://help.surveymonkey.com/articles/en_US/kb/508-Compliance

Tandem Association. (n.d.). Smart Public Transport. Retrieved from

<http://www.asociatiatandem.ro/smart-public-transport/>

Transport-, Bygnings- og Boligministeriet. (2017). Om ministeriet - Transportministeriet [About the

Ministry - Ministry of Transport]. Retrieved from <https://www.trm.dk/da/ministeriet/kontakt>

United States Department of Justice. (2013). Introduction to the ADA. Retrieved from

https://www.ada.gov/ada_intro.htm

Vodafone. (2017). Mobile phone app a beacon for visually impaired people travelling in Bucharest [Blog post]. Retrieved from [https://www.vodafone.com/content/index/what/technology-](https://www.vodafone.com/content/index/what/technology-blog/visually-impaired-people-in-bucharest.html)

[blog/visually-impaired-people-in-bucharest.html](https://www.vodafone.com/content/index/what/technology-blog/visually-impaired-people-in-bucharest.html)

World Wide Web Consortium. (2017). Web Content Accessibility Guidelines (WCAG) overview. Retrieved from <https://www.w3.org/WAI/intro/wcag>

Wiederholt, M., Bendixen, C., Dybkjær, L., & Bonfils, I. S. (Eds.). (2002). *Danish disability policy - Equal opportunities through dialogue*. The Equal Opportunities Centre for Disabled Persons. Retrieved from <http://www.dch.dk/publ/disabilitypolicy/clean.html>

Chapter 2 Appendices: Additional Public Transportation Maps

This appendix includes maps of the various public transportation systems in Copenhagen.

A2.1: S-train and Regional Train Lines



Figure 4. Map of the S-train lines (DSB, 2018)

This map shows the S-train (colored lines) and regional train (grey lines). A green box with the letters "Re" represents the point where the S-train interfaces with the regional lines.

A2.2: Regional Train Routes



Figure 5. Map of railways in and around Copenhagen (Koch, 2014)

This map shows the regional train routes that extend from Copenhagen to further parts of Denmark, along with the location and names of stops.

A2.3: Copenhagen Metro Maps

A2.3.1: Current Metro



Figure 6. A Map of the current Copenhagen Metro Lines (Metroselskabet, n.d.-b)

A2.3.2: Planned Metro



Figure 7. A Map of the planned Copenhagen Metro (Metroselskabet, n.d.-c)

Chapter 3 Appendices: Research Protocols and Data

This appendix gives examples of the questions that were used to gather information from various sources in Denmark.

A3.1: Survey Questionnaire

This questionnaire was distributed via email (to about 90 people) and the Danish Association of the Blind's Facebook page (about 2700 followers) to gather general information about their perspectives on the accessibility of information in the public transportation system and their use of the system.

ENGLISH:

1. CONSENT (required answer to be YES)
2. Do you use public transportation in the greater Copenhagen area?
 - ☐ No
 - ☐ Yes
3. If yes, which mode of transportation do you use most frequently?
 - ☐ Metro
 - ☐ S-tog
 - ☐ Bus
 - ☐ Re-tog
 - ☐ Other e.g. Flexstrafik (please specify): [text entry]
4. Do you find that public transportation in the greater Copenhagen area provides full accessibility to blind or partially sighted commuters?
 - ☐ No
 - ☐ To some extent
 - ☐ Yes
5. Do you ask for assistance (about the identity of a bus, for example) from surrounding commuters?
 - ☐ No
 - ☐ Sometimes
 - ☐ Yes
6. If yes or sometimes, do you find that people are willing to help?

- No
 - Sometimes
 - Yes
7. Is it difficult to receive information about your trip from stations or the vehicle?
- No
 - To some extent
 - Yes
8. What accessible features do you notice as helpful when using public transportation in Copenhagen? [multiple selections allowed]
- Audio announcements
 - Tactile signs (braille)
 - Other (please specify): [text entry]
9. What features do you notice as difficult to use when on public transportation? [multiple selections allowed]
- Multiple modes of transportation
 - Audio announcements are not loud enough
 - Signs are not available in braille
 - Other (please specify): [text entry]
10. Do you or have you ever used aids or smartphone applications? If so, which? [text entry]

DANISH:

1. Ved at svare ja til at du har læst og forstået ovenstående, accepterer og giver du samtykke til at deltage i undersøgelsen.
 - Ja [only option, may be left blank]
2. Anvender du offentlig befordring i Storkøbenhavn?
 - Nej
 - Ja
3. Hvis ja, hvilken/hvilke anvender du hyppigst?
 - Metro
 - S-tog
 - Regionaltog
 - Bus

- ☐ Anden form for befordringsmiddel angiv, venligst i skrivefeltet? [includes text field]
- 4. Synes du at offentlig befordring i hovedstadsområdet giver fuldstændigt tilgængelighed for blinde og svagsynede brugere af offentlig befordring?
 - ☐ Nej
 - ☐ Til en hvis grad
 - ☐ Ja
- 5. Spørger du nogle gange om hjælp fra medrejsende f.x. om hvilke busser der ankommer til stoppestedet hvor du befinder dig?
 - ☐ Nej
 - ☐ Kun nogle gange
 - ☐ Ja
- 6. Hvis ja eller kun nogle gange, synes du medrejsende er villige til at give dig hjælp?
 - ☐ Nej
 - ☐ Kun nogle gange
 - ☐ Ja
- 7. Er det svært at få information om din rejse på stationen eller i transportmidlet?
 - ☐ Nej
 - ☐ Til en hvis grad
 - ☐ Ja
- 8. Hvilke informationsformer mener du er til stede i den offentlige befordring i hovedstadsområdet? [allows selection of multiple responses]
 - ☐ Højtalere
 - ☐ Taktile skilte (punktskrift)
 - ☐ Andet: skriv venligst i tekstfeltet. [includes text field]
- 9. Hvilke informationskilder mener du ikke er til stede eller svært at anvende i den offentlige befordring? [allows selection of multiple responses]
 - ☐ Anvendelse af flere transportmidler samt ved skift mellem forskellige typer af transportmidler
 - ☐ Beskeder over højtalersystemer (på station og i bus, tog, metro er ikke give ved tilstrækkelig lydstyrke)
 - ☐ Skiltning forefindes ikke på punktskrift
 - ☐ Andet: skriv venligst i tekstfeltet. [includes text field]

10. Anvender du mobility hjælpemidler eller Apps på smartphone? Hvis ja, hvilke? Angiv i tekstfeltet. [answer in a text box]

A3.2: Interview Questions for the Blind and Partially Sighted Community

These are the questions that we asked our interview participants that were blind or partially sighted to gain an understanding for how they feel about the current accessibility of public transportation.

- How often do you use public transportation?
- What types of activities do you use public transportation to get to (e.g. social activities, jobs, etc.)?
- How do you feel about the accessibility of public transportation?
 - What aspects of the public transportation system do you find frustrating?
 - What aspects of the public transportation system do you think help your commute?
- How do you get updated information about public transportation (e.g. schedule changes, arrivals, departures, and which bus or train is the bus or train you want to be on)?
 - What is difficult about getting updated information? Do you use any assistive devices to aid you in your travels?
 - What are some actions you take to receive current information about public transportation?
- What would you suggest to improve the accessibility of information in the public transportation system?
- Do you have any other comments or questions?

A3.3: Focus Group Questions with Blind or Partially Sighted Students

We conducted a focus group with five students at the Institute for the Blind or Partially Sighted.

Below are the questions that we prompted the group with.

- How do you feel about the current accessibility of information about public transit?
- What do you like or dislike about how information in the bus system is distributed?
- What do you like or dislike about how information in the Metro system is distributed?
- What do you like or dislike about how information in the S-tog is distributed?
- What do you like or dislike about how information in the regional train is distributed?
- Do you use any mobile phone apps to help obtain information about public transportation? If so which ones?
- Is it more difficult to navigate and find information about unfamiliar routes?
- How do you feel about the audio announcements in the stations?
- How do you feel about the placement of braille or tactile signs in large stations? Are there places where you think braille or tactile signs would be useful?
- In an ideal world, what would you suggest to improve the accessibility of information in the public transportation system?

A3.4: Observation Protocol: Surveying Infrastructure of a Station

Name of Observer:

Date:

Time Started Observation:

Time Stopped:

Name of Station / Location of bus stop:

GUIDELINES FOR SURVEYING:

- Use a map of the area that you did infrastructural surveillance within the station

Infrastructure Evaluation:

Plot on map and describe within the map

- Presence / Location of tactile indicators in surrounding area
- Information gained from braille or tactile signs
- Area the bus or train pulls up to
- Location of speakers that make audio announcements
- Presence / Location of station attendants
- Observation: Compare what is on the boards to what is announced

A3.5: Maps for Observations

As stated in our protocol, we plotted the points that we observed within each station.

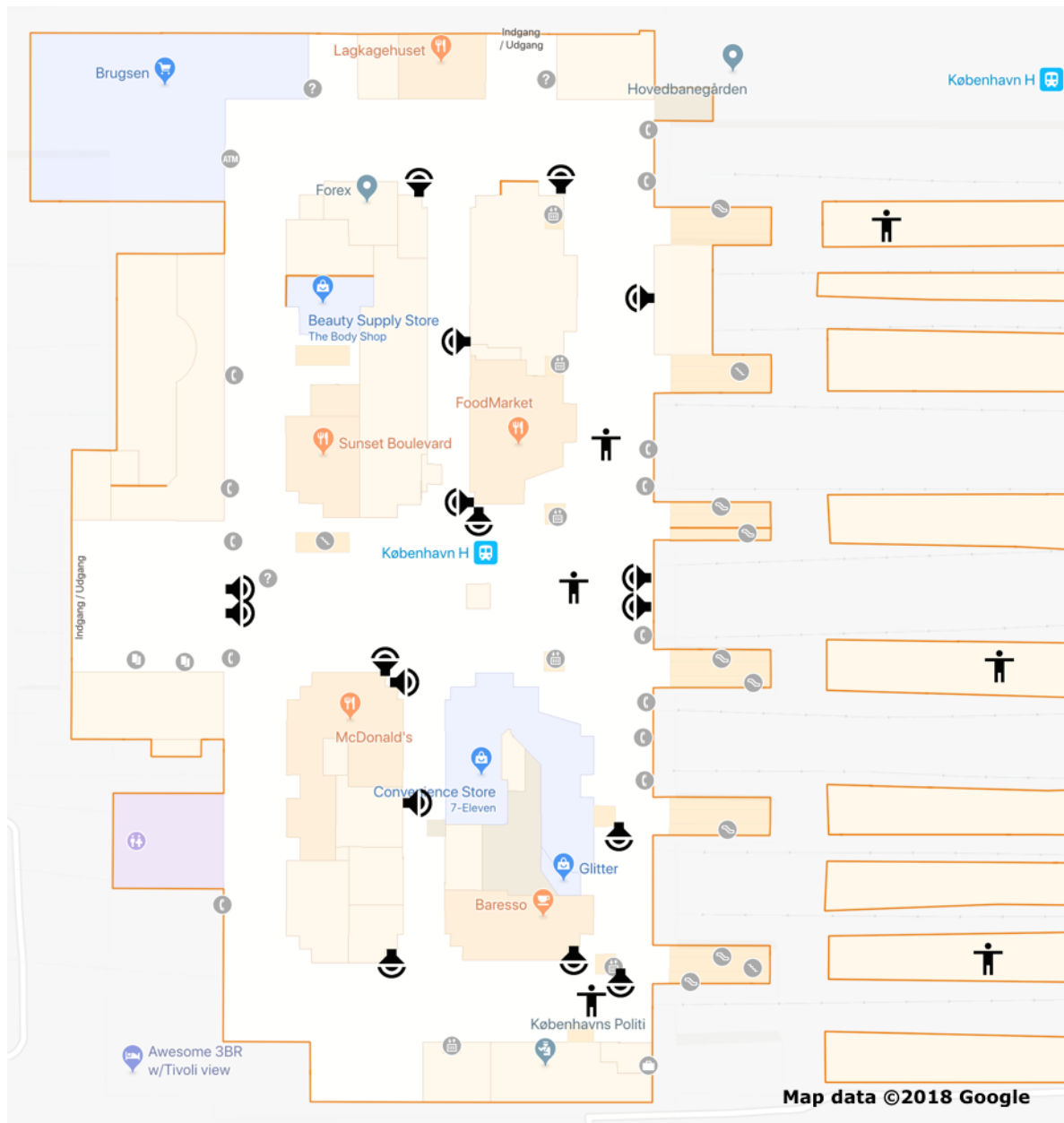


Figure 8. Observation map for Central Station (Google, n.d.-a)

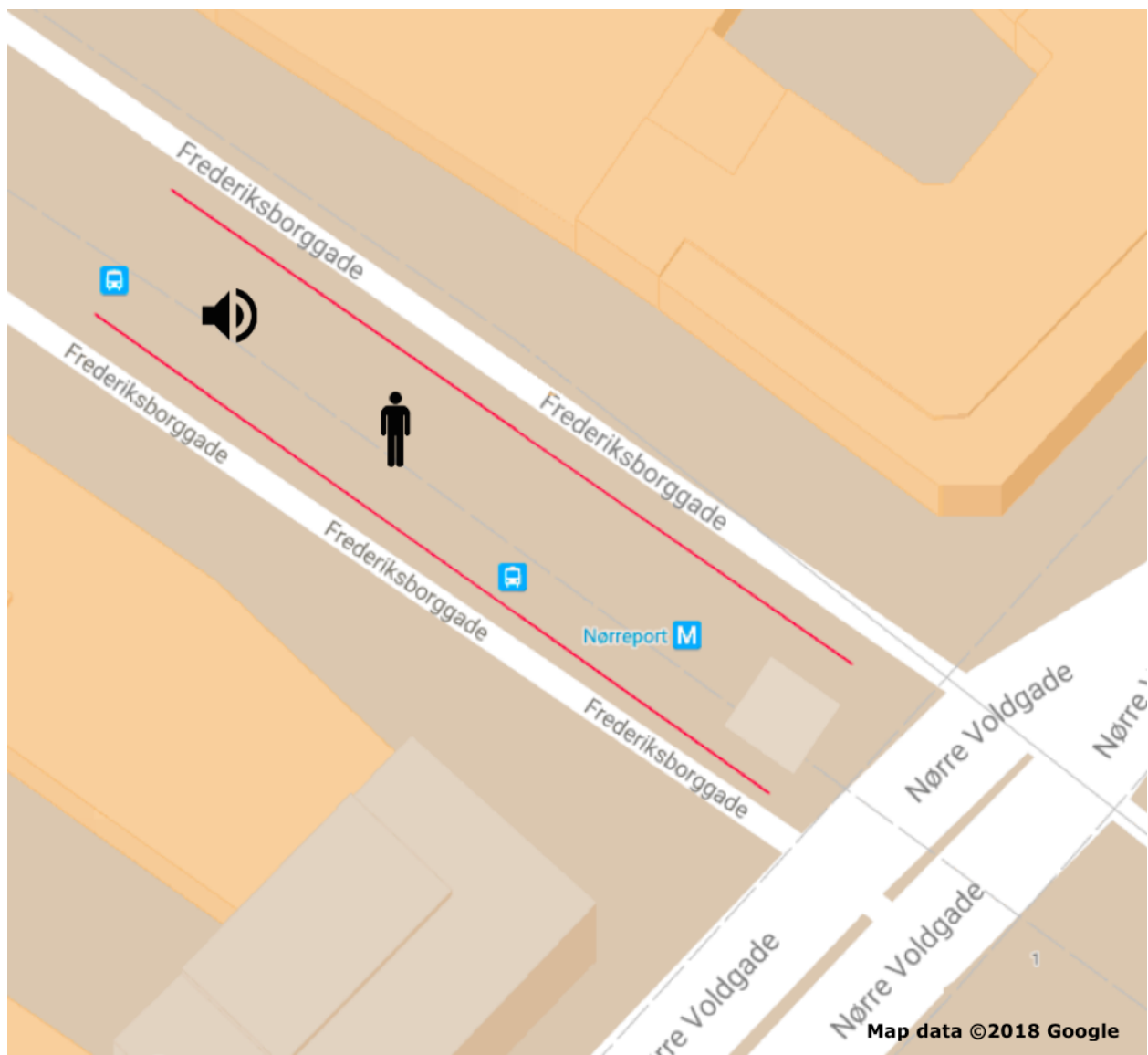


Figure 9. Observation map for Norreport Metro (Google, n.d.-b)

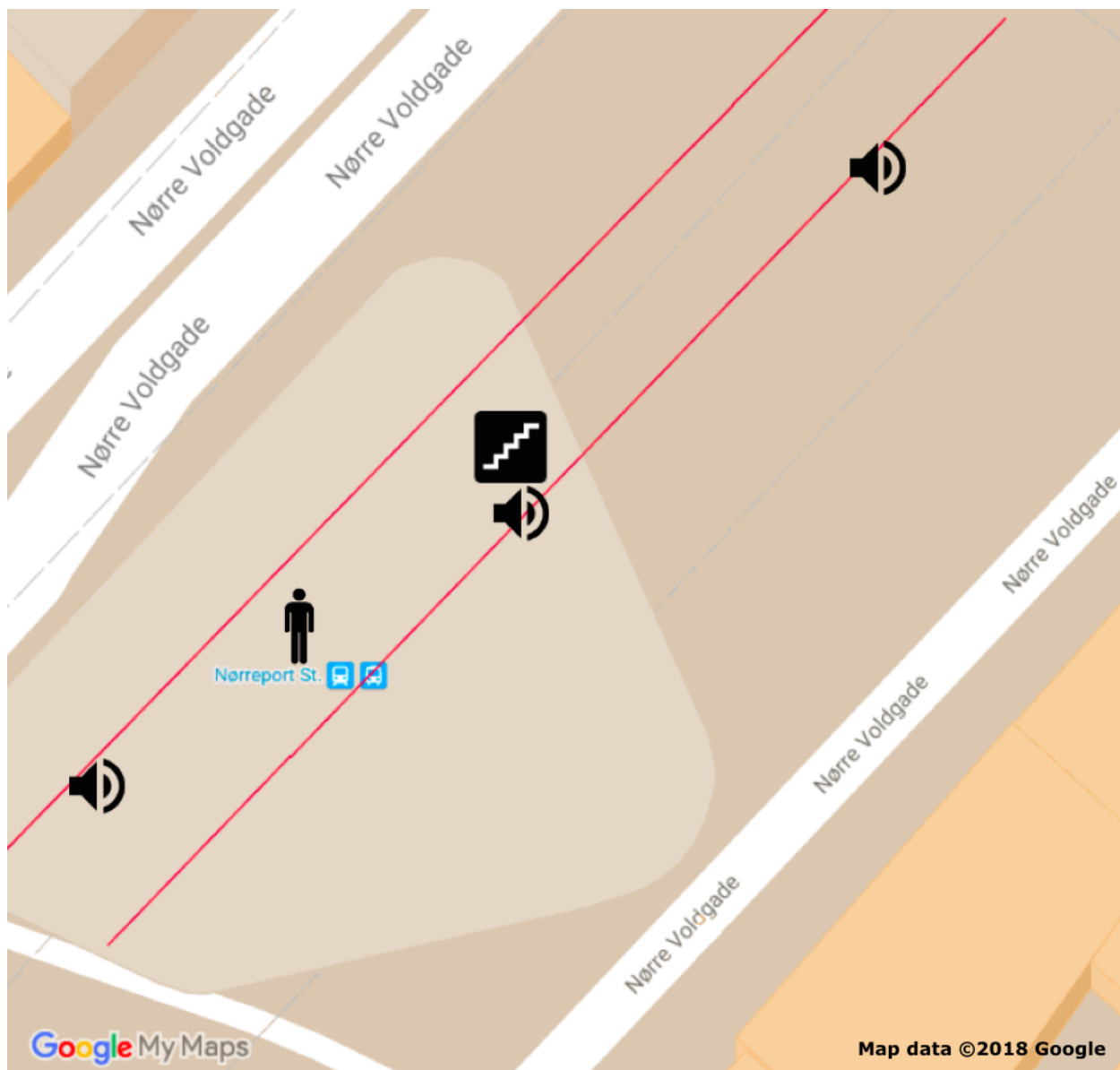


Figure 10. Observation map for Norreport S-train (Google, n.d.-c)

A3.6: Observation Protocol: Observation Within the Bus or Train

Name of Observer:

Date:

Time Started Observation:

Time Stopped:

Mode of transportation:

Line of transportation:

Where observation of bus or train started:

Where observation of bus or train stopped:

GUIDELINES FOR OBSERVATION:

- Try to sit in one seat
- Observe for fifteen minutes
- Observe during rush hours (8:00 - 10:00 and 15:00 and 17:00)

Audio Announcements:

Note in excel sheet

- Time of announcement
- Content of announcement

Stops:

Note in excel sheet

- Time bus or train stops
- Station at which the bus or train stops
- Note when bus or train stops without an audio announcement

Evaluating Ambient Noise:

Describe as a scale

- Number of people within train (Take pictures)
 - Less than 10 people: Not busy
 - 10-30 people: Moderately busy
 - 30+ people: Very busy
- Number of people at the bus (Take pictures)
 - Less than 5 people: Not busy
 - 5-15 people: Moderately busy
 - 15+ people: Very busy
- Note if announcement is obscured by noise

A3.7: Data Sheet for Observations

Below is an example of the data sheets that our team filled out while observing buses and trains, platforms, and stations/stops.

Example Bus/Train Observations: 37 to Nordhavn St.

Stop or announcement	Time	Notes
Get on at Classensgade	11:20	
"Next stop: A"	11:23	
Stop at A	11:24	behind another bus
"Next stop: B"	11:27	no stop
"Next stop: C"	11:30	
"Next stop: D"	11:32	
Stop at C	11:33	at stop
Get off at C	11:33	

Example observation from the platform: København H, S-train platform

Train	Platform	Arrival	Departure	Sounds	Announcements	Notes
B to Høje Taastrup	9	8:36		bell when doors open and close	Name of line/destination after door opens	
Re 1335 to Høje Taastrup	10	8:52		brakes, conductor's whistle before doors close	none	

Example observation from the station:

Announcement	Time	Notes
"Some train is leaving platform 12 in 7 minutes"	8:56	Repeated in English
"Some train is leaving platform 12 in a few minutes"	9:00	Repeated in English

A3.8: Observation Protocol: Observation of Trains on Platform

Name of Observer:

Date:

Time Started Observation:

Time Stopped:

Name of Station / Location of bus stop:

GUIDELINES FOR OBSERVING:

- Stay on the platform for one hour
- Switch location on platform every 15 minutes
- Plot the points that you are located on the map
- Observe during rush hours (8:00 - 10:00 and 15:00 and 17:00)

Audio Announcement of Identity of bus or train:

Note in excel sheet:

- Time of announcement
- Content of announcement
- Identity of bus or train
- Times bus or train arrives and leaves
- Time doors open and time doors close
- Any indicating noises of the doors opening or closing
- Track train departs from

Evaluating Ambient Noise:

Describe as a scale

- Number of people within train station (Take pictures)
 - Less than 10 people: Not busy
 - 10-30 people: Moderately busy
 - 30+ people: Very busy
- Number of people at the bus station (Take pictures)
 - Less than 5 people: Not busy
 - 5-15 people: Moderately busy
 - 15+ people: Very busy
- Note if announcement is obscured by noise

A3.9: Observation Protocol: Observations of Bus Stops

Name of Observer:

Date:

Time Started Observation:

Time Stopped:

Name of Station / Location of bus stop:

GUIDELINES FOR OBSERVING:

- Stay at the bus stop for 30 minutes
- Plot where you are located while observing
- Observe during rush hours (8:00 AM - 10:00 AM and 3:00 PM and 5:00 PM)

Note in excel sheet

- How many buses come by
- How many of the buses stop at their stop
- How many buses stop behind another bus at their stop
- How many buses stop behind another bus and at the stop
- How many buses pull out before the bus in front of them
- Identity of bus
- Time bus arrives
- Plot on map:
- Where the buses pull up
- Where the sign indicating the bus line is located

Evaluating Ambient Noise:

Describe as a scale

- Amount of people at the bus station (Take pictures)
 - Less than 5 people: Not busy
 - 5-15 people: Moderately busy
 - 15+ people: Very busy

Note

- Other sources of noise that may obscure announcements

A3.10: Mobile Phone Application Assessment Protocol and Data Sheet

Two group members met with one of our sponsors, to observe and assess the use of mobile phone applications with VoiceOver Technology. We prompted the participant to use each application, searching for which features of the app are inaccessible. We wanted to learn about why the participant chooses to use one app rather than another, and which features could be improved. Prior to this, one of our team members completed an application evaluation of the features of the apps that were available to him as a sighted user. We then compared these data to decipher which applications need to be improved and how. Below is the table that we used to assess the accessibility of each application. A condensed assessment of these four applications can be found in the chart below.

Application Feature Assessment

Feature	Afgange	DSB	Rejseplanen	Moovit
Buy tickets	N/A	Y	Y	N
Show schedule for specific bus/train	Y	N/A	N/A	Y
Show nearby stations	Y	N	Y	Y
Show upcoming departures	Y	Trains only	Y	SOME
Show ongoing delays / changes	Y	Y	Y	N/A
Plot routes between locations	N/A	Y	Y	Y
Traffic information	Y	Y	Y	N/A

Prior to our application assessment, we identified the primary features of each application used by our research participants. Note that although the subject who participated in our assessment did not use Moovit, we chose the applications to evaluate based on applications named in our interviews, so its features are listed in the table.

A3.11: Interview Questions for Stakeholders: DSB

In order to better understand which aspects of the public transportation system are controlled by DSB, we asked these questions in a formal interview with representatives from public transportation companies. First, we asked questions about how the system operates normally, and how it responds to irregularities. Then, we asked about DSB's previous work to improve accessibility within public transportation.

Questions about normal operation

- What aspects of the train system does DSB control?
 - Does DSB control the display boards within the station?
 - Does DSB control the audio announcements within the train stations?
- How does such accurate information get from trains to the screens at the stations? Slash how does the station know where trains are?
 - How does that information get to Rejseplanen?
 - How does the information from the platform get to the display board?
- What happens if there is a delay or change in the schedule?
 - How does the system deal with that?
- Do all platforms have the capability to make audio announcements?
- When or why are audio announcements made normally?
 - Differences between types of trains.
 - How do they decide which trains make audio announcements inside the trains?
 - What stations routinely make audio announcements?
 - Who decides what is said over the audio announcements?

Questions about accessibility

- What are your policies regarding accessibility?
 - Does DSB have any specific strategies for incorporating accessibility?
 - Has DSB made any changes to make the display boards more accessible?
- Through our observations, we have noticed that DSB trains have audio announcements within them that aid people who are blind or partially sighted. Has DSB made any other accommodations specifically for the blind and partially sighted commuter?
- What are some factors limiting accommodations?
- Does DSB have a specific budget set aside for making accommodations?
- To what extent do you communicate with advocacy organizations for people with disabilities, specifically blind or partially sighted, about the need for more accessibility features?

A3.12: Interview Questions for Stakeholders: Banedanmark

We were made aware by DSB officials that Banedanmark and DSB share many aspects of the train system. We interviewed two representatives of DSB first, which allowed us to form clarifying questions. The following questions helped us understand which parts of the system are controlled by which company.

Questions about normal operation

- What aspects of the train system does Banedanmark control?
 - To what extent does Banedanmark control the display boards within the station?
 - To what extent does Banedanmark control the audio announcements at the station or on a platform? Does Banedanmark control the hardware of the announcement systems?
 - Do all stations have announcement systems?
- DSB told us about the sensors on the tracks that updates the train's proximity to the station in a form of an estimated time of arrival. We know that this is present mostly in the S-train system, but how does updated information get from trains to the screens at the stations?
 - A representative of Rejseplanen told us that Banedanmark provides them with information. How does that information get to Rejseplanen?
- What happens if there is a delay or change in the schedule?
 - When there is a delay or unexpected problem, how is that information relayed from the train to Banedanmark? Is that process automated?
 - How does a schedule change get relayed to Rejseplanen quickly?

Questions about accessibility

- What are some factors limiting accommodations?
- What are your policies regarding accessibility?
 - Does Banedanmark have any specific strategies for incorporating accessibility?
 - Has Banedanmark made any changes to make the display boards more accessible?
- Through our observations, we have noticed that DSB trains have audio announcements within them that aid people who are blind or partially sighted. Has Banedanmark made any accommodations specifically for the blind and partially sighted commuter?
- Does Banedanmark have a specific budget set aside for making accommodations?
- To what extent do you communicate with advocacy organizations for people with disabilities, specifically blind or partially sighted, about the need for more accessibility features?
- How can the automated announcements in stations be modified? In the regional trains?
 - Are there special procedures Banedanmark has to follow to change contents or timing of the automated announcements?
- Could the system play each announcement twice when they are made (or in Danish, then English, then Danish again)?

A3.13: Interview Questions for Stakeholders: Movia

Through a telephone interview with a representative from Movia, we were able to ask these questions to gain a better understanding for how the bus system is run and regulated. We also sought information about how much control Movia has over the buses, bus stops, and bus drivers.

Questions about normal operation

- To what extent do you communicate with advocacy organizations for people with disabilities, specifically blind or partially sighted, about the need for more accessibility features?
- How does Movia collect and distribute the updated schedule information displayed on boards and in mobile phone applications such as Rejseplanen?
- Through our observations, we have noticed that the buses in the Movia system have audio announcements within them. Has Movia itself made any other accommodations specifically for the blind and partially sighted commuter?
 - Is there a potential for a way to announce the identity of the bus line at each bus station?
- Does Movia control the audio announcements within the buses? If so, is there a standard template for what is said over the audio announcements?
 - How does the system with these announcements normally work and how does it account for delays in the system?
- Does Movia control the display boards within the bus stop? If so, has Movia made any changes to make these display boards more accessible?
- What role does Movia have in driver training?

Questions about accessibility

- We would love to learn more about the potential for the Beacons at bus stops. We have looked into Beacons quite a bit as a solution to help the blind and partially sighted, especially for identifying the bus line. We would like to know more about:
 - What purpose does Movia intend to use the beacons for?
 - How will Movia continue to update the Beacon information?
 - Where will these beacons be placed?

A3.14: Interview Questions for Stakeholders: Rejseplanen

A representative presented a general slideshow to our team that briefly explained the history of Rejseplanen and the services that they provide to public transportation. Following this presentation, we were able to ask clarifying questions to better understand how Rejseplanen provides information to public transportation companies and therefore commuters.

- Where does Rejseplanen get their information about schedules?
- Have you found any accessibility problems with the Rejseplanen website and app in the past? If so, could you give us some examples? What has previously been done to make Rejseplanen's website and app more accessible?
- Besides your work with Diversa, do you use any other strategies to test your products for accessibility to those who are blind or partially sighted? If so, how else do you test your products?
- To what extent do you communicate with advocacy organizations for people with disabilities, specifically blind or partially sighted, about the need for more accessibility features?

A3.15: Interview Questions for Stakeholders: Kontakt.io

In order to learn more about how much a beacon system would cost in Denmark, we contacted a beacon company that already supplies beacons to the building the DAB is held in. We hoped to complete an economic evaluation of this project, and to do this we asked the questions below.

- We saw on your website that you focus mainly on indoor solutions. Would it be possible to use Kontakt beacons for outdoor solutions?
- Would it be possible to make beacons that make noise?
- Theoretically, how much would it cost to equip 3000 buses with beacons?
- Is Beacons for Good a project that is still ongoing? Would Dansk Blindesafund and Movia qualify for Beacons for Good?
- Has Kontakt.io provided beacons for transit before?

A3.16: Interview Questions for Exemplary Beacon Project: Tandem Association

- We know that the Tandem Association provides opportunities for people at risk of social exclusion, including people who are blind or partially sighted. Could you describe how the Tandem Association does that? What else does the Tandem Association do?
- You mentioned that the Tandem Association has 3 projects for urban accessibility using iBeacons that cover busses, street navigation and subway.
 - Could you describe these projects?
 - How did the Tandem Association start these projects?
 - Whose idea was the project?
- Why did you chose beacons? Have beacons been successful?
- Could you describe the pilot testing process?
- Is the Smart Public Transport project ongoing?
- What are they using beacons for within the public transit system?
- What kind of relationship does the Tandem association's relationship have with public transportation companies? In particular, what do those companies do to keep Smart Public Transport running, if anything?
- How many beacons do you have per mode of transit (i.e. bus, train car, metro)?
- How did the Tandem Association subsidize the cost?
- So overall, you would say that this project has been very successful?
- Would you like us to put you in contact with our sponsors at the Danish Association of the Blind?
- Have you run into any problems with people not wanting to use the app?

Chapter 4 Appendices: Findings

This appendix includes documents and results that are pertinent to the findings chapter.

A4.1: Observation Results Table

Nørreport Station Observation (4/18/18)

Bus # and Location	Time of Arrival	Notes
150S: pulled up to the stop, no other buses in queue	16:08	
42: pulled up behind 150S	16:08	
6A: pulled up behind 150S and 42	16:08	
6A: pulled up behind 150S, 42, and 6A	16:08	
6A: pulled up to stop, no other buses in queue	16:11	
15E: pulled up behind 6A	16:13	
184: pulled up to stop, no other buses in queue	16:14	
150S: pulled up behind 184	16:15	There was no name on the screens on the front or the side of the bus.
6A: pulled up to stop behind 150S and 184	16:16	

End of Observation

Central Station Observation (4/12/18)

Bus # and Location	Time of Arrival	Notes
5C: pulled up to the stop, no other buses in queue	12:58	
9A: pulled up behind 5C	12:58	Left before 5C
5C: pulled up to the stop, no other buses in queue	13:00	
9A: pulled up behind 5C	13:01	Left before 5C
2A: pulled up to the stop, no other buses in queue	13:01	
66: pulled up to the stop, no other buses in queue	13:02	
34: pulled up to the stop, no other buses in queue	13:03	
5C: pulled up to the stop, no other buses in queue	13:06	
9A: pulled up to the stop, no other buses in queue	13:07	
2A: pulled up to the stop, no other buses in queue	13:10	
250S: pulled up to the stop, no other buses in queue	13:11	
66: pulled up to the stop, no other buses in queue	13:11	

End of Observation

Re-Train From Høje Taastrup to Nørreport (4/12/18)

Line	Time	Notes
Start at: Hoje Taastrup	15:49	whistle blew, door closed
"_"	no announcement	
Stop at Valby	15:58	no announcement
"_"	no announcement	
"Next stop: Central"	16:03	very difficult to understand, seemed to be information about other trains and several destinations.
Stop at Central	16:05	
"_"	no announcement	
Arrive at: Norreport	16:10	no announcement

End of Observation

Re-Train From Østerport to CPH Lufthavn (4/13/18)

Line	Time	Notes
Start at: Østerport	19:07	
"Next Stop: Nørreport"	19:08	
Stop at Nørreport	19:09	no announcement
"Next Stop: Copenhagen Central Station"	19:12	Automatic
"Next Stop: Copenhagen Central Station in a few moments"	19:12	Automatic
"Our next station is Copenhagen Central Station and we will be continuing to Copenhagen Airport"	19:13	Manual, Harder to hear
Stop at Central Station	19:14	
Train Leaves Central Station	19:16	Operator Blows Whistle; Doors close with Beeping
"Next Stop: Ørestad"	19:21	
Stop at Ørestad	19:22	Doors open without sound
"Next Stop: Tårnby"	19:23	Doors close without sound
Stop at Tårnby	19:24	Doors beep when opening
Train Leaves Tårnby	19:25	Operator Blows Whistle
"Next Stop is Copenhagen Airport. The train does not go any further. We kindly ask passengers to keep track of their belongings"	19:27	
Train Arrives at Copenhagen Airport	19:28	

End of Observation

Central Station, Regional Trains: Tracks 1 and 2

Number of Trains	Number of Identification Announcements
11	0

Central Station, S-Trains: Tracks 11 and 12

Number of Trains	Number of Identification Announcements
16	16

Bus Line Observations

Line	Stops passed	Announcements	Actual stops	Mis-timed Announcements	Missed Announcements
3A Nordhavn St.	13	13	13	2	0
6A Rødovrehallen	10	10	9	0	0
6A Buddinge St.	5	1	5	0	4
37 Nordhavn St.	8	8	5	1	0
37 Amagerværket via Kløvermarksvej	11	11	8	0	0
1A Hvidovre Hospital	4	4	4	0	0
37 Nordhavn St.	9	9	6	0	0
14 Østerbro, Ryparken	7	7	4	2	0
21 Hellerup St.	3	3	1	0	0
169 Hellerup St.	6	6	4	0	0
21 Rødovre St.	18	18	13	0	0
2A Lergravsparken St.	13	13	8	0	0
21 Rødovre St.	6	6	3	1	0
14 Mozart Plads	15	15	14	0	0
3A Kongens Enghave Valbyparken	4	0	4	0	4
42 Ballerup St.	11	11	10	0	0
37 Amagerværket via Raffinaderivej	10	10	8	0	0
1A Hvidovre Hospital	8	8	8	0	0
150S Nørreport St.	9	9	9	0	0
Total	170	162	136	6	8

A4.2: Interview Content Analysis Table

These tables show how we completed content analysis for both our community interviews as well as our focus group, through creating categories and codes. We took note of how many participants answered for each code.

Content	Number of Interview Participant Responses (out of 7 total participants)
Activities to reach	
Jobs	7
Social engagements	6
Family/friends	2
Sport	2
Everything	3
Feelings about current accessibility	
Usable	5
Needs improvements	2
Transit Problems	
Obtaining updated scheduling information while traveling	4
Schedule/route irregularities	6
Announcement problems	4
Apps	3

Content	Number of Interview Participant Responses (out of 7 total participants)
Identity of line	4
Unfamiliarity with systems	3
Existing Solutions	
Audio announcements	7
DSB phone service	1
Other commuters	5
Planning ahead	2
Apps	7
Radio	1
Suggestions for improvement	
Better announcements	7
More accessible apps	1
More accessible website	1
Automatic identifications of vehicles	3
Obligation of vehicle to stop at specific stop	1
Systems to distribute information (BLE beacon, etc.)	2
Tactile indicators	1

Content	Number of Focus Group Participant Responses (out of 5 total participants)
Things they like about how they obtain information	
Trains stop at every stop	4
Buses tell the stops	2
Metro tells you where it's going; most accessible	5
Feelings about current accessibility	
Fairly Accessible	1
Easy	1
Need to pre-plan your journey	3
Transit Problems	
Obtaining information while traveling	5
Announcement problems	5
Identity of line	5
Familiarity with systems	3
Mobile Phone Applications	

Content	Number of Focus Group Participant Responses (out of 5 total participants)
Journey Planner	5
Movia	1
Suggestions for improvement	
Better announcements	5
Automatic identifications of vehicles	5
Tactile indicators	4

A4.3: Survey Results

The survey received a total of 21 replies, 13 from the emailed version and 8 from the facebook post. The first two questions (asking for consent and if the respondent uses public transportation in Copenhagen) are not listed here, as all respondents answered yes to both.

Question 3: Which mode of transportation do you use most?

Response	Number of Replies
S-train	11
Bus	9
Regional Train	3
Metro	1

Note: This counts respondents who said "other: s-train and bus" and other similar answers as all categories they said they used frequently, so the total number of replies does not match the number of respondents.

Question 4: Do you find that public transportation in the greater Copenhagen area provides full accessibility to blind or partially sighted commuters?

Response	Number of Replies	Percent of Total Replies
No	6	28.57
To some extent	15	71.43
Yes	0	0

Question 5: Do you ask for assistance (about the identity of a bus, for example) from surrounding commuters?

Response	Number of Replies	Percent of Total Replies
No	2	9.52
Sometimes	7	33.30

Response	Number of Replies	Percent of Total Replies
Yes	12	57.10

Question 6: If yes or sometimes, do you find that people are willing to help?

Response	Number of Replies	Percent of Total Replies
No	0	0
Sometimes	6	31.60
Yes	13	68.40

Question 7: Is it difficult to receive information about your trip from stations or the vehicle?

Response	Number of Replies	Percent of Total Replies
No	4	19.10
To some extent	12	57.10
Yes	5	23.80

Question 8: What accessible features do you notice as helpful when using public transportation in Copenhagen? [multiple selections allowed]

Response	Number of Replies
Announcements	19
Braille	1
Other	6

Note that as question 10 was open-ended, some respondents gave multiple replies.

Question 9: What features do you notice as difficult to use when on public transportation? [multiple selections allowed]

Response	Number of Replies
"Multiple Modes"	9
"Quiet Announcements"	14
"Lacking Braille"	10
Other	9

Note that as question 10 was open-ended, some respondents gave multiple replies.

Question 10: Do you or have you ever used aids or smartphone applications? If so, which? [text entry]

Response	Number of Replies
Rejseplanen	6
DSB	3
Pendlerpal	2
Afgange	1
Afgangstider (app)	1
Blindsquare	1
Check-out app	1
SIRI	1
Taking pictures and zooming in	1
Cane	5
Guide Dog	2
None	1

Note that as question 10 was open-ended, some respondents gave multiple replies.

A4.4: Rejseplanen Interview Notes

These notes are a summary of our interview with a representative of Rejseplanen. Our full interview transcription is available in Supplemental Materials.

Rejseplanen Interview, April 10 @11:00

Interviewer: Caroline

Scribe: Jacob

Normal operation

Different companies submit their timetables 24 hours in advance. Rejseplanen compiles this data. Users can use Rejseplanen data to plan the best journey for them from point A to point B

Standards/Policies

Rejseplanen codes to live up to WCAG 2.0, which is part of EU law. Rejseplanen ensures HaCon complies to these standards.

Plan for Accessibility

Rejseplanen's main goal is to deliver a solution that will live up to the expectations of the blind and partially sighted user. Their secondary goal is do a bit more to make using Rejseplanen an extremely easy experience. The problem is that all of the traffic companies would have to agree on these changes. At the moment, accessibility is not the "hot topic"; planes and bikes and ride sharing are hot topics because that's where the money is. Going above and beyond would include identity of the line and info about the accessibility of the trains or the buses (i.e. if a wheelchair could fit into the train).

Rejseplanen is starting work with Diversa Consulting. There was a conference on Friday 4/13 (Which we attended. Diversa will ensure that every accessibility problem is actually solved and that the website complies completely to WCAG standards. Diversa also can give ideas on how to go above and beyond complying to the standards. Rejseplanen is fixing the website first and then the app. They want to get a Diversa report every 6 months. Diversa can show them the problems rather than telling them the problems - an important distinction that makes it much easier for the software engineers to figure out how to fix what is wrong. Rejseplanen also wants to learn how to perform Diversa-approved checks for accessibility.

Working with Advocacy

In the past, Rejseplanen has asked Dansk Blinesamfund to test app and website for screen reader accessibility, then asked their software developer to fix the issues. They have also asked Dansk Blinesamfund about obvious accessibility changes.

Our interviewee also used to work for Movia, and he said that Movia had a relationship with an advocacy organization for their old bus identity app, which they no longer use.

The aspects of the system do they control

Rejseplanen displays the best journey from point A to point B. They generate the information on the signs on the train platforms. However, Rejseplanen doesn't control the content of the information: the transport companies control that. They do not control the coding of the website and app: HaCon codes the app and then Novo Nordisk checks the app - they're in very close contact with HaCon, they talk at least once a week. HaCon likes Rejseplanen a lot because they have control over a whole country

Movia controls the poles that say what number the line is, the schedules and timetables, which companies drive the buses and which provide the buses. Movia doesn't control the big stations, the local authorities control that, nor do they control the buses or the bus drivers, they contract that out to other companies.

Information distribution

Movia used to have an app that could read out which bus was coming into the station. The transportation companies talk to each other to decide on a date to have the timetables done to make sure they match up and work out. Then they give data to Rejseplanen and then they take the organized journeys back because they want HaCon's capabilities. Rejseplanen focuses on displaying a good search result.

Economics/Budget

Right now, Rejseplanen is working with Plane companies and bike and car share companies because they pay Rejseplanen but they don't have stake in Rejseplanen. With all big projects, money is a concern, and all of the stakeholders have to be on board for it to get funding.

Accessibility Problems in the past

In the past, Rejseplanen has found that there is no alt text description for some of their pictures in their website. At one point, the screen reader was coded to read the journey from the destination up to the start point. Old Version of the website is solved for the majority of accessibility problems, new version might not be.

Company	Ownership Percentage
DSB	48.4%
Movia	21.7%
Metroselskabet	3.2%
NT	5.6%
Midttrafik	10.7%
Sydtrafik	6.6%
Fynbus	3.2%
BAT	0.6%

Each company's share in Rejseplanen is determined by the amount of traffic it receives.

A5.1: Community Interview Notes

These notes are a summary of our interviews with people from the blind or partially sighted community member. Our full interview transcriptions are available in Supplemental Materials. *These appendices have not been directly referenced in our paper.*

Community Interview A, March 22 @10:15

Interviewer: Caroline

Scribe: Jackie

Q: How often do you use public transportation?

A: Very, everyday. I am a frequent user of public transport.

Q: What types of activities do you use public transportation to get to (e.g. social activities, jobs, etc.)?

A: I use it to go to work, social, private engagements, dinner, concerts, meeting up with friends.

Q: How do you feel about the accessibility of public transportation?

A: I think it is good enough but could be better. Depends on where you're going: Home is a 5 min bus ride to get to train station. Only one bus so it isn't confusing. More buses can make it more confusing. If you don't know which bus is in front of you, as there are 4 in the queue you don't know which one you need to take. The city is more confusing.

Q: What aspects of the public transportation system do you find frustrating?

A: Lots of buses in the city is frustrating. Your bus can pass you by because you are late. You can grab someone and ask, but if not it'll leave without you. Automatic announcements in the buses are sometimes not on. Bus drivers may turn them off. Centrally controlled system but sometimes it isn't on.

Q: What aspects of the public transportation system do you think help your commute?

A: The announcements on trains telling you where you are. In a train station with heavy traffic, trains announce themselves when they pull into the station, "This is the b line going to this station."

If you ask, someone can tell you wrong information. It's nice to listen and make sure it's your train because it announces itself. Automatic announcements help you not panic. Whenever it stops it announces what stop it is but if they aren't on you have to worry about how many stops and calculations can be off.

Q: How do you get updated information about public transportation (e.g. schedule changes, arrivals, departures, and which bus or train is the bus or train you want to be on)?

A: I use people, fellow commuters, audio announcements. I also use a mobile phone app called departures. It's a satellite app that can see what buses are nearby and can tell you what time they are leaving, trains as well, at the nearest bus stop or nearest train station. It can tell you whether the bus has been delayed. It may not be correct but at least you are aware of a delay. It's not 100% correct but it does a good job. I also listen to the radio which gives traffic updates and information and shows signal issues.

Q: What is difficult about getting updated information? Do you use any assistive devices to aid you in your travels?

A: It isn't hard to get updated information. When the train pulls into the train station it may not pull into the same spot all the time. Train to the city at central station can either go on track 11 or track 12. The app can tell her one thing and then they change it last minute. Opened on the left side not on the right side. When the doors open on the wrong side, it gets confusing. I sometimes don't know if I should turn to the right or turn to the left, and makes me lose my way.

Q: What would you suggest to improve the accessibility of information in the public transportation system?

A: It would be wonderful if it announced "We have reached Høje Taastrup station and we are sitting on this track". Sometimes a train usually stops on the left side but sometimes it decides to pull up on the right hand side, so a train announcing where it is is useful. When the trains switch tracks, they should announce the changes. It happens sometimes, but it is not consistent.

Q: Any Mobile Phone App Improvements?

A: In the city there is a queue of buses, help us get information: there are 3 buses in the queue and bus 5A is first in the queue, bus 2 is 2nd in the queue. Especially at Tivoli Gardens: lots of buses and it is hard to tell what is the correct bus. Figuring out what bus is coming first would be amazing. Buses could announce themselves, but that can be confusing. They announce themselves in Jutland but this feature is not widespread.

Q: What would you want to see? What you like/ don't like?

A: The system is not bad, it's worse elsewhere. Things just need to be touched up.

Community Interview B, March 22 @ 11:19

Interviewer: Alyssa

Scribe: Jacob

Q: How often do you use public transportation?

A: Every day

Q: What types of activities do you use public transportation to get to (e.g. social activities, jobs, etc.)?

A: Primarily job, secondary spare time activities such as training.

Q: How do you feel about the accessibility of public transportation?

A: It's pretty good, actually. It's knowing which train to go with: if the train can tell me which it is and which stops we are at while travelling then that's good. Finding the doors can be individual, but that's easy for me, same for navigating within a train. Trains are good, especially the S-tog.

Q: What aspects of the public transportation system do you find frustrating?

A: Usually there are delays, train can be cancelled, not sure if app is as up-to-date as the screen on the platform. You wonder: Why isn't the train here yet? Last-minute changes, the app may not update enough, and when it's a matter of minutes, it's a problem. Announcements about such changes aren't as well-done.

Q: How do you get updated information about public transportation (e.g. schedule changes, arrivals, departures, and which bus or train is the bus or train you want to be on)?

A: I use the DSB app. It usually works well, as long as there are no changes. The app says when/where train leaves, etc. I think it is quite easy when it works.

Q: What is difficult about getting updated information? Do you use any assistive devices to aid you in your travels?

I used to use another app, can't remember name. Often people ask if you need help.

Q: Do you ask for help often?

I want to be as independent as possible. People sometimes ask to help without being asked.

Q: What would you suggest to improve the accessibility of information in the public transportation system?

A: More audio information, improvements to my accessibility often help many others. Also, standing on platform with long train and a coach reservation, how do I know where to get on? This is

only given by some signs. They used to say where each coach would be, and that would help me a lot, as well as fully-sighted people. They are good at announcing cancellations, which is a big help.

Community Interview C, March 22 @ 13:15

Interviewer: Caroline

Scribe: Jackie

Q: How often do you use public transportation?

A: On a daily basis

Q: What types of activities do you use public transportation to get to (e.g. social activities, jobs, etc.)?

A: Job commute, leisure travel, various culture activities. I don't have my own vehicle, so I depend on walking or taking public transportation.

Q: How do you feel about the accessibility of public transportation?

A: Over the years public transport has improved in terms of accessibility. When I was younger the S-train didn't make any announcements so you had to count the stations and ask other commuters where you were. The announcements are really helpful. The automated trains came first (integrated at the turn of the century). The buses started making announcements in about 2009. Announcements made most of the time is better than no announcements. Also the courtesy of the driver; asking them where you are or where you are going. They may sometimes forget you had asked.

Q: What aspects of the public transportation system do you find frustrating?

A: When you have multiple lines for a train or bus at the same place, especially buses because when you have different lanes for buses with 10-20 buses coming in, with other traffic and the bus engines, the noise level is super high. I also have a hearing impairment that can affect his orientation in certain places to a certain degree. When you have to get an overview, you need to know where the specific bus is situated. Even when you know what bus it is, there may be multiple buses in a queue, and it is hard to distinguish which is which. They may not come to their designated spot and you risk missing your bus. Trains are mainly a problem in central: southbound and northbound both have two tracks. The ambient noise and the train announcement system isn't that loud, you may miss the announcement and it is only repeated once. You may also mishear it and end up on the wrong train. Once the trains are completely automated, there is no way to ask the driver to ask. To get information, I ask other people, ask the driver and to make sure you know your surroundings. Delays may make it difficult. I plan my journey ahead.

I use Journey planner and Rejseplanen for places I don't know or places under construction. I have various apps on my iPhone - For the bus stops nearest me for planned changes in the system I use Afgange. Afgange also gives information about planned and unplanned delays as well as if there are escalators out of order or anything like that. Loudspeaker announcements don't give enough information about true changes, and routes in these trains might be longer because of changes, but if you know the area then you know that you're safe.

Q: What aspects of the public transportation system do you think help your commute?

A: The automated announcement systems, when they work they are usually reliable.

Q: How do you get updated information about public transportation (e.g. schedule changes, arrivals, departures, and which bus or train is the bus or train you want to be on)?

A: I plan beforehand. Not all stations with the s-train announce it. Sometimes they turn the system off. Sometimes it says its going to stop but it doesn't

Q: What would you suggest to improve the accessibility of information in the public transportation system?

A: It would really help to automatically get information regarding which specific vehicle is approaching where you are. If, in a bus terminal, something saying "this is bus stop """, and it's supposed to be here". Tactile/braille information is helpful too, so you can tell that this is area A, B, C... etc. Specific tracks that buses and trains are going to be on and an announcement saying "Train coming from ... going to ...". The bus itself telling us what it is: Many of the bus drivers are immigrants so they don't speak Danish, and some are afraid of the dog or just not friendly. It would be cool If a bus comes to have an app that send a signal and tells you what bus it is or some sort of QR code on the sign. In the greater copenhagen area, there are many different modes of transportation and we are getting another "light rail" in 4 or 5 years. Unless you are a frequent traveler, you lose the memory. Accessibility features being identical across all modes would also help. What is being done elsewhere? It'd be good to see what works/what doesn't in terms of reliability, accessibility, cost effectiveness.

Community Interview D, March 23 @ 10:05

Interviewer: Alyssa

Scribe: Jacob

Q: How often do you use public transportation?

A: Almost every day, primarily the bus and train

Q: What types of activities do you use public transportation to get to (e.g. social activities, jobs, etc.)?

A: Primarily to/from job and going places with family. Also as part of job; traveling in the country for meetings via Long-distance trains.

Q: How do you feel about the accessibility of public transportation?

A: It's usable, but it could be much better.

Q: What aspects of the public transportation system do you find frustrating?

A: Getting "trustworthy" info at station or bus stop. When I am there, which bus is coming, confirmation that I'm boarding the right train. Once you are in the train, esp. long-distance, check that you are in the right car because trains split for different destinations. Also for pre-booked seats, you must ask for help. But confirmation that I'm using the right bus/train is most important. Which bus will be the coming first and, how long will I have to wait. Checking in and out with the card can be hard; finding the check-in and -out points without help can be hard.

Q: What aspects of the public transportation system do you think help your commute?

A: The S-train and metro, announcements are clear. Announcements of the type of train coming, destination; announcements are helpful. When waiting at platform for train, announcements tell which train arrives. This shows that announcements are possible. And they are very helpful. Sometimes there are technical difficulties. It is noticeable when they don't work. Announcements of stops on trains and (most) buses are helpful. So I don't need to be alert at all times.

Q: How do you get updated information about public transportation (e.g. schedule changes, arrivals, departures, and which bus or train is the bus or train you want to be on)?

A: Tactics are most important for trips besides standard trip (e.g. not going to work). I use Rejseplanen to plan the trip. Takes schedule changes into account. At the station, I use the telephone service. Tells which trains are at which platforms, etc. Noisy surroundings make it harder to use. Stations with many trains make it harder to use. You can book phone service. Go through menu by pressing

numbers on keypad. I don't use smartphone apps. *[So uses Rejseplanen website.]*, I can plan my journey by voice using Rejseplanen.

Q: What are some actions you take to receive current information about public transportation?

A: Rejseplanen to plan around changing information. I ask for help when necessary. Sometimes bus routes change. You don't always know in advance, and don't always notice until it is too late. You can ask for updates

Q: What would you suggest to improve the accessibility of information in the public transportation system?

A: The main issue is once you are at the bus stop/terminal or train station, identifying the right one. More external announcements for buses would be helpful. How that should be done, I don't have a preferred solution. The confusing situation at the busy bus terminals is the main issue. In a new area, identifying bus stops can be an issue.

Community Interview E, March 23 @ 10:05

Interviewer: Caroline

Scribe: Jackie

Q: How often do you use public transportation?

A: 3 or 4 days a week

Q: What types of activities do you use public transportation to get to (e.g. social activities, jobs, etc.)?

A: Work, social, sport, everything

Q: How do you feel about the accessibility of public transportation?

A: I manage to get around so it can't be that bad. There is always room for improvement and things that can be better but I am able to get around on my own.

Q: What aspects of the public transportation system do you find frustrating?

A: Mostly the non-information about track changes and delays on the trains. When I go to the main central station, there are often track changes made on the screens. They are sometimes said aloud, but most of the time not. I live in a small town and I have been traveling here for 10 years, so my neighbors recognize me and help me find my way. I am lucky that way. I do still have trouble getting around. I use all the apps and I get push notifications from them but they often come too late. I do not feel comfortable to trust it. Rejesplanen, Afgange, Moveit are all apps used for transportation.

Q: What aspects of the public transportation system do you think help your commute?

A: It's really good that the S-trains have mostly reliable announcement systems in them. They announce inside and out. I take the regional train back home and the train doesn't say anything so I have to ask my fellow commuters where the train is going. I can't assume that because it is the right time, that we are at the right stop. Most people are helpful and there was one time that I didn't get a response, but then I realized that it was a pole that I was talking to.

Q: How do you get updated information about public transportation (e.g. schedule changes, arrivals, departures, and which bus or train is the bus or train you want to be on)?

A: Other than apps, I use other people and the speakers on the tracks. There is a number that I can call where there is a recording of the tracks etc. but I have never used it. I think it takes too much time to call the number and put the code in. There used to be this large board that showed the announcements, wasn't on the track, only in the main hall in central station, but it had buttons you could push and it would tell you the information. Track was supposed to come in on track 2 but it came

in on track 1 and 300+ people had to run to get the train on track 1, going under the track and up and down etc. I am good at running but if i was in a wheelchair or I had a baby stroller, I couldn't make it.

Q: What would you suggest to improve the accessibility of information in the public transportation system?

A: I would like the regional train to have the announcements in the train as well as outside. They don't work sometimes. Many buses have indoor announcements inside but finding the correct bus is difficult. And i have to ask the driver and other passengers if it is correct. Beacons of something in the bus stop. To find the bus stops easier and telling you which line it is and where it is heading. I have a guide dog that helps me with a lot of stuff. The tactile guidelines in the stations are not as good as they should be in many places. In B.. where I live, they have tactile strips but they are not extended to the edge of the platform.

Community Interview F, March 23 @ 11:13

Interviewer: Alyssa

Scribe: Jacob

Q: How often do you use public transportation?

A: Every day, at least twice a day, five days a week. At least back and forth from work on weekdays, and sometimes to meetings. On weekends, sometimes.

Q: What types of activities do you use public transportation to get to (e.g. social activities, jobs, etc.)?

A: Jobs, social, leisure

Q: How do you feel about the accessibility of public transportation?

A: Not sufficient. Could be poorer. We are at a low to medium level. There are some measures, but definitely not enough, either for information or physical facilities

Q: What aspects of the public transportation system do you find frustrating?

A: Many stations have poor physical accessibility. Often they are missing tactile indicators. It's hard to find the check-in points, because they are placed randomly. Without tactile surface indicators, it is hard to navigate the platform. You have to use the white cane along the edge of the platform, which works, but is dangerous and violates regulations. You have to be alert to pull cane back for trains. Some trains have announcements outside, others don't. You have to find the door, which can be difficult. Sometimes, a conductor or other people are present to help, but not always. For trains besides the S-train, can be hard to determine which train it is and where it is going. Some, but not all, trains don't have announcements of the station they are going to or what side the platform will be on. Sometimes, the correct door beeps. The other door is usually locked, but sometimes it opens. But not always.

Q: What aspects of the public transportation system do you think help your commute?

A: Where announcements are used, or tactile strips are present, they are helpful. When other people are around, they can be helpful. People don't talk much on trains, at least partially because they are using phones. This makes getting help harder.

Q: How do you get updated information about public transportation (e.g. schedule changes, arrivals, departures, and which bus or train is the bus or train you want to be on)?

A: I don't use apps. I have them, but haven't taken the time to update or learn how they work. Sometimes I ask a colleague before I go to check for delays. I go to station, follow what information is

available there. It's a bit disorganized. Often, at stations the noise and other trains can make it hard to get the right information.

Q: What would you suggest to improve the accessibility of information in the public transportation system?

A: A button at bus stops or train platforms that tells which/when buses or trains are incoming/present. More information inside trains and buses telling the next stop/station. Same at platforms, telling about incoming bus/trains and their destinations. Traffic regulations requiring each bus to stop at the actual stop when multiple buses are at the stop. Lined-up buses open their doors at once, then leave at once. If you need to get on the third bus, and you are waiting at the first, how do you identify and get to yours in time? And more tactile indicators.

Community Interview G, March 27 @ 10:13

Interviewer: Alyssa

Scribe: Jacob

Q: How often do you use public transportation?

A: Almost every day. Not every weekend, but often.

Q: What types of activities do you use public transportation to get to (e.g. social activities, jobs, etc.)?

A: Both jobs, social activities (theater, visiting friends), shopping, because there is nobody to drive me.

Q: How do you feel about the accessibility of public transportation?

A: Physical or informational? There's no problem on routes I'm used to. Going by bus to unfamiliar locations; it is hard to find bus stops. It's hard to find information on the way.

Q: What aspects of the public transportation system do you find frustrating?

A: We had an app (bus train metro) that was very helpful, but it no longer works. Other apps aren't as accessible. Some are, but some only have buses, some only work for nearby. You need to use several apps, but they are not all accessible, or are partially accessible and have unnamed buttons, etc. The Rejseplanen app isn't fully accessible. Information on the platforms and in buses; you can't always hear the announcements, and the announcements aren't always made.

Q: What aspects of the public transportation system do you think help your commute?

A: Automatic announcement of stations and stops is very helpful. The not-fully-accessible apps are still useful. Changing plans, delays, etc need an app to help. But people who can't use apps will have more problems. The DSB phone line is helpful. Maybe give 2 hours' warning, or they're trying to get there? But it can't be used for the S-train. Private railways (Helsingør to Hillerup) don't have the same help. Drivers can help, but they can't help find the next bus or train.

Q: How do you get updated information about public transportation (e.g. schedule changes, arrivals, departures, and which bus or train is the bus or train you want to be on)?

A: Rejseplanen website

Q: What is difficult about getting updated information? Do you use any assistive devices to aid you in your travels?

A: Primarily the inaccessible parts of the apps. They don't work with VoiceOver. Sometimes they aren't updated, but that's rare. Need multiple apps, because Rejseplanen isn't good enough.

Q: What would you suggest to improve the accessibility of information in the public transportation system?

A: Automatic announcements in buses should be improved and mandatory for all buses. Apps should be improved, especially the ones made by public organizations. Websites (dinoffentligetransport.dk, dot.dk) should be improved; bus plans inaccessible. I tested it. The schedule isn't always available in a table, so screen readers have issues

A5.2: Company Interview Notes

These notes are a summary of our interviews with representatives of companies we spoke with. Our full interview transcriptions are available in Supplemental Materials. *These appendices have not been directly referenced in our paper.*

DSB Interview, April 9 @13:00

Interviewer: Caroline

Scribe: Jacob

Normal operation

Information system is owned by Banedanmark and DSB. DSB operates the tracks and the platforms, but not all of the aspects of information. The s-train is a closed system that uses a “sensor” system to display distance to the platform. Normal operation is a collaboration between Banedanmark and DSB.

Standards/Policies

DSB follows the TSI PRM guidelines. These define standards that public transport companies have to follow if there is any new construction or updates to existing stations. The TSI PRM is an European Rail Union standard that is consistent across the EU.

Plan for Accessibility

The representatives both shared that DSB is hoping to move away from audio announcements and use the mobile phone application more. They said that apps are the future and they thought that this is where the technology and accessible features were headed. They had planned to make the DSB app more accessible by 2019, and the website more accessible by 2021. They did not specify a plan to make this happen, but expressed interest to improve this service.

Working with Advocacy

One of the interviewees (D1) is in charge of the accessibility and PR service with DSB. D1 is the chair of the “handicap panel” that DSB has, which meets four times a year with advocacy organizations. This group discusses problems and potential improvements. D1 works closely with John and the DAB, along with the Danish Handicap Organisation.

The aspects of the system do they control

DSB does not control the intercity and regional traffic, the stations and moving parts (trains), the Rejsekort cards for customers, or the Main tracks. DSB is in charge of the information that is said on the monitors and announcements, but Banedanmark controls the monitors on the platform. DSB controls

the platforms and the tracks, along with the trains that use the tracks. DSB is in charge of the s-trains and the closed system that encompasses that information. Rejsekort cards for commuters is also a DSB service, as they control all of the ticket sales. They work hand and hand with Banedanmark, and it is difficult to draw the line between the two companies, as they control and collaborate similar parts.

Information distribution

DSB controls what is said on the platform screens and the signal system for the s-trains. There is a Banedanmark/DSB collaborative office in the Control Center of Central Station. Accidents get reported by the conductor calling the station. Information about an accident or sudden change will be announced through loudspeakers on the platforms or in the station. S-train information is built into the trains, and information is announced as a customer passes through the door. S-train has automatic information announcements about the next station. Information can also be accessed through the telephone system, which the representatives of DSB felt as though this was an accessible form of information.

Economics/Budget

5 or 8 years ago they were awarded more money to apply to the system to increase accessibility. That money was used to increase the presence of tactile strips throughout the stations and platforms. A lot of money is spent to provide the service that allows a disabled person to sign up to receive help at a station from a trained assistant. Economics are a constraint to making more improvements.

Tandem Association Interview, April 17 @10:00

Interviewer: Caroline

Scribe: Jacob

Tandem Association Description

There is not that much accessibility legislation in Romania. The Tandem Association works with people who are blind and partially sighted to provide a sense of community and figure out ways that technology can improve the lives of people with disabilities.

Beacon Projects

The beacon projects started because the Tandem Association's blind founder wished to have a sound corridor that could help with navigation throughout public transportation. The public transportation system in Bucharest does not have consistent audio announcements within their buses, trains, and stations. 4 years ago, they found beacons that can play sounds, so he decided to move forward with the project. As of right now, the Tandem Association controls over 3000 beacons in the city. Besides technical issues, overall the project has been a success.

Smart Public Transport

The buses in Bucharest do not have GPS. There is an announcement system, but it isn't always reliable. Therefore, the Tandem Association installed iBeacons within Bucharest's buses and had an IT company develop a corresponding app for the beacons system. At stops, the app alerts when bus approaches. On the bus, app alerts about approaching stops.

The beacons have had some problems. Ideally, beacons on the bus could beep at the station when someone is waiting for them. However, most beacons don't make noise. Some are made in China, but that's hard to import and hard to send in for repairs. A Romanian company (Onyx Beacon) used to create the beacons Tandem used, but the company is going out of business.

Subway Project

Beacons in subway stations for navigation. The beacons are set up to create paths through the stations, letting user know how to get out of the station through their app.

Street Navigation Project

The Tandem Association also placed beacons at bus stations. The app tells people when they are at the bus stops. There are very few tactile strips in Bucharest and very few aural crossing signals as well. People will run you over even if you have a white cane. So this project also helps with navigating through the streets to the bus station.

Why Beacons?

The Tandem Association got sponsorship from Vodafone and two other companies. Vodafone is willing to help anyone do this sort of thing. Their beacons cost 20€ per beacon, which may have been a bulk price, but Onyx Beacon was pretty cheap. More expensive beacons have extra sensors that these users don't need. Tandem just wants waterproof beacons that can make noise. Beacons can be helpful for foreigners/tourists as well.

Problems with the Beacons

They have to change all the beacons' batteries, requires many (18) volunteers. Accessing beacons to change batteries is tricky (they have to be placed high up). Using bluetooth headphones can interfere with BLE. "Beacons work wonderfully," but we need them to work ten times better than they do now.

We need them to respond in 1 or 2 seconds, because buses move fast. Varies between beacons, but the beacon manufacturers need to give you the CMS for their beacon. Connecting to the database adds another few seconds to the delay. They solved this by having the app update the database locally daily. Even blind people don't want beeping *everywhere*. Delay depends on various factors. Can be nothing, can be 5 seconds, with two beacons on the same street communicating with the same phone.

Onyx Beacon's beacons are temperature-resistance, but had some problems with the shaking of the buses. This was one of the biggest problems with the buses. Onyx Beacon has stopped making those beacons. Now working with universities to make better beacons, and has started to contact a beacon company in Canada as a potential beacon supplier.

Also, sometimes users do not want to use the app, as "people with visual impairments can be set in their ways". It "takes some convincing", but once they see that it works, they become more open to trying new systems.

Maintaining Beacons

There needs to be a server for the beacons, with all beacons registered. They need to install beacons before setting their data. To make sure beacons are working and up-to-date, need to go through and check them every few weeks. The bus companies maintain the beacons on the buses (because nobody else is allowed to mess with the buses, or at least to enter the bus lots). Tandem provides batteries (and has to find sponsors to fund that).

The Tandem Association would like to expand their associations worldwide

Movia Interview, April 16 @11:00

Interviewer: Caroline

Scribe: Jacob

Movia Description

Movia is a Public Transport Authority for Zealand and a little bit of Zealand's surrounding areas. Movia is in charge of setting the bus time tables and contracting out the physical operation of the buses out to different companies. Arriva is their biggest contractor, controlling about 40% of buses and transporting 60% of the customers. They have 16 different operators running full-sized buses. They also contract to family-owned/one-owner companies with 5-10 buses. When Movia sets their contracts, they set them for all of their 16 different operators. All signs are controlled by Movia. Movia designs the information at the stops.

Movia does not control the physical stops. Local authorities buy stops and signs and maintain them. Bus stop company (in mail) builds the actual sitting areas, makes money by advertising. The more remote stops (without commercial value) are run directly by the municipalities. Movia does not directly interact with bus drivers; operators do their own hiring and training. However, Movia awards bonuses for customer satisfaction. They get this customer satisfaction information from surveys. Also, Movia has the power to not renew different contracts.

Announcements within Buses

The ability to make announcements in the buses is required in operator contracts. Newer contracts have more specific requirements with the audio announcements, so if there are inconsistencies with the audio announcements, they are usually the older bus lines. Some older buses only announce major stops, some don't announce at all. Announcements should be made before buses arrive at the stop. Approximately 95% of customers get full announcements. In the future, all buses will need to announce all stops. The Technical details of announcement system not specified in operator contracts. Only that it must be clear/loud enough.

Announcements are controlled by software. Almost all buses use GPS to control announcements, a certain number of meters or seconds before the stop. Zone changes are announced as well. The buses are tracked with GPS.

Data Distribution

Movia works in cooperation with DSB and Metro in a company called DOT to make transit information uniform. The big screens at bus stops are through DOT. Movia sends Rejseplanen all their data. Movia has an SMS number that can be texted for updated information about the whereabouts of

the bus line. Also, there used to be a QR code that would give that information, but at night and through the winter it was really hard to see and it wasn't being used so they removed the codes.

Accessibility

Movia has not considered audio announcements outside the bus. It's *possible*. Banedanmark and DSB have started in the past 2–3 years. However, most buses running today do not have external speakers. Movia is not sure we want to provide that service; some people want quiet bus stops. Beacons could be used for the same effect (not part of current plans, though).

Potential for a Beacon Project

Movia is looking at what is possible with beacons and what can be done with that in the future. They are about halfway through the evaluation. They have an app developed and they have placed beacons throughout their private offices. The app can read out updated information about the bus stop in front of the Movia building. Movia has found a lot of talk about beacons, but few examples in use. The interviewee was unaware of Smart Public Transit in Bucharest. Movia prefers accessible systems that benefit everyone to systems that only help people who are blind or partially sighted. They also want the beacons for some commercial use.

Relationship with DAB

Movia taxi service is helpful. Movia learned to remove the Braille and Tactile on the sign posts because one advocacy organization mentioned that the tactile numbers were not being used.

A5.3: Banedanmark Tour Notes

We took a tour of Banedanmark's Control center near Central Station. Our tour was conducted by a team manager. We did not conduct a formal interview, so we did not have an interview transcription.

Banedanmark Control Center Description

The Banedanmark control center in Central Station is the major hub for all information about the train tracks throughout Denmark. The control center we visited controlled had employees from both DSB and Banedanmark. This control center had control of the east side of Denmark, there was a different control center for the west side and DSB, and there is a different control center for the S-togs. The control center in Central Station has control over all screens in all stations on the east side of Denmark, as well as all of the automatic and manual audio announcements.

The trains are tracked by sensors on the tracks that recognize sensors within the train. There are also GPS systems within the trains. If an incident occurs that would make the train late, the conductor calls the Banedanmark/DSB control center and the control center decides what to do. When trains are behind where they should be, the information is updated automatically on the screens and in Rejseplanen. If a delay or track change is more than 10 minutes away from happening, the control center will automatically announce the delay on the train platform and within the train station. The automatic announcements are supplemented with manual announcements if a delay or track change is less than 10 minutes and customers have less time to figure out how to get to their new track.

A5.4: Kontakt Beacons Customer Service Call Notes

We called a sales representative from Kontakt Beacons to inquire about their beacons in use in public transportation. We did not conduct a formal interview, so we did not have an interview transcription.

Cost

Outdoor beacons cost about \$12-13 per bus. For a bus system with about 3000 buses, the beacons would cost about \$40,000 total. The cost of the software must also be taken into account. The representative did not know these exact costs, but there is a monthly charge for a software development kit, as well as other charges for software development and maintenance. There's an organization in the UK with an open source SDK that would be free.

Beacons for Good

Each year, Kontakt beacons collects project descriptions from different advocacy organizations and evaluates them, awarding the winner with about 100 free beacons. Dansk Blindesamfund or Movia can apply if the beacons are to be used for people with disabilities. The application is not open for this year yet.

Kontakt beacons used in transit

Kontakt beacons have been used in stations for navigation and ticket machines before. They have also been used for similar solutions in Spain. Kontakt has also partnered with Blindsquare and Mawingu to create solutions for the partially sighted.