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Universal Design of ICT

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Developing speech recognition in public transportation for universally designed information flow

Abhijeet Sapkota

Department of Computer Science

Faculty of Technology, Art and Design

OSLOMET

Preface

This master thesis has taught me a lots of things and I would like to thanks each individuals and companies who helped me in completing my thesis. I would specially like to thank my super visor Raju Shrestha. HLF for providing me an incredible amount of data in which the thesis is totally dependent on. I would also like to thank all my friends and colleague who helped me directly or indirectly with all the information.

Abstract

Today, information in public transport is largely provided through speakers. This is especially true in unforeseen events, such as signal failures, platform change and in emergencies such as fire, evacuation and the like. Such situations are often chaotic, and the driver / conductor / pilot is reading messages about what happens and what passengers are going to do. This rarely helps the hearing impaired to bring along. There is therefore a need for a system that recognizes the speech to the driver / conductor / pilot and translates speech to text on screen. And this thesis has explained the procedure and possibilities of creating such a system for the public transportation system.

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1 Introduction

The prosperity of developing and extending urban metropolitan locales is generally associated with the arrangement of sufficient and fitting transportation administrations. An extending urban population expects access to business exercises, training, work and recreational openings. The area of these administrations and the arrangement of sufficient transportation framework, for example, roads, mass travel, and discontinuing settlement, is the pith of urban arranging. The transportation framework has an extraordinary influence and effect on local examples of advancement, financial reasonability, natural effects, and on keeping up socially satisfactory levels of personal satisfaction. This leads extensive assets being consumed by government offices in the arranging and improvement of more effective transportation system. While the way from arrangement specification to framework usage is not clear or deliberated, it is imperative that procedures be built up and used by which execution and accomplishment of objectives might be observed and estimated. Here the usages of transport lead to generation of important information, which should be easily accessible to the public. Therefore, this report is a proposal for a system that helps a specific disability of hearing impairment.

1.1 Problem statement

The notification of important information about specific events to passengers onboard has been a special challenge in public transportation system all over the world. These circumstances arise due to some sudden and unpredicted events such as platform change, system failures and various emergencies like fire, evacuation, disaster, accidents, etc. In order to handle these chaotic situation, driver/conductor/ pilot reads messages about the situation and provides instructions to passengers. However, information is generally provided through speakers, it hardly helps people with hearing impairment.

1.2 Research question

i. How can we develop a system that makes public transportation information accessible to group of people with hard of hearing?
ii. How effective is speech recognition system, which displays information on screen that enables hearing impaired to access information?

1.3 Aim and Objectives

The proposed information system mainly focuses on sensory and cognitive disabilities. Therefore, the main aim is to develop a speech recognition system that recognizes driver's speech during travel and displays on the screen, which allows people with auditory impairment to access the information. Whereas, the same speech can be announced through the speakers for people with visual impairment. This proposed system also emphasizes speech translation process where any passengers receives an information announced by the driver during travel, translated into certain language in visual form.

Objectives

- Detail study of speech recognition and translation API
- Use of existing open sources program like Python, Google Translation and Speech Recognition API for program development.
- Manage required resources for both program development and implementation.
- Survey with participants made available by HLF to understand the real time scenario during the travel.
- Survey with various public transport departments with effective study for implementing the proposed system.

Proposed system will be applicable in different public transportation system such as metros, trams, trains and buses.

2 Literature review

2.1 Information Communication Technology (ICT) and Barriers

In general, ICT is a collection of various technologies allowing electronic communication for data collection and processing those data in distributed network systems. ICT ranges from simple electronic communication like email, telephone - communication to complex system like hydropower management system or traffic control system. Various ICT systems generate various information in audio-visual format including picture, text, speech, signs, etc. If any user fails to access these contents of ICT due to some conditions, those conditions refers to ICT barriers. These barriers are generate due to different classified models (Black & Van Geenhuizen, 2006).

2.1.1 The Social Model:

This model describes any environment created by society, which hinders people with disability to access or participate in activity related to ICT. This also includes creating infrastructure inappropriate for disabled people or by excluding their needs to access those resources. For example, announcing information on speaker without any concern for displaying it into screen that excludes people with hearing impartment while accessing the information.

2.1.2 Medical Model:

There is a complete inconsistency between medical and social model. Medical model describes one disability as lack of capacity in user himself due to some physical, sensory and mental problem. This model denotes permanent and temporary disability of users for accessing any type of resources. For example, people with mental or sensory problem may not understand signage used to provide direction in public transport.

2.1.3 The Relational or the Gap Model:

The disability gap model describes disability as the gap between requirement of environment and ability of an individual. The red horizontal arrow in Figure 1 shows the gap that creates disability. Some conditions cannot fulfill physical and social requirement of an environment, which denote barriers. These barriers are the main reasons to create gap between individual abilities and requirement of environment.

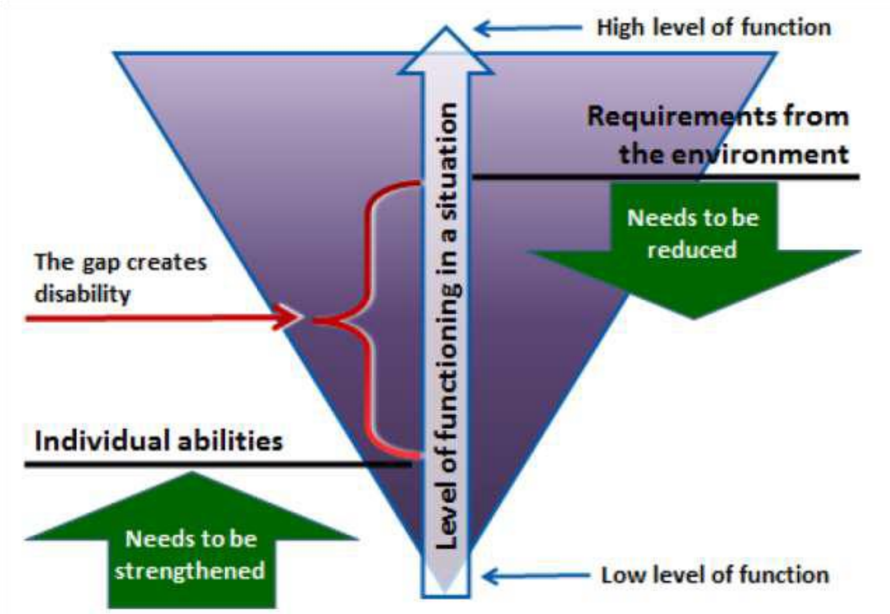


Figure 1: The gap model (Fuglerud, 2014).

In addition to disability, Figure 1 depicts disability as a relation between different environments or situations that surrounds an individual. This gives in height eminence to the level of function i.e. higher the level of function, lower the disability and vice versa. Thus, emphasizes to the change in factors to decrease the requirement of environment or to increase the individual functionality to reduce disability. Considering the use of currently available Assistive technology (AT) as superlative tool can strengthen one's abilities to shrink disability gap, which increases the opportunity to access resources by everyone (Fuglerud, 2014).

2.2 Information system in the public transportation

The influence of information and communication technologies (ICTs) on transportation has brought an evolution in development and practical use of public transport. Adapting ICT applications like wireless technologies, embedded with other electronic infrastructure of any means of transportation adds direct and physical dimension of optimizing transport operations. This brings an opportunity to inherit changes in mobility behavior such as transportation of goods and people (Wagner et al., 2004). However (Zapata Cortes, Arango Serna, & Andres Gomez, 2013) states Transport Information Systems (TIS) are part of ICT and implementing TIS in transport facilities allows to exchange real time information which includes integration between vehicles and the road infrastructures with service providers and non-transport related organization and passengers. TIS are referred as, a huge network of different information systems with single goal of transport management in urban cites driven by combination of technologies such as programming, wireless communication, internet, exchange of electronic data implemented to capture, compute and communicate required information before, during and after transportation. Beyond transport management TIS has increased efficiency and effectiveness of safe routes and deliver relevant information to all the users.

Improvement in transportation system is not only sufficient, if we do not consider the need of passengers while they use any transportation media. (Bachok, 2007) has discussed about Passenger Information System (PIS) that focuses on providing information to passengers regarding public transport. Mainly, information that assists passengers to make decisions with their pre-trip to at-stop or at-terminal. Pre-trip information provides passengers with options to choose for a specific trip. Additionally, at-terminal information states waiting time before arrival of next mean of transport at certain location. However, information of unpredictable events such as bad traffic, accidents, emergency evacuation and such, occurred during the trip impacts the decision of drivers and passengers to find some alternatives. Internet, mobile application, websites are now able to provide information regarding pre-trip and at-terminal information which are also displayed at stations or platforms. On the other hand, drivers and staffs on-board announce information during travel for the next station. Nevertheless, survey on passengers found that appropriate amount of information is lacking in overall journey.

2.3 Information accessibility in public transportation

Public transportation planning is as critical as the evolution and the growth of urban areas in the world. Any consideration taken in the improvement of transportation determines the impact of current and future transportation infrastructure development (Murray, Davis, Stimson, & Ferreira, 1998). Regards to accessibility in public transport, (Zając, 2016) has signified that majority of public transport experts and city planners are highly concerned about foundations of passengers rights which indicates to non-discrimination, accurate, timely and accessible information with immediate and proportionate assistance. The right of passengers for universally designed public transport is directly proportional to the design of overall infrastructural elements such as stations, stops and transport hubs. This also includes universally designed accessible information to people by all possible means regardless their age, ability or disability. Strategies such as employment equity, better health care and rehabilitation services are situated at specific location that increase the requirement of any person either with abilities or disabilities to use public transport services.

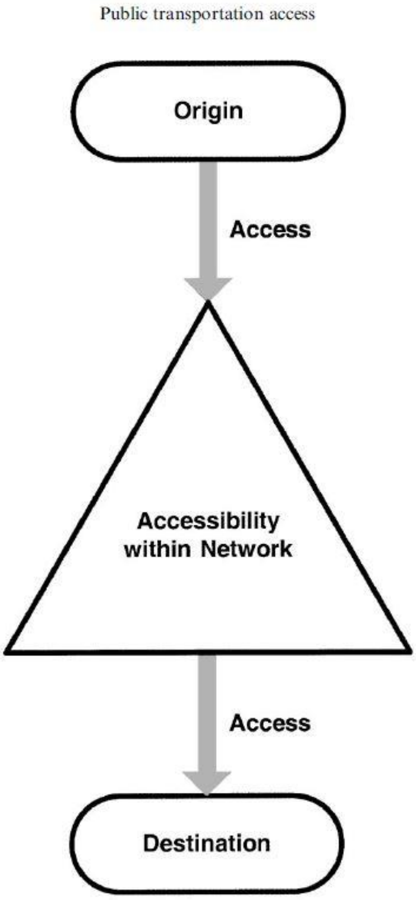


Figure 2: Public transport system access (Murray et al., 1998).

A study by (M Mashiri, 2005), indicates the needs of majority of persons with disabilities (PWD) still need to be fulfilled. Especially, people with intellectual and sensory disabilities face major barriers while accessing information in appropriate format, which includes accessibility of information, services or fares. Therefore, appropriate means of information services are extremely required to characterize and present information into accessible format. Transport information consists of vital information including signage (low steps, ramps, seats, tactile signs) and other general information like routes, ticketing and schedule of departure and arrival, accessed by all the passengers. Current information provision for public transport includes

- Direct information to disabled traveler (e.g. audio signs or customer service telephone help-line)
- Public information sources allowing person to access general information
- Interactive information (e.g. web pages and public information kiosks).

Delivery of accessible, useful and usable information to the traveler can adequate the requirement of passengers. In addition, designs that incorporates information redundancy, audiovisual information, non-textual visual information and tactile information are various issues and modes of accessible transport information. Here, the special needs of PWD generates certain provisional requirements related to the format and content of transport information. The classification of these requirements is possible depending upon the nature of disabilities as follows:

Physical disabilities: The presence of physical access to any resources of public transport is necessary for people with physical disabilities.

Sensory disabilities: People facing sensory disabilities such as auditory and visual impairment obliges for information in a format, which they can actually perceive and understand thus, different range of media must involve ensuring accessibility.

Cognitive disabilities: Preparing effective standard in design of information, sign, vehicles and practice can assist people with cognitive issues. This may include use of information with pictures rather text based information.

Multiple disabilities: Multiple disabilities creates a huge challenge while making any resources available to the user. This group consists of older adults, children, and people with multiple disabilities like both loss of hearing and seeing. Therefore, multiple formats of information is necessary to address these types of disabilities.

(Programme, 2019) has explained some guidelines for different aspect of information generated in public transportations. They have also emphasized on implementation of help points and emergency assistance services within the reach of all users. Some of the guidelines for specific information as they mentioned are as follows:

Lighting of static signs:

Use of bright signs can help person to read the information as reading to a newspaper. Ambient light level is not as good as illuminated signs. Glossy signs and bad lightning should be avoided which causes glare and does not help people with lower vision impairment.

Concise:

A considerable amount of data is seen while in transit when the eyewitness himself is moving – maybe strolling or possibly on a transport or a prepare. The time accessible to see, read and comprehend the data may in this way be very short. This at that point underlines the significance of keeping data as brief as could reasonably be expected and stresses the benefit of utilizing images. The French organization COLITRAH has produced comprehensive recommendations on signage – chaine signaletique – which makes the point that for passengers in transit signs should be designed to give an instantaneous 'snap-shot' of information. Symbols can be very helpful in this process because people with low levels of literacy can understand them, but they must be used consistently, be unambiguous and if or when new ones are introduced, they should be accompanied by a verbal explanation until the public is fully familiar with the symbol and its meaning.

Hearing information:

The attention to hearing impairment is as important as visual impairment. However incapable of hearing is likewise critical, particularly in catastrophes and for informing regarding unforeseen changes to information. Visible information is not confined to announcements at stations and on-board open transport vehicles. Different applications incorporate phone data, ticket workplaces and data focuses.

Many personal hearing aids incorporate a 'T-coil', which provides direct inductive coupling with a second coil, for example in a telephone receiver or at a ticket office window. As not all hearing aid users have a T-switch, telephones should also have user-controlled amplification of received sound. Amplification is implemented via a button on the telephone, which automatically reverts to the ordinary sound level once the telephone handset has been replaced.

Some telephone information services now include a Telecommunications Device for the Deaf (TDD). Text phones are available and are essential for those people who are profoundly or severely deaf.

Accurate and timely:

Any information in whatever form should be accurate. A mistake in a timetable may be the cause of irritation to anyone, but to a disabled person the consequences can be much more serious.

Any information provided in stations or inside vehicles should be accurate and concise. This means more than just making sure that it is correct at the time it is first presented; it also implies a process of updating and checking to make sure that it continues to be accurate. A slight mistake or alteration of information may create havoc and chaos within public area, which may lead to irritation, quarrel and most of all difficulties faced due to this misunderstand, by disabled person is worst consequences.

Timing of information is also important. Thought should be given not just to the content but to the point in the journey when it is needed. To take one simple example, an audible announcement of the next stop on a metro is very helpful particularly to visually impaired people but it needs to be made in sufficient time for the passenger to get ready to leave the train.

Audible information:

Audible announcements are helpful to most people but particularly to people with visual impairments. Public announcement (PA) systems in stations or terminals should be clear and loud enough to be understood by people with hearing impairments, who typically require announcements to be at least 5 dB above the ambient noise levels. Inside public transport vehicles, the use of a PA system is recommended in large vehicles for announcements about major stops to be heard. However, this may not be affordable, or indeed necessary in smaller vehicles with up to about 30 seats. In such cases, the driver or conductor should announce information at least loud enough to be heard by passengers in the priority seating area. Some telephone information services include a Telecommunications Device for the Deaf (TDD), while text phones are useful for people who are profoundly or severely deaf.

Emergency information:

Emergency exit routes from buildings or vehicles should be clearly signed. To serve both visually and hearing impaired people, emergency alarms should have both audible and visual features, such as an alarm sound coupled with a flashing warning light.

2.4 Analysis of existing information system for hearing impairment

The vehicle data framework comprises of the denoting the line and the fundamental course of line, when the electronic boards and acoustic sounds are utilized it is conceivable to give more data to travelers, for example, the present time, next stop, exceptional character of the stop, duty zone, crisis circumstance, the overseer control, and so on. Some declarations are in the Norwegian language yet some imperative stops in the English language. The information display panels are situated on the front, side and back piece of vehicle. (Prof. Ing. Jozef Gnap, 2014) also mentioned basic features of direction indicator in public transport vehicles.

In the context of signage and information used in transport, the main concern would be displaying them in proper manner with correct alignment and management within the vehicle itself. Satisfactory data – and particularly constant data that reflects changes as they generate – only enables travelers with no impairment. For individuals with disabilities, approaching data in usable organizations is especially imperative, to help stay away from superfluous exertion and to help design their trip with certainty. For individuals with visual, hearing or mental disabilities, real-time information might be the only medium that enables them to travel freely.

Signage and data that is very much intended for individuals with handicaps will encourage everyone. Clear signage and data will push foreigners to a region, and the utilization of pictograms and basic wording is especially critical for individuals who refuse to talk communicate with neighborhood. This section discus all arrangements made for signage being used as a part of public transportation, stations and on-load up vehicles; printed handouts and timetables; and capable of being heard declarations. It focuses on best work on in regards to arrange, yet in addition gives some direction on the general substance of signs, messages and classes of data. In light of an alternate reason, directing on great plan for availability can be utilized to bring issues regarding transport administrators and local experts to the necessities of impaired individuals. In the Netherlands, for instance, leaflets are being set up with direction with accessibility in public transport, for parking, office ways, bus stations and others. The catch is that any passengers or walker will find universally designed information about direction so that help in conveying the information easily as discussed by (Programme, 2019).

This program also describes about the process of placement of signage and information board in public transport. The perfect position for seeing a sign is on a level with the eye line of the individual, yet this is frequently unrealistic. Signage and display board kept at that level in, for instance, a railroad end would imply that unless a person is close by the sign he/she would not have the capacity to see it due to other passengers on the way blocking the insight. So the display unit or sign should be raised. The degree to which it is raised will rely upon the particular area, yet to maintain a strategic distance from other individuals acting as a burden it ought to be set at the very least 2.3m over the ground level. In substantial territories like a station concourse signs will be a considerable measure higher in light of the fact that individuals need to see them from far away. There are a few rules on the extent of lettering in connection to remove fluctuating as per the level of visual impedance of the onlooker. The figure underneath demonstrates the example of display screen hung inside a public bus.

Figure 3: Display screen for information inside the bus.

To address the issues of elderly individuals and others with rather poor sight, a letter stature of 25mm is required with distance of 7.5m. At 20m apart, letters ought to be around 75mm. Some vehicle experts have even more demanding benchmarks. For instance, London Transport's standard depends on 10mm letter stature for each meter of review separate, with no lettering under 22mm.

There is an expanding utilization of variable message signs, especially in air and rail administrations, yet in addition on transport benefits also. These take an assortment of structures from TV screen presentations, LED and fiber optics to the more antiquated yet at the same time much utilized flip circles. Following the counsel given for printed writings and static signs will enhance the intelligibility of these showcases – lucidity, proper size of letters and difference are similarly as vital. By their inclination, variable message signs change by looking over or flipping. It is most vital that speed of progress ought not be too quick, generally individuals who can read, however not well, will think that its hard to comprehend the message. It is suggested that a line of content ought to be shown for no less than ten seconds, ideally somewhat more. Dynamic signs ought to have non-intelligent glass and ought to be protected from coordinate daylight (N.N. Sze, 2017). There are expanding population of community and information terminals and stands at transport terminals and on-road. It appears to be likely that this will increase the amount of data in near future, which should be managed in such a way that false, inaccessible information are reduced.

Similarly, (Øksenholt & Aarhaug, 2016) has evaluated various aspect of Norwegian transport system. In their research, they have found various information about transport facility in Oslo region. Their main reason to choose public transport in Oslo represents traditional universally designed public transport. In their research, they extracted that Norwegian standards and guidelines for universal design requirement throughout the information system in transportation industry. Sight-disabled individuals encounter challenges situating themselves at the stop or stage preceding boarding and again in the wake of landing. A key test for them is essentially in getting on board the right transporter, needy as they are on the driver getting out the course number and goal. Some sight-debilitated don't utilize a stick or have a guide puppy, thus it is troublesome for the moving toward driver to realize that somebody at the stop has a hindrance, in which case s/he won't not make the correct move.

Besides, to land at the correct stop the sight-debilitated are again regularly subject to the driver or staff for help. A typical dissension of all the incapacitated was absence of assistance from the driver, which could be expected in addition to other things to tight timetables.

During survey it was discovered that information, or absence of it, was a hindrance to utilization of open transport, which is in accordance with the discoveries in their meetings. For sources with diminished vision, finding the stop and getting on the correct transport are testing, and if there is an absence of data on the vehicle, either transport or metro, it can be hard to know the correct stop. Another witness, with another issue, indicated the advancement of quiet stations as spots where it was especially hard to get one's course. While much of the time, this is a minor issue, it can be not taken lightly when there are deviations from the timetable, all signifying a feeling of infirmity. No less than one source expressed that it was hard to get to the correct platform. One participant could not recognize vehicles with and without a conductor. Another source indicated weakness made by not knowing regardless of whether a train or tram has low floor. The in-vehicle information frameworks are likewise a potential aspect of problem. One source expressed that it was hard to hear the data being announced by driver. However, the study found that, two out of six journeys, where people did not hear or misunderstood the information announced by the driver. In another two journey, the volume was relatively undetectable. Despite the fact that this is a likely an excessively unfortunate rate contrasted with the ordinary disappointment rate, it in any case indicates why it is seen as untrustworthy and a wellspring of weakness.

2.5 Use of speech recognition in public transport:

(Shi, Taib, Choi, & Chen, 2006) introduced a multimodal human-computer interface design that operates under traffic incident management (TIM) system. Their main aim was to reduce entire time-consuming operation like detection, verification with response and clearance time regarding traffic incidents. As operators in control room handles multiple incident reports, the need of rapid, convenient means of receiving information was necessary. For the same purpose, a user interface based on natural speech and free-hand gesture input system became an important multimodal user interface for Metropolitan Transport Management Centre. This design used natural vocabulary from speech and handwriting as input, which passively monitored operator’s conversations and automatically generated incident reports. They also hypothesized about using keywords compared against synonym list and location names with popular acronyms as a strategic element to generate automatic reports. Hence, demonstrates the possibility of using speech recognition is high in current technological advancement.

Current interest of people, organizations and industries primarily focuses on recognition of human speech in to large range of application used in society. Considering the current trends of technological opportunities, the potential of implementing speech recognition any electronic devices is inevitable. (Husnjak, Perakovic, & Jovovic, 2014) has discussed about the possibilities of speech recognition into smart terminal devices. Their analysis completely based on the transport environment produced various potential advantages and disadvantages of such system and principles. Speech recognition allows any machines or program to identify any words and phrases of spoken language and convert them into machine-readable data. However, the paper describes two different types of speech recognition, which gives general overview about working principle of speech recognition to develop a system proposed for the thesis report.

a) Speech recognition that operates direct/offline
b) Speech recognition that operates on a server/online

Recognition system using direct or offline mechanism operates on the existing devices with speech recognition program, which is in fact restricted to relatively small vocabularies with various limitation including memory, computation power and power consumption. These type of speech recognition is suitable if and only keywords are used to command to execute certain task. On the other hand, speech recognition that communicates with server that recognizes the received speech value and transmit back the result to end program.

Speech recognition has many other applications if utilized in productive manner. According to (McCallum, Campbell, Richman, Brown, & Wiese, 2004) use of speech recognition into vehicles can help in reduction of driver distraction while driving. Use of cell phone and other communicating means inside vehicle while driving has been a major attention grabbing issues to public, policy maker, media and other researchers. As functionality increases in advance devices like smart phones and smart dashboards, drivers are more prone to diversion of their cognitive, perpetual and psychomotor capacities away from their driving task. For the same reason, this report has proposed a speech recognition and speech synthesis method to access these distracting technologies hands free and head-up. This paper reviewed on the reduction of accidental risk and discussed human interaction with in-vehicle telematics devices, and conducted studies to reduce driver distraction and prevent probable accidents.

Another important study of (Laffitte, Sodoyer, Tatkeu, & Girin, 2016), which studied about deep neural networks for detecting automatic screams and shouted speech in subways and train. This was the basic study based on real time scene examination in the installed transport condition, for example, tram, trains. This sort of setting has as of now prompt diverse investigations, e.g. for transport transportation, for trains, and for metro. In the present paper, the undertaking centers around programmed discovery of shouts and yelled discourse, delivered in anomalous circumstances in the metro where a man in physical trouble, a squabble between at least two people, freeze circumstances, calls for help, and so forth. Although such sort of signs is very particular, this errand stays testing, for a few reasons. To begin with, there exists an expansive irregularity amongst "speakers", and furthermore between various acknowledge of shouts and yells, contingent upon the causing occasion, the enthusiastic state, and so on. Second, the installed transport condition is as a rule extremely loud, rich, and firmly factor. In the present case, the acoustic scene incorporates clamor coming from the vehicle itself (e.g., engine commotion, boogie-rails contacts), commotion originating from the encompassing condition (e.g., railroad activity, station clamor, boisterous speaker declarations), what's more, commotion delivered by the travelers. With a specific end goal to plan a reasonable framework, a devoted database was outlined and recorded. This database comprises of genuine signs recorded in the Paris metro. A metro line was reserved for the account sessions, because of the Paris metro organization (the RATP) being an accomplice of the undertaking. Unusual circumstances were authorized by on-screen characters, including additional members speaking to a group. As a result every one of the accounts utilized as a part of the introduce ponder are genuine and not gotten from engineered signals or on the other hand recreated acoustic blends. Concerning the classifiers, we utilized cutting edge Deep Neural Networks (DNNs), for example a mix of Restricted Boltzmann Machines (RBMs) and Profound Belief Networks (DBNs), connected on acoustic MFCC highlights. We set the assignment as a 4-class arrangement issue into shouts, yelled discourse, and conversational discourse and commotion condition.

2.6 Limitation of speech recognition

Speech recognition can contribute in various field of ubiquitous computing to make system more interactive and with ease of access. However, it also consists of various drawback that any developer should consider while implementing into any system or products. The performance of speech recognition totally determined by its accuracy and delay of speech transcription at a time. There would be fewer downsides while implementing speech recognition to a stable system like computer system or in house devices. Nevertheless, use of speech recognition into transport medium like cars, buses, trains should highly consider the availability of various resources like computing power, network connectivity and power consumption. For the same reasons automotive industries are spending tons of money and resources to equip transportation infrastructure with high-end equipment (Husnjak et al., 2014). The main limitation of network connectivity would occur if we implement cloud server speech recognition. Due to the fact of inefficient and insufficient speech transcription of offline version of speech recognition, the best solution is cloud based speech recognition. Yet, speech transmission over network and its recognition are crucial structure to develop real-time interactive speech recognition application. This type of system does not perform well if the network connectivity is less robust and may decrease its performance due to variation of jitter, packet loss and bandwidth. Therefore, detailed study of such environment is necessary to implement speech recognition in transport media (Assefi, Wittie, & Knight, 2015).

2.7 GloVe (Global Vectors for Word Representation)

Word embedding is word representations in the form of vectors that enable certain semantic word information to be maintained. There are different ways to take advantage of the word's semantic information, as there are different ways to generate the word vectors that represent those words (e.g. Word2Vec model vs. GloVe model). By using semantic information to capture the word embedding, we can build approximations to compare semantic information between phrases or even documents rather than words. As (Rodríguez, 2017) uses GloVe tool in his thesis, presented by Stanford University, to compare between Spanish phrase and compare the accuracy of the system.

2.7.1 Glove algorithm

The co-occurrence statistic of word is collected in a matrix A such that each element of A represents how many times the word appears in the context of matrix B. Usually the given sentence is scanned through the predefined word vectors. More the vector size more accurate co-occurrence is defined. Thus, helps in finding similarity between given sentences. Before implementing the GloVe embedding to compare the similarity of given sentences, the system should be trained with vectors provided by GloVe tool. GloVe's training goal is to allow program to learn word vectors so that their dot product is equal to the logarithm of the co-occurrence probability of words. Because the logarithm of a ratio is equal to the logarithm difference, this objective associates (the logarithm of) ratios of probabilities of co-occurrence with vector differences in the word vector space. This information is also encoded as vector differences because these ratios can encode some form of meaning. The resulting word vectors therefore perform very well on word analogy tasks, with the outcome of precisely similar words without affecting semantic and the context. Whenever the driver makes an announcement the google speech recognition API converts announcement into text and returns it into the system. However, the result is not always accurate and to solve this inaccuracy the glove embedding algorithm plays a significant role in comparing the announcement text and stored announcement script in the system. This will help the system to display the correct information on the display panel.

2.8 Use of onboard Wi-Fi system

The fact that it frees up time is one incentive for people to take public transport. The bus or tramway is a place for many passengers to read, listen to music, or interact with a mobile device. More and more passengers are carrying smartphones or tablets while they are traveling and accessing cellular data services. They check headlines, interact with social media, send and receive messages, stream entertainment, and otherwise remain in transit connection. The typical consumer device is equipped with a single SIM connected to the network of a specific mobile operator, and the coverage quality may vary from point to point. Onboard Wi-Fi, on the other hand, can be configured for the best connection at any point to aggregate signals from all the cellular networks in a given area. By combining load-balancing features and quality of service (QoS) policies, operators can specify how their own operations management functions and passenger-facing functions prioritize and share bandwidth. The approach also allows operators to use public and private cellular networks more flexibly. Taking this approach means a better experience for passengers, while transport agencies are gaining new ways of improving efficiency, reducing costs, and preparing for future development.

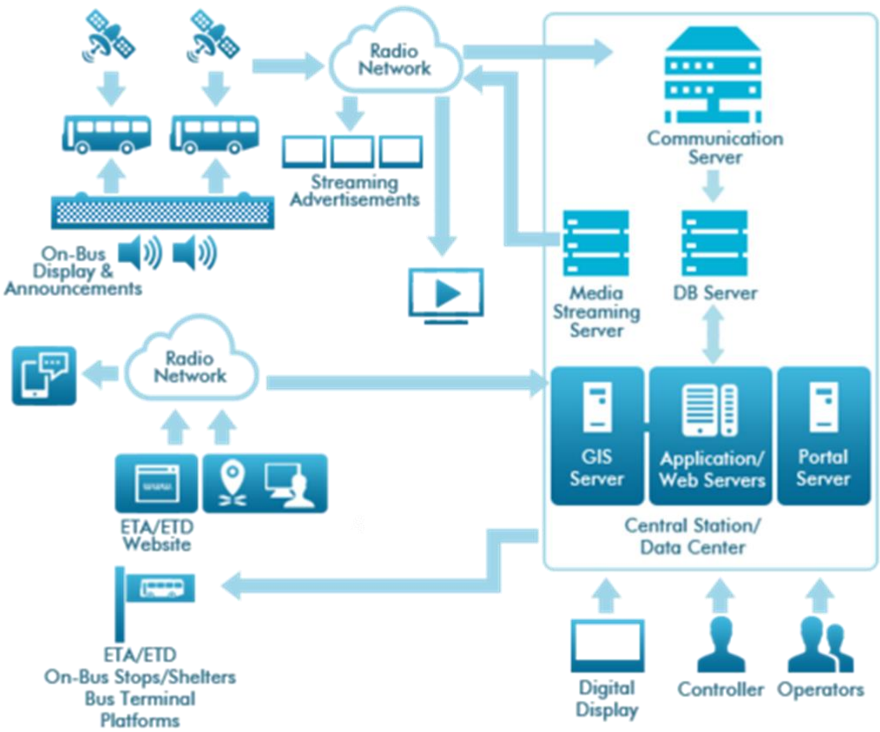


Figure 4: General system architecture used by public bus

The mobile multi-radio gateway can provide information about telematics for real-time location and traffic management. It can also provide vehicle diagnostics to support maintenance schedules and can be used to monitor on-board activity by video surveillance. To be more specific, the onboard gateway can be used for more efficient and responsive route and schedule management with automatic vehicle location (AVL) systems. With vehicle-camera systems capable of storing and/or streaming video, it can support video surveillance to improve bus safety and passenger safety as described by (Elias, Nadler, Stehno, Jrosche, & Lindorfer, 2016).

Similarly, (Niu, He, Zhong, Ai, & Chen, 2019) describes, cellular network is the general concept of public system architectures for mobile communications systems. Cellular networks are constructed on the basis of a number of small geographic areas, cells, covering a larger area. Each cell is a base station that transmits the information within a limited area. These areas are sometimes represented as hexagonal cells for analytical purposes, which is the most similar uniform method of tessellation to real patterns of transmission. As the transportation like buses and tramps are always in motion it becomes difficult for receivers to connect to single cellular network. Therefore, the public transport can consist of multiple connection from different cellular network providers. In this way, the transportation system can have uninterrupted connection to internet and allows the smooth function of the proposed system as well as execute various other services like on-board internet connection for passenger travelling long distance, real-time streaming of surveillance camera and other features.

To sum up, the study made it clear that the composition of all these services and technologies can create a system which is capable enough to provide immediate information to the passengers during their travel.

3 Methodologies

In this section, methodologies for preparing this project is mentioned which includes both research and development methodologies. As this thesis involves, both research of current accessibility and development of a system for public transportation, it is necessary to include both methodologies to understand the work flow related to information gathering and step by step development process of the system.

3.1 Research method

Available research methods are very effective in extracting intense data and information in any field of study. Therefore, in order to answer all the research question, a decision is taken to use both qualitative and quantitative research methodologies.

3.1.1 Qualitative research approach

This research approach is a technique to perform intensive data collection through conversation and interaction between related stakeholders. Qualitative research method mostly answers why people uses certain products, system or services. In simple explanation, this approach focuses to observation of the use of any products, system or services in regards to people's cultural beliefs, behavior, motivation and perception (Bhat, QUALITATIVE RESEARCH: DEFINITION, TYPES, METHODS AND EXAMPLES, 2018). To extract all these human thoughts and reasons to use any system or products, following approach is designed with multiple forms of data which includes interviews, observations and documentation. Using these collected data sets, this method tries to solve complex issues by understanding meaningful references and explanations given by participants. Collection of data is usually done in real time as to observe the problems and issues faced by participants (Strategic Education, Inc, 2015).

3.1.2 Quantitative research approach

This research approach typically defines a technique which uses various questionnaires and surveys to the target participants and collect measurable responses. These responses are later used into statistical analysis between predicted outcomes and satisfaction levels of number of participants using certain system, product or services. Generally, qualitative research is conducted to determine the number of population or how many people are interested in using proposed system, product or service. Also, use of this approach collects data in numerical form which can be further processed for quantified results using some statistical formulas (Bhat, QUANTITATIVE MARKET RESEARCH : THE COMPLETE GUIDE, 2018).

3.2 Research plan

According to the problem statement this thesis focuses on the study of information system available in public transportation and its accessibilities to hearing impaired passengers. Therefore, research plan was divided into two different phase which are:

3.2.1 Evaluation of public transport information display system

Different public transport operators own different modes of transportation system in Oslo, Norway. Number of public transport operators are presented in Table 1

Mode	Operators
Metro	Oslo T-banedrift As
Tram	Oslotrikken AS
Bus	Nobina AS, Norgesbuss AS, Nettbuss ØST AS and Unibuss AS
Boat/Ferries	Oslofergene AS, Skibs AS Bygdøyfergene and Norled AS (formerly Tide Sjø)

Table 1: Different transport system in Norway (Global Mass Transit, 2013)

Evaluation of Public transportation in Oslo was conducted to better understand the information system installed within it, which provides real-time information to passengers. This evaluation includes the study of various devices and equipment used to display information inside different types of public transportation. For this thesis some selected transportation medium is evaluated that includes metro (T-bane), trams (trikk) and bus.

3.2.2 Interaction with hearing impaired participants

In cooperation with HLF (Hørselshemmedes Landsforbund), Norwegian association of hard of hearing with approximately 5500 members, conducting a semi-structured interview session with hearing-impaired individuals will help to determine in-depth requirement for the system. HLF has informed to gather participants for the interview sessions.

3.2.2.1 Semi-structured interview

As decided, the use of semi-structured interview format for qualitative research is considered for the data collection. Semi-structured interview actually refers to qualitative study approach which involves both interviews and observations. This means open ended questions are prepared for participants in order to gather keen understanding and opinion towards topic of interest. Similarly, use of this interview type, will allow participants to expand their point of view and explain in greater detail about the subject in contrast to structured interview. Although questionnaires are prepared beforehand the interview will be conversational and interviewer can make changes in order of question during the interview session.

In other hand, flexibility provided by semi structured interview, interviewer requires good experience of planning and conducting interviews, which also means that interaction and conversation with participants should not lead interview to go out of topic. Interviewer also need to consider different types of participants while taking interview where some participants barely talks or are unwilling to elaborate their answers and some participants talk much dragging the interview to irrelevant topics.

Thus, main reason of choosing semi-structured interview for this thesis is to answer the research question by allowing participants to discuss about their opinion on various problems faced by them while accessing various information in public transportation on daily basis. This approach with open-ended questions will help further adjust predefined questions by adding or removing questions during the interview session, taking participants willingness to explain their opinion into consideration (Grimsholm & Poblete, 2010).

3.2.2.2 Participants

As proposed by HLF organization, the target group of this master thesis are hearing impaired who have faced or are facing problem in accessing public information announced by driver during their travel. Before conducting interview with participants, the organization was sent a copy of research questions for approval and necessary changes are made according to their feedback. As informed, the organization will help in providing participants for observation and testing of the system as this organization is constantly finding solution for hearing impaired. However, the recommended number of participants are set to 10 or more due to the large scale of impact made by the system in daily life of many people. Therefore, the research is able to produce very meaningful data if the participation is in higher number.

Finally, as participants with hard of hearing are involved, an obvious question arises "How is semi-structured interview conducted with this group of participants?". Also, to better understand their problem and extract as much as information out of their experiences, semi-structured interview is necessary. Therefore, interpreter is managed to address questions.

3.2.2.3 System demonstration and observation

The prototype developed during this phase is presented to all the participants where different scenarios are taken into examples. During demonstration, a random person will announce the specific transcript for specific scenarios and system generated text based and symbol based (if possible) output will be display on screen to all the participant. Different scenarios may include, accidents, traffic delay, important information about the type of station platform, emergency announcement and others.

3.2.2.4 Feedback after system demonstration

After successful demonstration of the system every participant is asked to provide feedback about their experience with the system and whether they have achieved some ease of access to the information provided during the demonstration. And these feedbacks can be further studied to improve the system in later phase. The feedback form is generated using google form in both English and Norwegian language.

3.3 Development method

This SDLC model provides an easier approach while making any changes in requirement of the system. Previously enhanced waterfall model was proposed as the software development approach. Since, previous development method would not produce any working software until its late stage of life cycle and can lead to higher change of risk and uncertainty, it is now decided to use RAD (Rapid Application Development) as a software development approach.

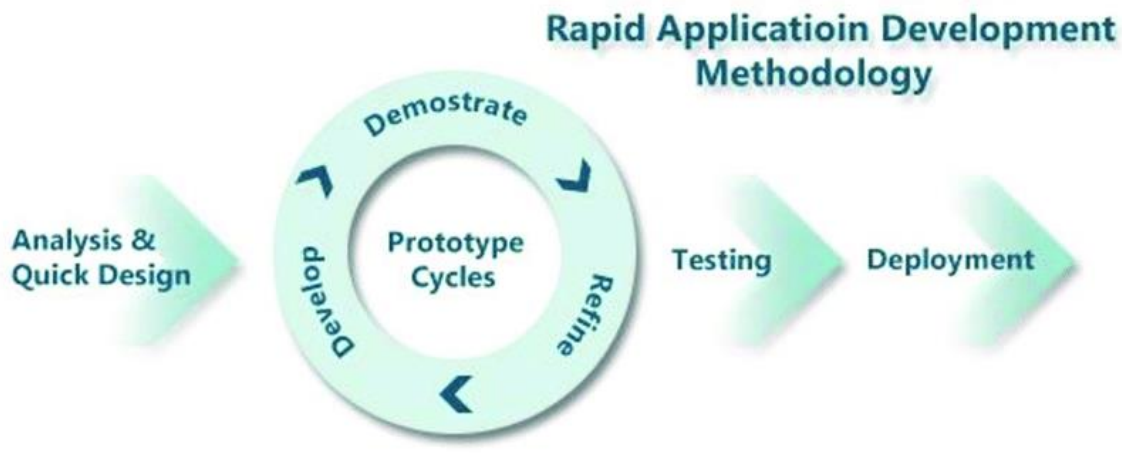


Figure 5: Rapid Application Development Methodology life cycle

As the system requirement is clear and known, this development approach would be suitable to quick design a working prototype of the required system which will be followed by a demonstration to target user group acknowledging general working mechanism of system in real life. Therefore, the main goal is to at least develop a working prototype to present in interview session. The later stages within this approach is final development of the system which would be a refined version of the existing prototype model. The prototype development cycle is repeated until it fulfills the research objectives. The testing phase validates the requirement and the research objectives compared with the function and features available within the system. The final phase would be deployment of the system into actual environment after the system environment is created according to the requirement.

4 Development

As development method for the system is already mention in previous section, this section will discuss about development environment and different tools and technique used to develop the system.

4.1 Development environment tools and techniques

4.1.1 Python

Python programming language was designed to easily understand programming. The reason to choose this high level programming language is due to its flexibility where programmers does not have to use specific hard rule while building features. Different approaches can be used to solve problems and easy to find out errors while any program compilation (Stoltzfus, 2018). As the program that is going to be developed involves some speech recognition techniques which falls under machine learning category. Therefore, it is described that python has all the necessary libraries and particular tools developed especially for machine learning system. In comparison to other programming language python has simple understandable language accessible to basic users (Why Learn Python?, 2018).

4.1.2 Google Cloud Speech API

During the initial stage of prototype development phase, Google Cloud Speech API is chosen. This API enables a method to convert audio to text by applying neural network models made available by google. Since we are using audio data, which can be greater than one minute at a time, the only drawback is current API restrictions and limitation of usage in Google Cloud Speech to text (Google LLC , 2018). Table 3 describes the limits and size of the content. However, for the purpose of prototype design these limits will be sufficient and further methods and techniques will be researched to increase the content limit if found necessary (Edmondson, 2018).

4.1.3 Google Cloud Translation API

Similarly, Google Cloud Translation API will be used in the initial stage of the prototype. This API is an easy-to-use translation service provided by google which takes HTML input and returns translated text. The prototype will be integrated with this service to translate the announced text into desired language and minimize the language barrier during information exchange during the travel. Likewise, google speech API, google cloud translate has limitation based on the number of characters translated. Table 4 has described the translation API pricing based on the characters translated.

4.2 System Architecture

The whole system is divided into four modules as shown in Figure 5. These four modules are described below.

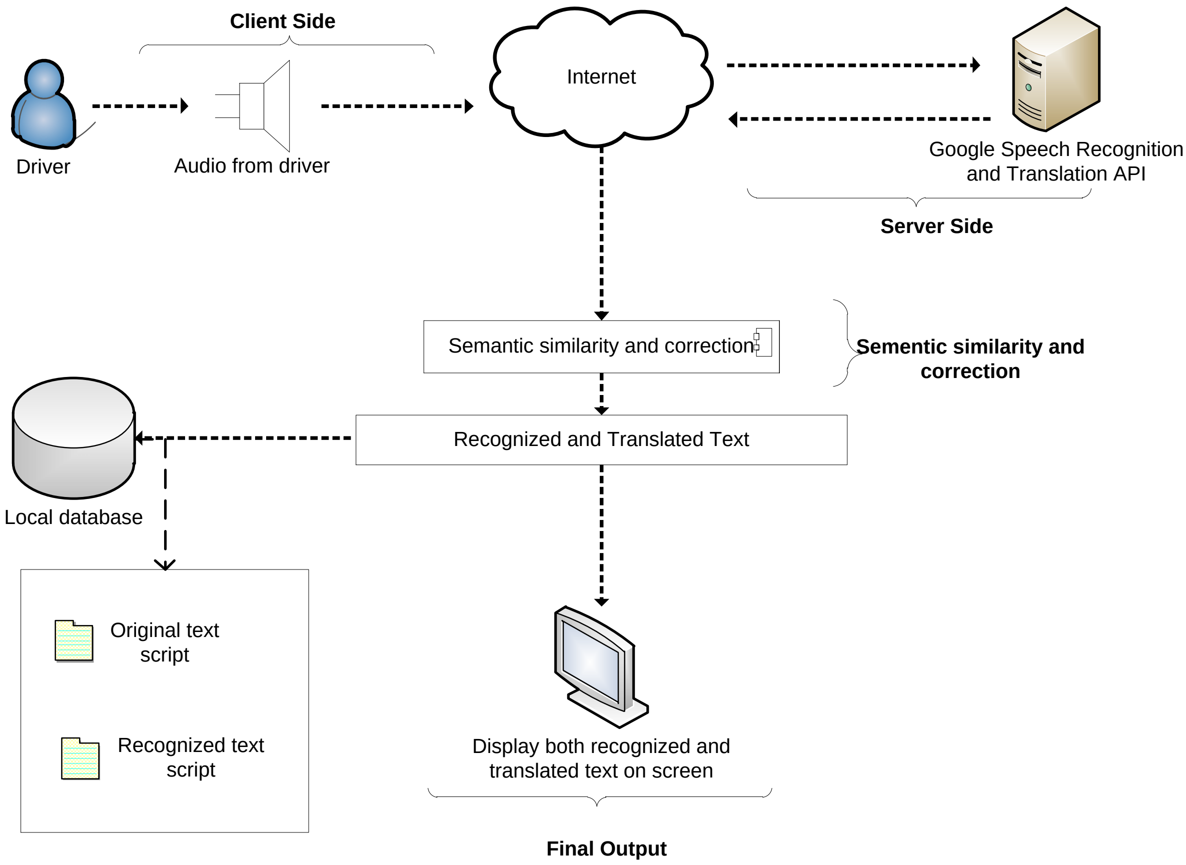


Figure 6: System Architecture

a) Client side module

This programming module takes drive's speech as a voice input and then transfer it to the server as a chunk of audio data with the help of internet connection. This module also determines the noise level and make sure that the voice input is clear without any interference.

b) Server side module

The server used in this module is actually google speech recognition API module, which receives audio input from any program linked to it, recognizes the word and then converts them into the text to transmit back to the pre-specified destination. Similarly, the use of the Google cloud translation API allows the translation of text between thousands of language pairs. This service uses larger machine learning API which increases the accuracy of the translation. In the context of this project, an announcement made in English will be translated to Norwegian language and vice-versa. The reason for using open source cloud-based speech recognition is its high computational power, availability and speech recognition neural network (Assefi et al., 2015). Although using google cloud API helps to perform speech-to-text and language translation, it requires a separate program that needs to be created from scratch in order to connect to google cloud.

c) Semantic analysis module

This module acts as the correction module where it tries to solve the problem of inaccuracy during the speech to text conversion. The main purpose of this module is to train the system with four hundred thousand word vectors provided by GloVe tool and these vectors will help to relate the syntactic structures of phrases, sentences and similarity between real time announcement text and stored announcement scripts. The most matched script will be displayed on the screen as the replacement of inaccurate speech recognition to text.

d) Final output

The final output of this system is the text that is displayed on the screen. The text displayed on the screen will the same announcement made by the driver. As the development and research were made there have been some changes with the system architecture thus, Figure 5 shows the updated system architecture. According to the updated system architecture, if the driver makes an announcement in Norwegian language, the system will display message in both Norwegian and English language and vice versa. Various UML diagrams are used to further describe system architecture.

4.2.1 Deployment diagram

Figure 6 represents the deployment diagram of the system which uses TCP/IP as network communication protocol between the google cloud server and the computer system inside public transport. There is a computer device that is installed inside the public transportation which is connected to internet through cellular network or its private network that provides internet access.

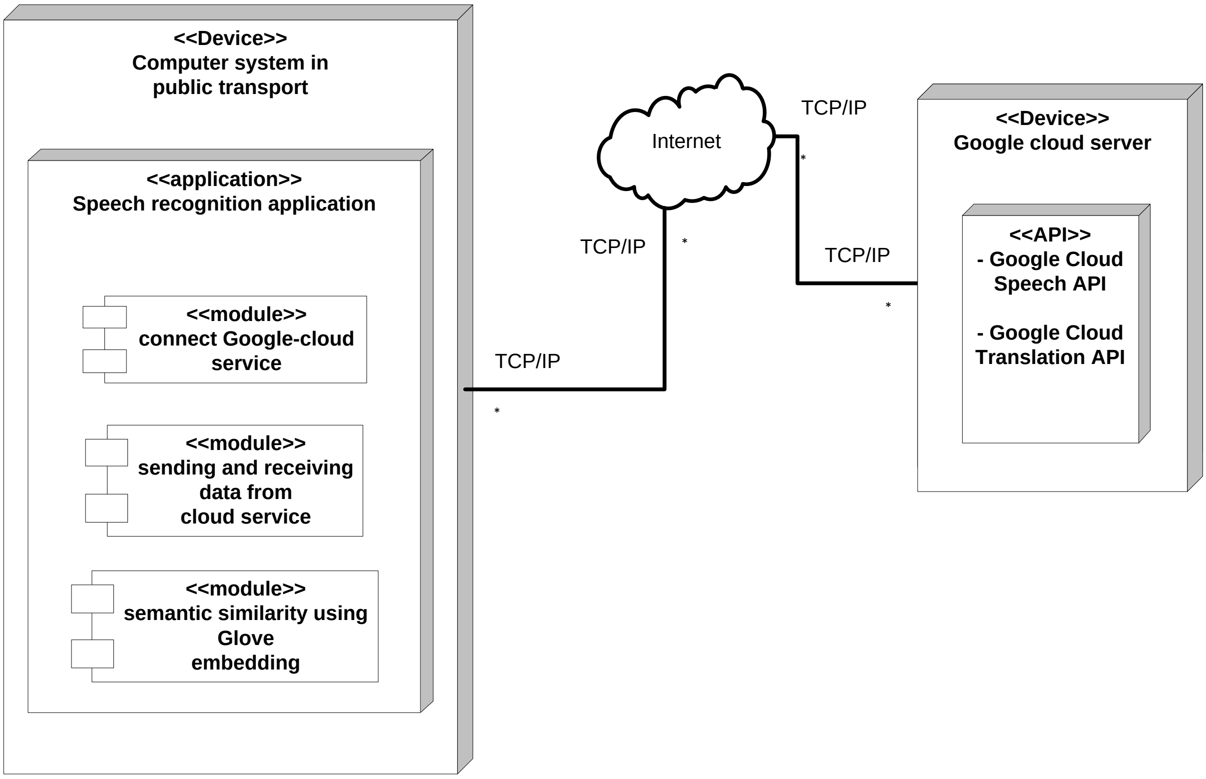


Figure 7:Deployment diagram of the system

4.2.2 Activity diagram

As the main focus of this system is to layout and understand the possible way of converting driver’s speech into text and translate into specific languages, these main steps are illustrated in the activity diagram that shows the process of converting speech to text in Figure 8 and translating text into desired language in Figure 9.

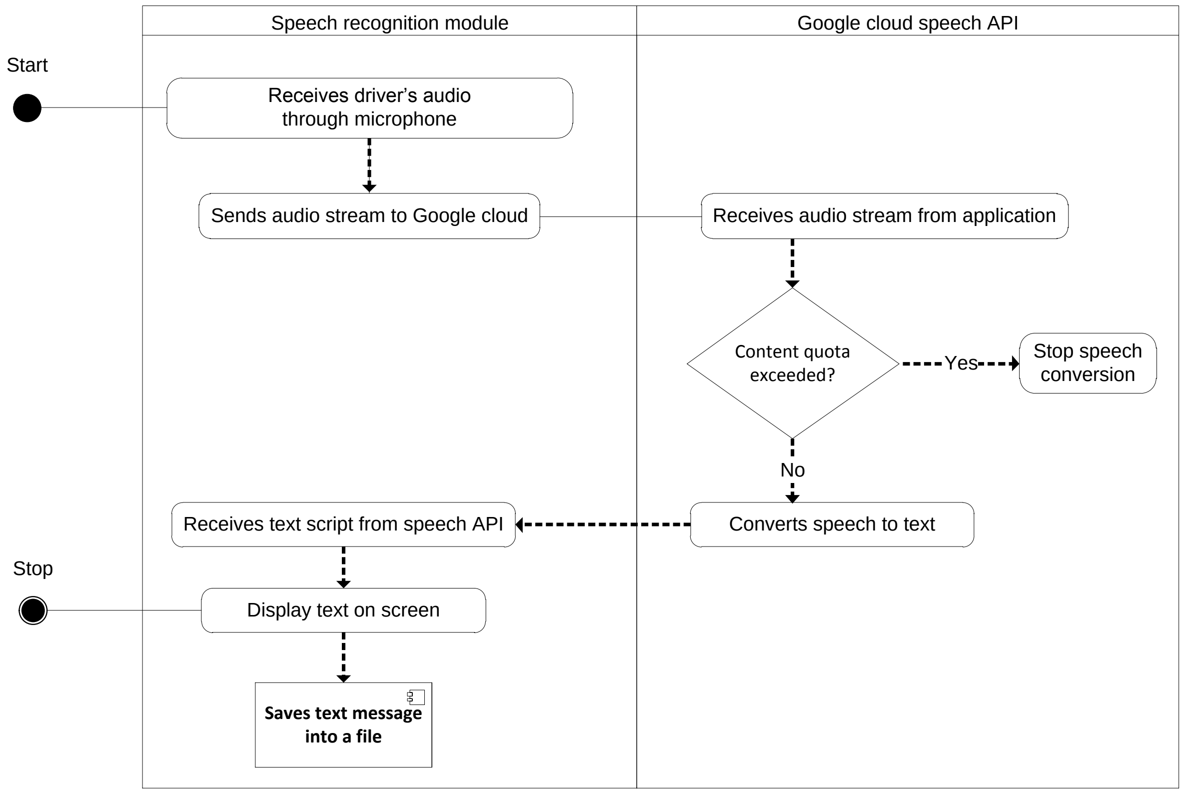


Figure 8:Activity diagram of speech recognition module

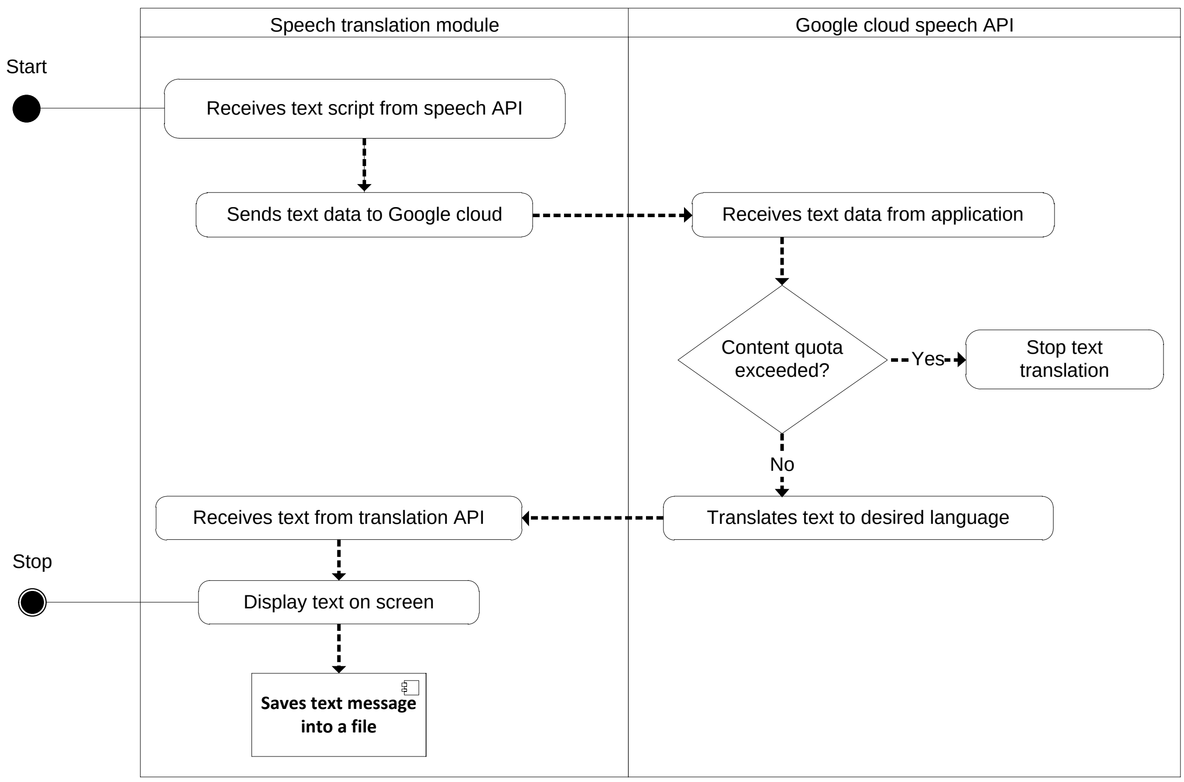


Figure 9:Activity diagram of speech translation module

5 Results

This section describes all the results achieved so far, which includes results found in research made with involvement of participants and development of prototype.

5.1 Development results

5.1.1 Frontend design

As the main focus of thesis was to provide information to the passengers in public transportation, two different prototypes were created based on the requirements provided by HLF. Although, both prototypes work on the similar system architecture, these were developed with different interface design and platform. The reason behind creating two varieties of interface was to determine the best preference of the passengers regarding text visibility and understanding while displaying the information. Similarly, different interface design platforms were used to figure out the if these prototypes can be implemented in current public information display system.

a) Prototype A

Here, Prototype A contains of various elements like in number one current time display, number two announcement header, number three symbol icon as shown in Figure 10. So the announcement header and symbol will change their color and symbols respectively when driver starts to speak for announcement. Similarly, in number four it has a button that will start the software and its whole process of speech to text conversion. In number five it has text display area where all the spoken text will be displayed. And finally, in number six there are two buttons one with image of Norwegian flag and another with image of British flag. So if the driver clicks on Norwegian flag, he can speak in Norwegian and the text in Norwegian language will be displayed on the screen. Likewise, if the driver clicks on British flag and speaks in English, the software will display all the text in English language.

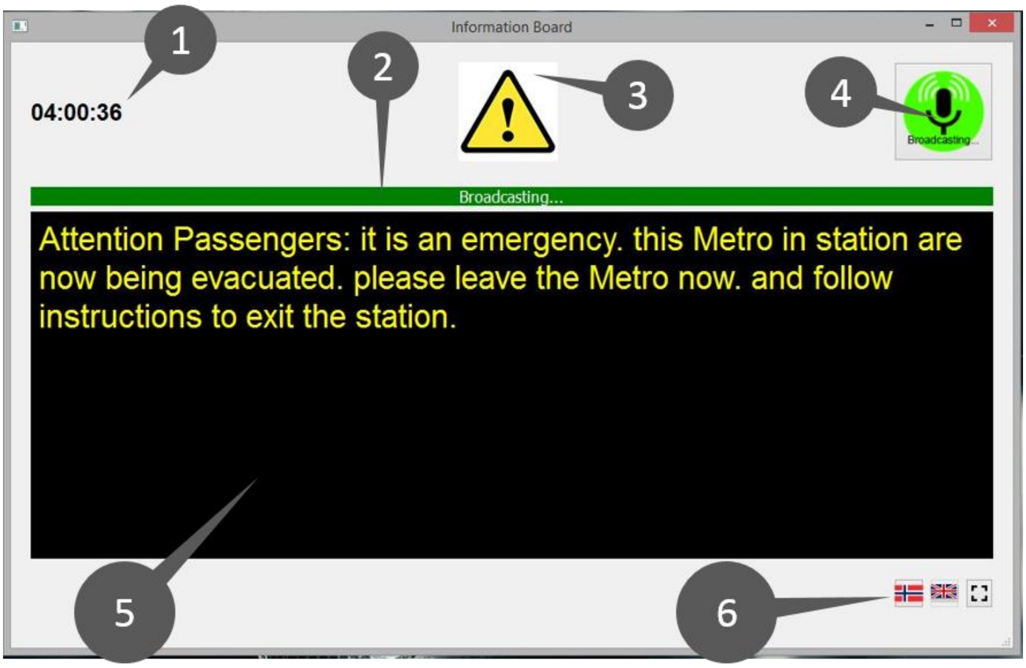


Figure 10: Prototype A

In this prototype, the interface design was developed using PyQt GUI toolkit for python.

b) Prototype B

This is a prototype that has a dark background and has few elements like number one time display and symbol number two announcement header number three button to start the speech recognition process and number four a display area where the message will be displayed. So in prototype B, the dark background will help to make the text more visible due to contrasting colors and helps passengers to read the message easily.

This prototype has a dark background which helps to make all the text more visible due to contrasting colors and helps passengers to read the message easily. Its various elements are explained below:

1. Time display and symbol:

This is the basic element that displays the time, date and day. It also has an icon that will change once the driver starts to make an announcement which can be very useful to grab the attention of passengers during the travel.

2. Text display area:

Text display area is divided into two different section upper section is to display the announcement into text and the lower section is to display the translated text. For example, if the driver chooses to make an announcement in Norwegian language, the upper section of text area will display text in Norwegian language and the lower section of text area will display text in English language and vice versa.

3. Mic button:

When the mic button is clicked, the application is ready to take the audio input and send it the google server.

4. Text Correction button:

This correction button will start the process of semantic correction once the button is clicked. This process will compare real time announcement text with the list of announcement text stored in the file.

5. Language option icons:

The two icons present with British flag and Norwegian flag in this prototype gives an option to make an announcement either in English or in Norwegian language. If the icon with British flag is selected the announcement has to be made in English language and the announcement text will be translated into Norwegian language. Similarly, if the icon with Norwegian flag is selected the announcement has to be made in Norwegian language and the announced text will be translated into English language.

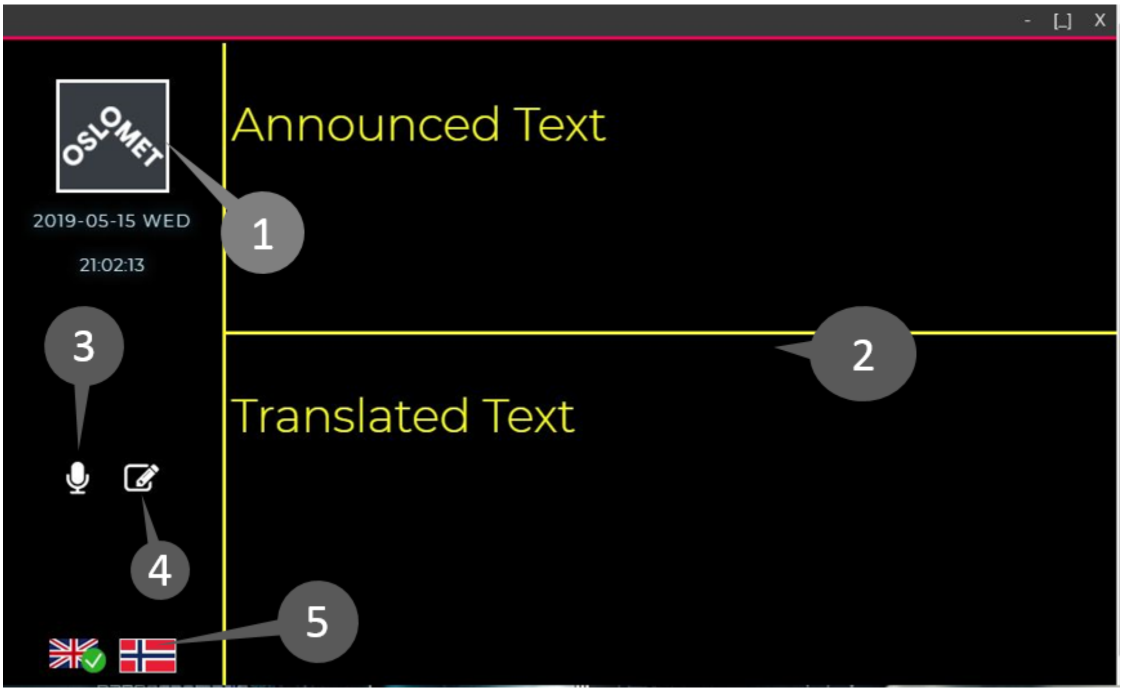


Figure 11: Prototype B

5.1.2 System testing:

The system was tested in various scenario which includes testing the system in a room with broadband internet connection and testing the same system in noisy environment like a canteen, where there are lots of people and the system was connected to internet through mobile network to test the reliability of the speech recognition and the translation. The system was also tested for the semantic similarity function to find the correct announcement message from the predefined message saved in the excel file. These test cases are explained in detailed below.

5.1.2.1 Test scenario 1:

In this scenario, the system is tested if it can find the correct announcement based on the incorrect text that was recognized by the system. After the recognized text has been displayed in the text area, text correction button as shown in Figure 11 is clicked to find the correct announcement from the list of announcement saved in excel file. Figure 12 represents the excel file containing announcement list.

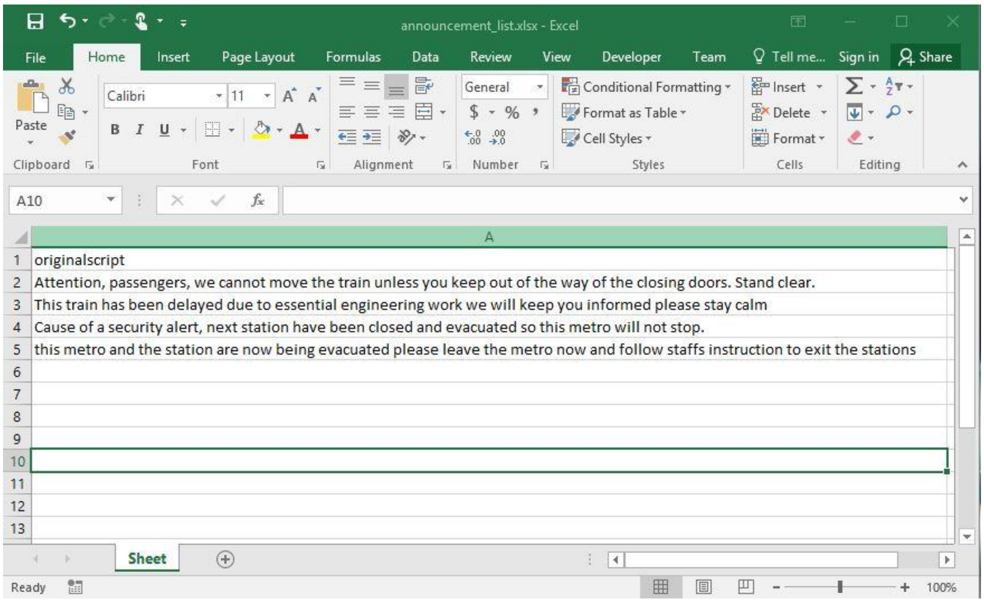
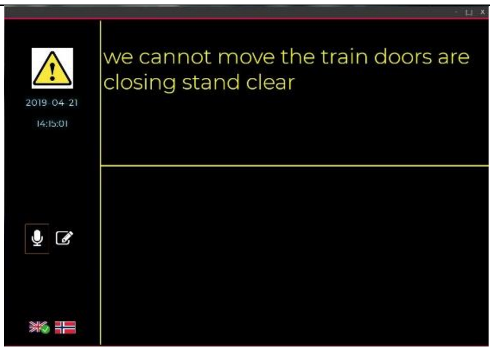
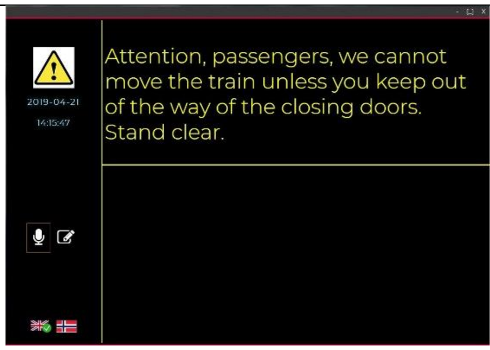


Figure 12: Stored list of announcement script

Test cases	Recognized script by the system	Original script
1)	we cannot move the train doors are closing stand clear	Attention, passengers, we cannot move the train unless you keep out of the way of the closing doors. Stand clear.
		
2)	security alert next station has been closed Metro will not stop	Cause of a security alert, next station have been closed and evacuated so this metro will not stop.

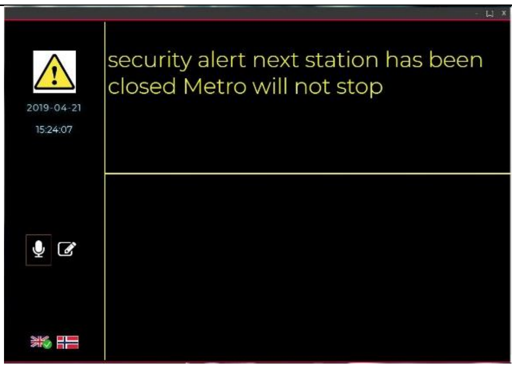
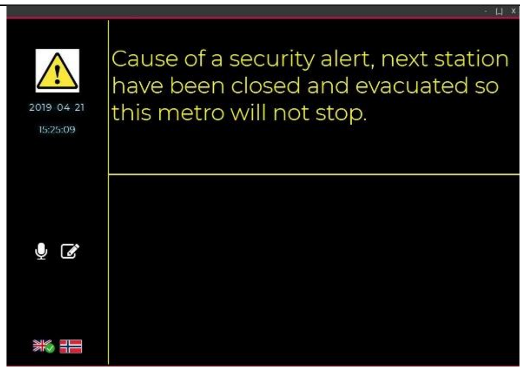
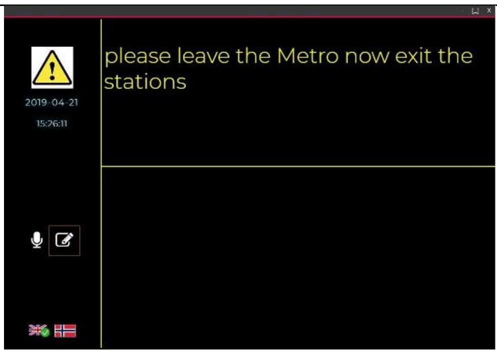
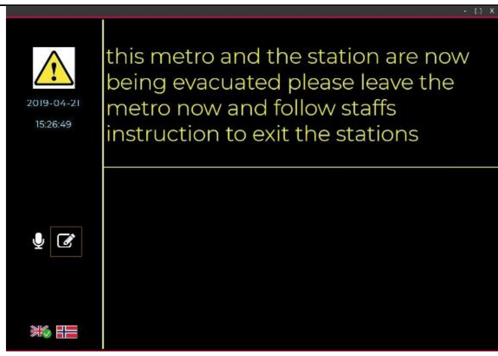
<table>
<tr><td></td><td>
</td><td>
</td></tr>
<tr><td>3)</td><td>please leave the Metro now exit the stations</td><td>this metro and the station are now being evacuated please leave the metro now and follow staffs instruction to exit the stations</td></tr>
<tr><td></td><td>
</td><td>
</td></tr>
</table>

Table 2: Announcement correction test

Table 2 above shows that if recognized text is incorrect compared to the original announcement made by driver we can use the Glove: Global Vectors for word representation to compare the similarity between them and the most matched announcement text with list of pre stored announcement script will be displayed on the screen.

5.1.2.2 Test scenario 2:

Similarly, in this test scenario the system was run in the room environment where the application was connected to broadband internet connection.

Test case 1	
Original script	Attention, passengers, we cannot move the train unless you keep out of the way of the closing doors. Stand clear.
Recognized script by the system	attention passengers we cannot move the train unless you keep out of the way Auto closing door stand clear

Translated text	oppmerksomhet passasjerer vi kan ikke flytte toget med mindre du holder ut av veien Automatisk lukke døren står klar

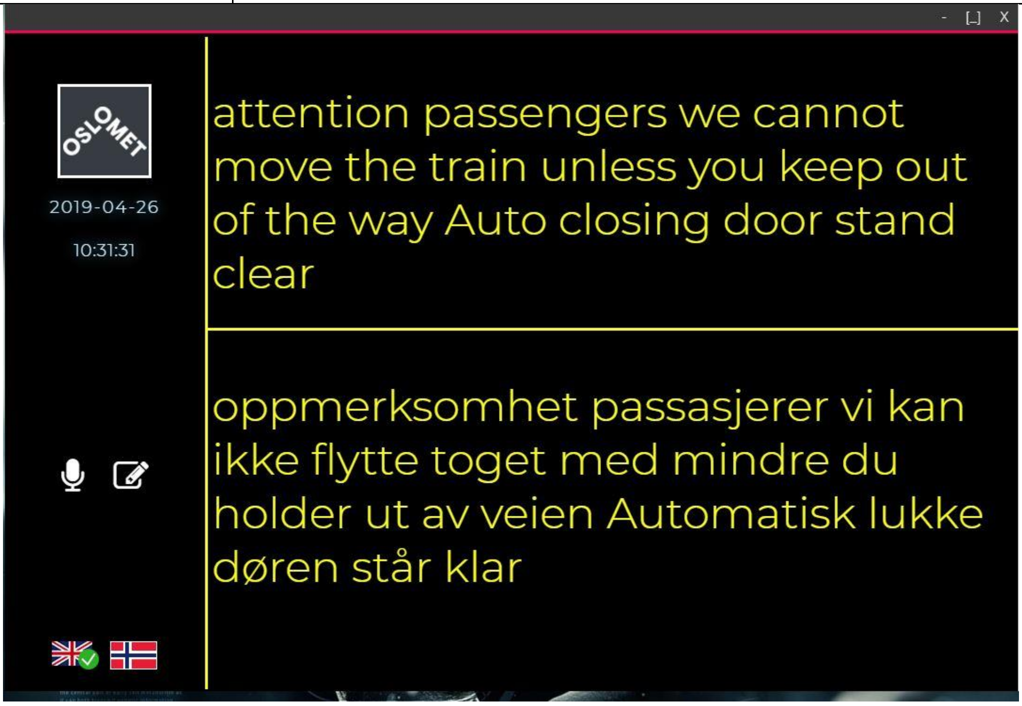


Figure 13: Test scenario 2 case 1

Test case 2	
Original script	This train has been delayed due to essential engineering work we will keep you informed please stay calm
Recognized script by the system	has been delayed due to essential engineering work we will keep you informed please stay calm
Translated text	har blitt forsinket på grunn av vesentlig ingeniørarbeid vi vil holde deg informert, vær så snill, vær rolig

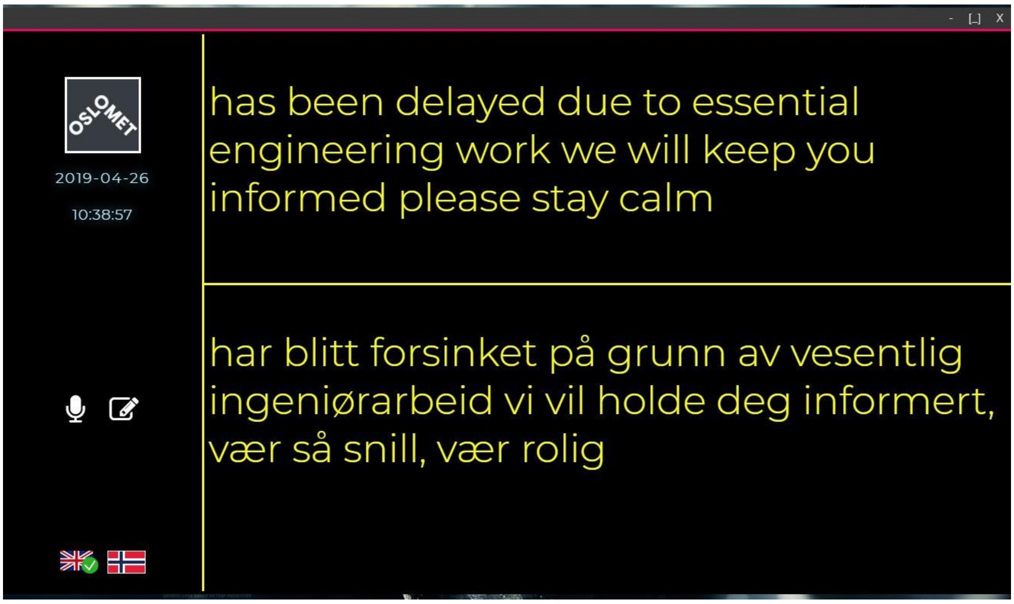


Figure 14: Test scenario 2 case 2

Test case 3	
Original script	Cause of a security alert, next station have been closed and evacuated so this metro will not stop.
Recognized script by the system	because of security alert next station will be closed and evacuated so the Metro will not stop
Translated text	På grunn av sikkerhetsvarsel vil neste stasjon bli stengt og evakuert, slik at T-banen ikke stopper

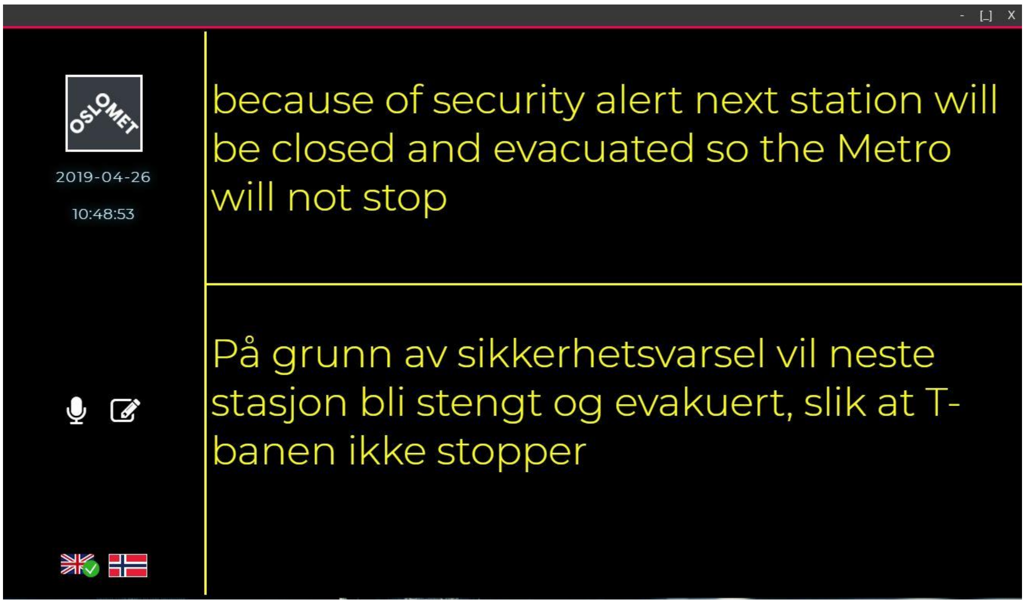


Figure 15:Test scenario 2 case 3

Test case 4	
Original script	this metro and the station are now being evacuated please leave the metro now and follow staffs instruction to exit the stations
Recognized script by the system	this Metro and station are now being evacuated please leave the Metro now and follow stops instruction to exit the station
Translated text	denne t-banen og stasjonen blir nå evakuert, vær så snill å forlate T-banen og følg stopper for å gå ut av stasjonen

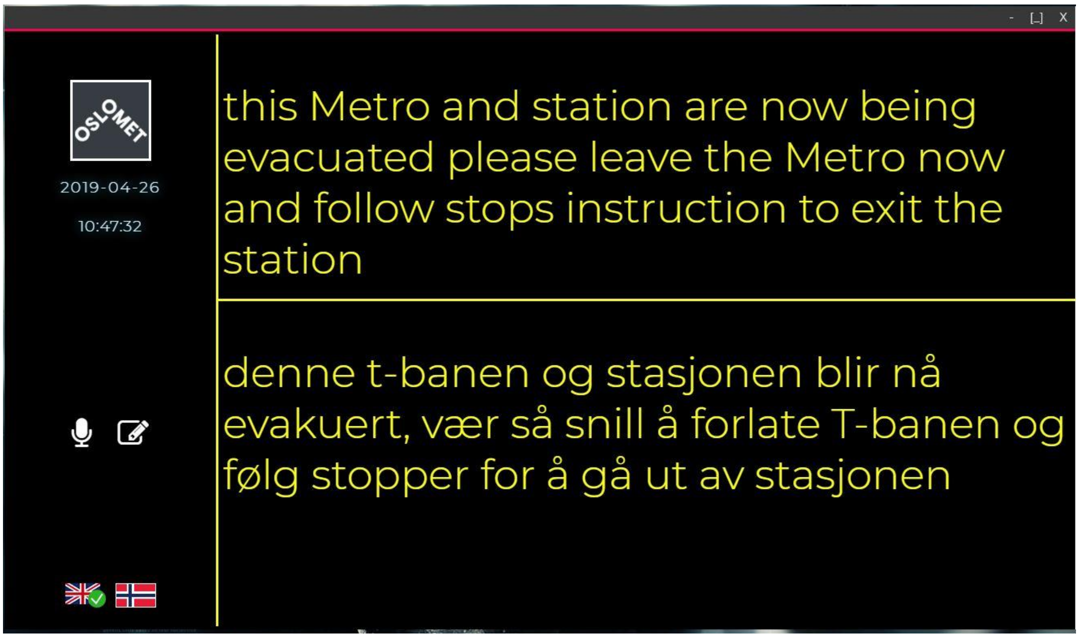


Figure 16:Test scenario 2 case 4

With the second scenario of testing, it was found that the accuracy level of recognized text was greater in comparison to test scenario 3.

5.1.2.3 Test scenario 3:

Finally, the system was tested in the noisy area to match the environment of running public transport. In this scenario, the system was connected to internet through 3G mobile network.

Test case 1	
Original script	Attention, passengers, we cannot move the train unless you keep out of the way of the closing doors. Stand clear.

Recognized script by the system	passengers we cannot move the train unless you keep out of the way of the closing doors stand clear
Translated text	passasjerer vi kan ikke flytte toget med mindre du holder ut av veien for lukkede dører står klart

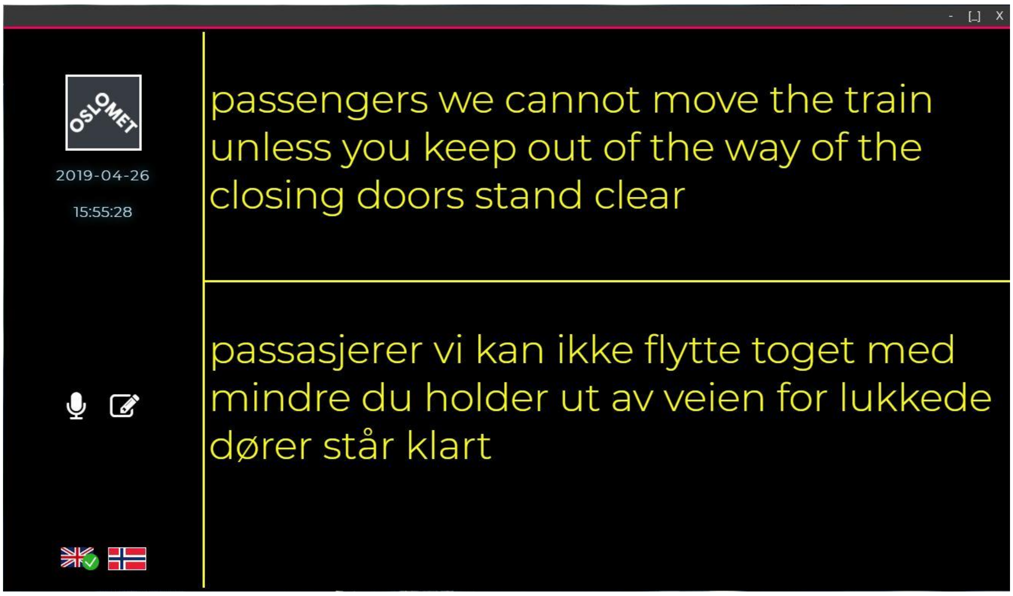


Figure 17: Test scenario 3 case 1

Test case 2	
Original script	This train has been delayed due to essential engineering work we will keep you informed please stay calm
Recognized script by the system	strain has been delayed due to essential engineering work we will keep you informed please stay calm
Translated text	belastningen har blitt forsinket på grunn av vesentlig ingeniørarbeid vi vil holde deg informert vær så rolig

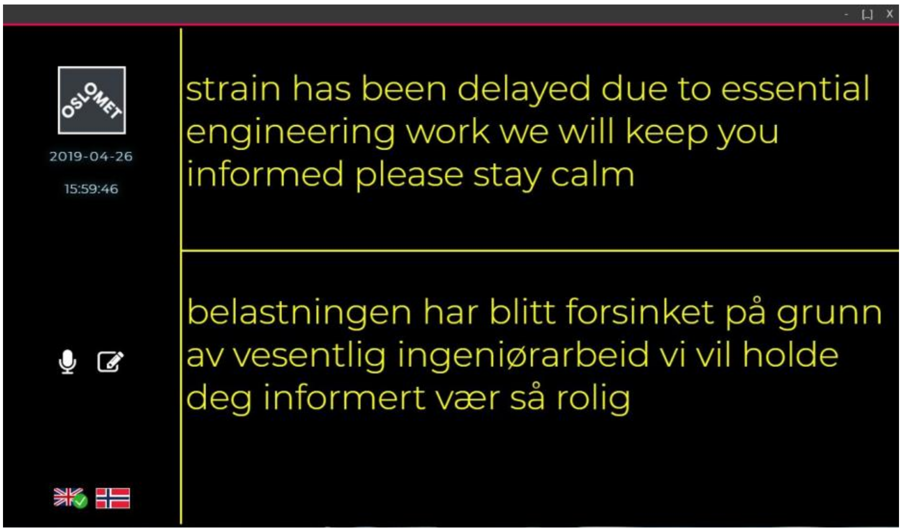


Figure 18: Test scenario 3 case 2

Test case 3	
Original script	Cause of a security alert, next station have been closed and evacuated so this metro will not stop.
Recognized script by the system	cast of security alert next station have been closed an evacuated so this matter will not stop
Translated text	Støt av sikkerhetsvarsel neste stasjon er stengt og evakuert, slik at saken ikke stopper

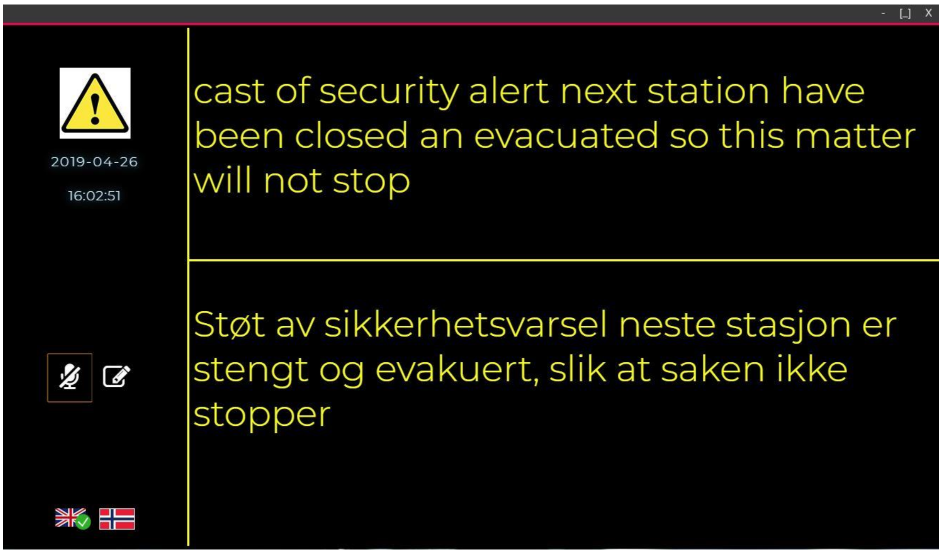


Figure 19: Test scenario 3 case 3

Test case 4	
Original script	This metro and the station are now being evacuated please leave the metro now and follow staffs instruction to exit the stations
Recognized script by the system	train station are now being evacuated please leave the Metro now and follow instructions to existing stations
Translated text	togstasjonen er nå evakuert, vær så snill å forlate T-banen og følg instruksjonene til eksisterende stasjoner

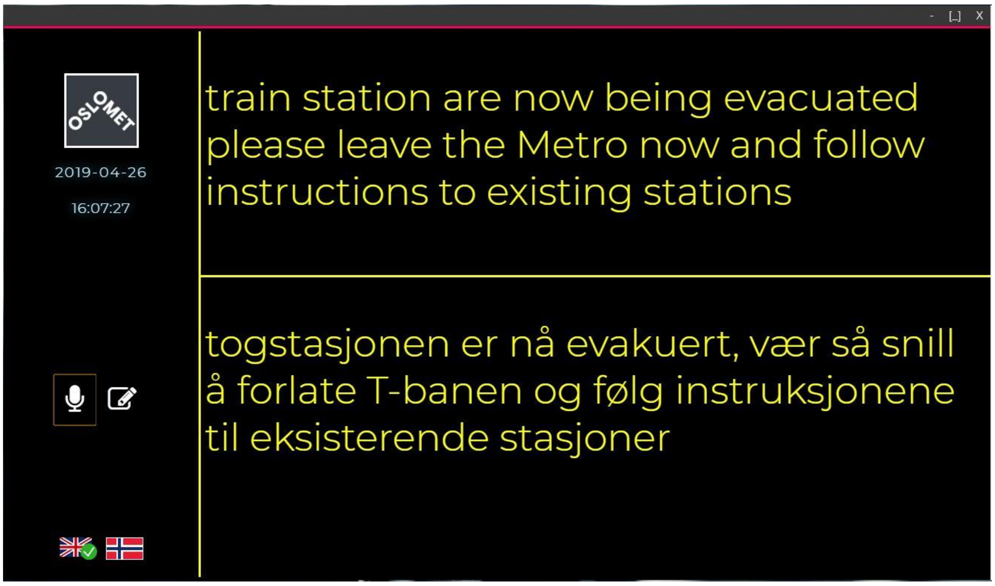


Figure 20: Test scenario 3 case 4

With the third scenario of testing, it was found that the accuracy level of recognized text was somehow less in comparison to test scenario 2.

5.2 Research findings

The overall system was demonstrated to 19 participants which includes hearing impaired personnel form HLF and students of Oslo Metropolitan university.

5.2.1 Participants review

These findings are based on the feedbacks given by 19 participants through the google form survey. The first section of questionnaires was used to gather the participant’s experience while using public transport. Similarly, second section of the questionnaires was used to gather the feedback from participants after the demonstration of the prototype.

5.2.1.1 Review of public transportation

1. What is/are your primary means of transportation?

Among 19 participants, more than 65 percent of them consider public transportation as their primary means of transportation as illustrated by Figure 21.

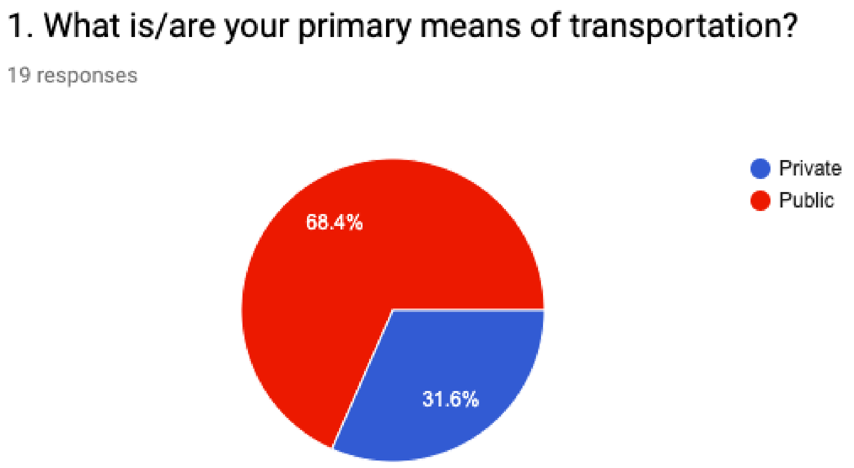


Figure 21: Difference in usage of private and public means of transportation.

2. How often do you use public transportation?

Almost 53 percent of participants uses public transportation daily in order to commute between their resident and work or university. It is also found that fewer participants hardly use public transportation as shown in Figure 22.

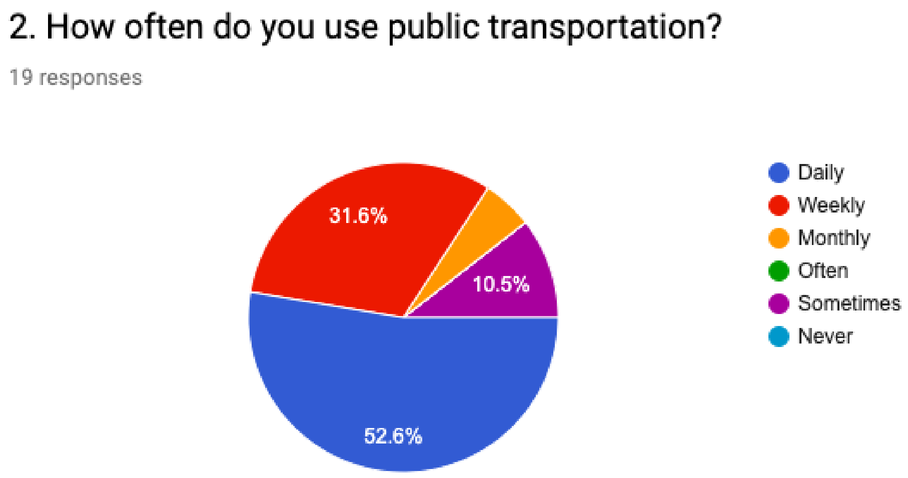


Figure 22: Recurrent use of public transport by participants

3. From which method of communication do you usually get information about transport during your travel?

Figure 23 represents that, almost 60 percent of participant depends on information display monitor to read information about public transportation during the travel

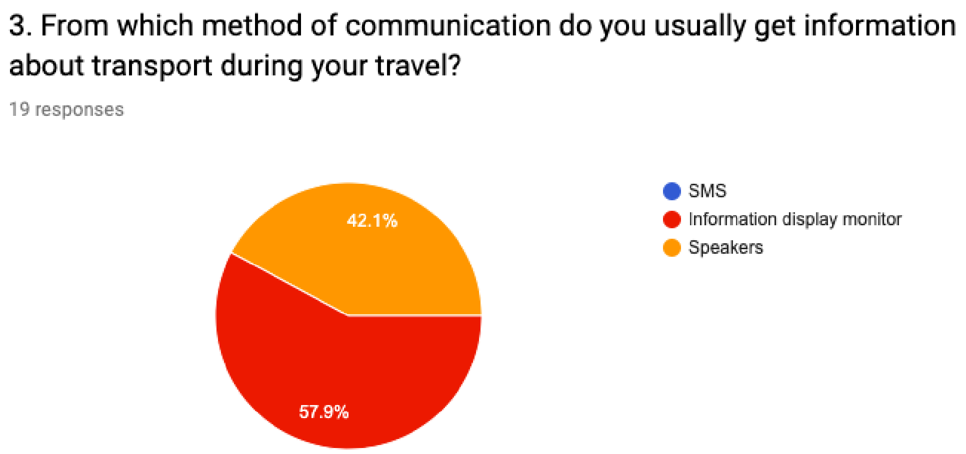


Figure 23: Relative difference between available information sources

4. Have you ever experienced a problem receiving information inside public transportation, if so how often?

It is found that, out of 19 participants almost 2 people always faces problem while receiving information inside public transportation. This means out of 100 passengers, 10 of them are likely to always face problems to get information during the travel as shown in Figure 24.

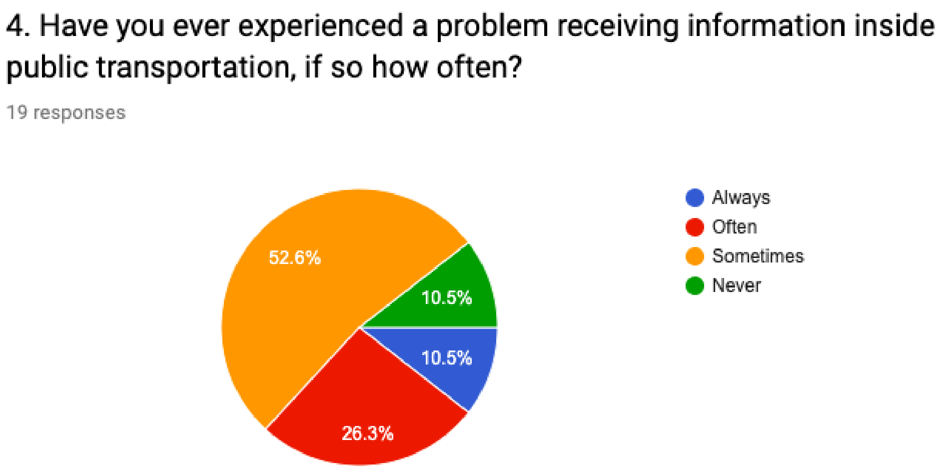


Figure 24: Recurrent amount of problem experienced by participants while receiving information

5. Do you agree that the public transportation system has enough resources to provide information for passengers?

More than 30 percent of participants believe that the current public transportation system does not have enough resources to provide information to the passengers as per Figure 25.

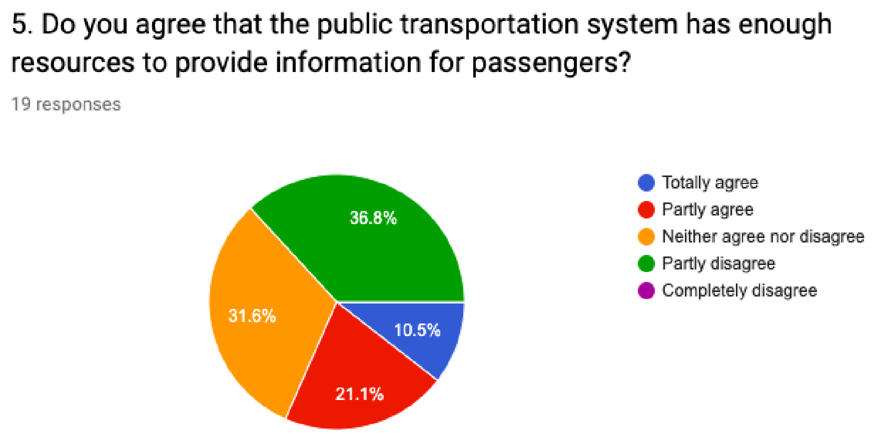


Figure 25: Statement on availability of information resources according to the participants

6. Do you notice announcements made by the driver while traveling in public transportation?

Among 19 participants, 5 of them address that they never notice announcements made by the driver which means, it is very necessary to have a reliable system that alerts all the passengers inside the public transport when the driver makes an announcement.

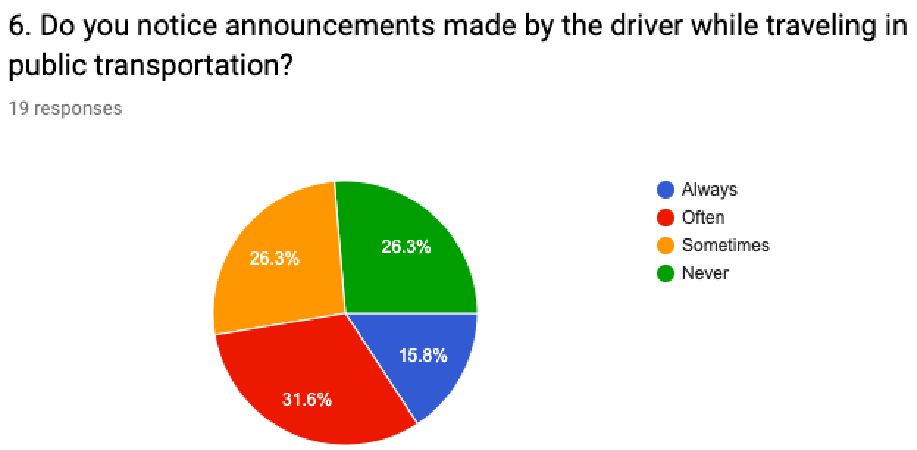


Figure 26: Percentage of participants notified by announcement

7. Do you need help for understanding the driver's announcement?

Almost 35 percent of participant address that they require help while understanding announcement of the driver.

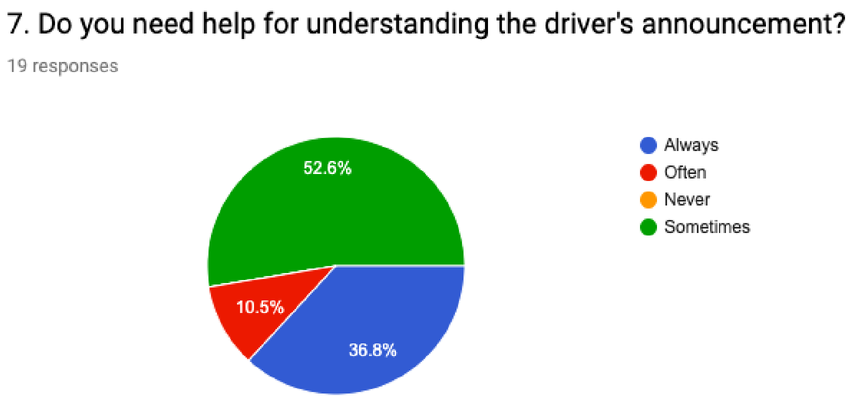


Figure 27: Number of participants needing assistant to understand announcement

8. How satisfied are you with current methods of communication system used by public transportation?

Half of the participants are partly dissatisfied with the current method of communication system used by public transportation system as shown in Figure 28.

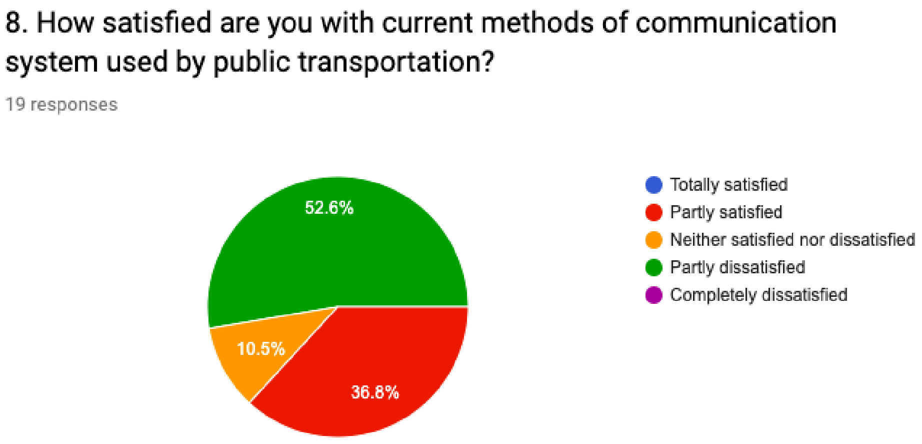


Figure 28: Satisfaction level of participants on communication method used in public transportation

9. Mention any problems that you face when announcements are made by driver.

There were various problems that were mentioned by participants that hinders them from understanding driver's announcement inside the public transport among which noise and poor language speaking skills were the most common problems. Participants also criticizes the sound quality from the speakers which are installed inside the bus and trams and driver not repeating the announcement. One of the international participant said,

- ***"The sound in the speakers on the bus is too low, it's hard to hear what the driver is saying. And often the drivers only say it once, and also not in English. And there is no written message."***

Similarly, few of other international participants explains about the language barriers that prevents them to understand the announcement, hence there need to be a system that also provides information in English language.

10. What improvement would you like to see in public transportation regarding communication methods?

Participants has mentioned if possible, they want information display monitor displaying announcement in real time, also both in Norwegian and in English. They have also recommended that the drivers could check if the screen are turned on and they are displaying the correct information about next station and other vital information. One of the participants said,

- **"The driver must check that the screens are on before they run and that they are correct in front. Bus stop + written announcements"**

5.2.1.2 Review of prototype

Both prototype A and prototype B were demonstrated to all the participants in order to determine the best prototype that can be implemented with the current public transportation system if possible.

11. How informative do you find this new system?

More than 80 percent of participants has found these prototypes informative which means these kind of system can be helpful to lots of passengers.

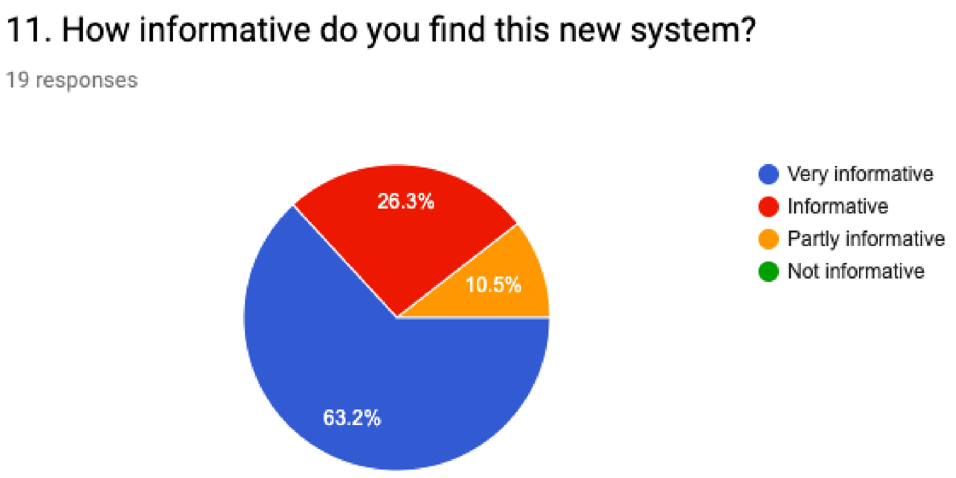


Figure 29: Level of communication of the prototype according to the participants

12. Is the text displayed on the monitors visible?

Almost 60 percent of participants found the text displayed on the monitor visible during the demonstration.

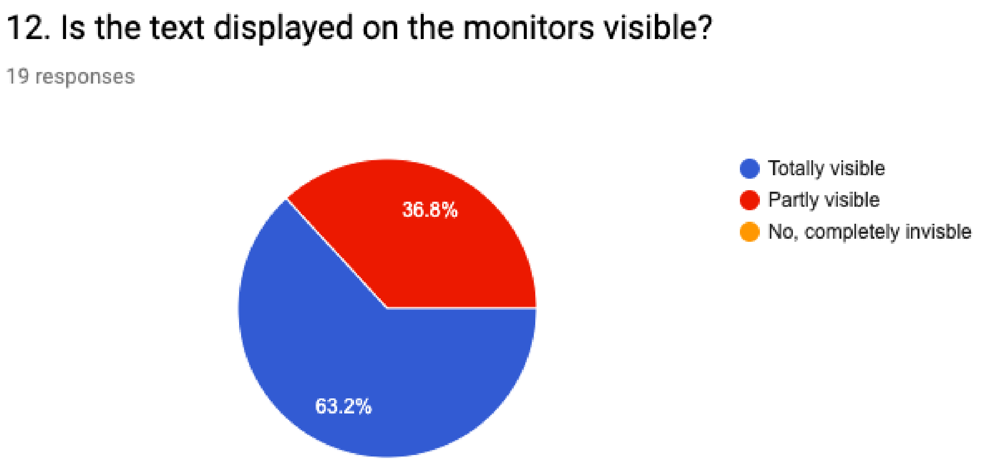


Figure 30: Comparison of visibility level of the text on the screen

13. Are the words displayed on the monitors readable?

Figure 31 represents that more than 40 percent of participants found the words displayed on the monitor readable.

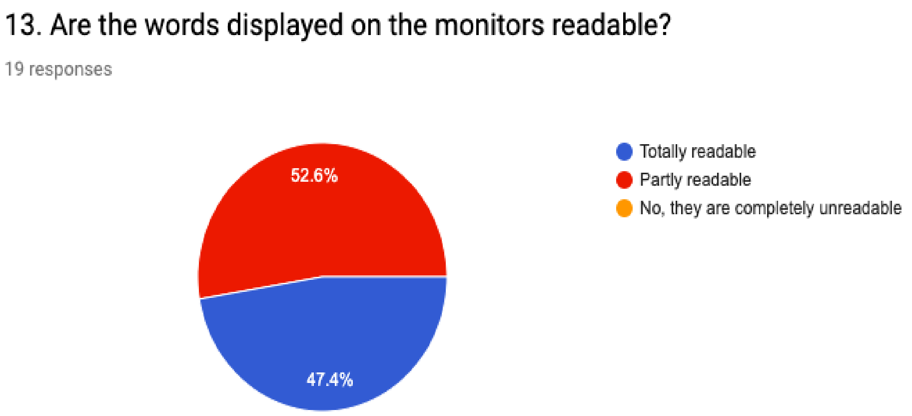


Figure 31: Comparing readability of words displayed on screen

14. Do you understand the meaning of the sentences displayed on the monitors?

Figure 32 represents that majority of participants found the text displayed on the monitor meaningful which means the system can produce meaning full text message based on the announcement made by driver.

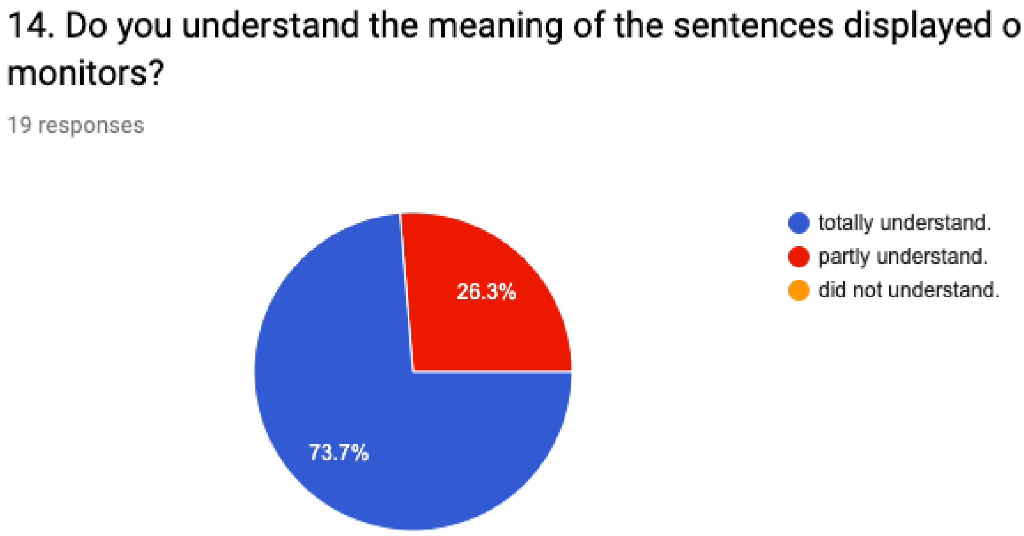


Figure 32: Comparing meaning of sentence displayed on screen

15. Which prototype has better text and color display?

More than 70 percent of participants has recommended that Prototype B has better user interface design based on color contrast and the layout.

16. If you could change one thing with this prototype, what would you want to change?

The recommendation for improvement given by all the participant are highly significant that will help further development of this system. Some of them recommended the use of dark background and white font color as it has higher contrast level. Use of larger and contrasting symbols and pictogram that can change its dimension based on screen size. In contrary, some has also mentioned to use complete white background as developed in prototype A. One of the participant appreciated the microphone symbol turning green while the announcement was made that allowed participants to be aware of the ongoing announcement. Phrase such as “It is an emergency” could be made larger and rest of the message could be displayed on the next line as suggested by one of the participants. Here are some greatly significant recommendations from the participants,

- **“I would maybe change the color to white on the font, because that is a bigger contrast against the black. Also maybe make each new sentence start on a new line, so you more easily can read it if it is an emergency.”**

- **“All new buses and trains already have one such display. The messages should be standardized instead of free speech. Then the regular speech synthesis can read them up either. In many cases there will be very poor quality of speech to the driver, then one certainly cannot manage to recognize what is said.”**

- **“Larger text and space between the text. Nice about the microphone symbol turned green on this prototype as it made it easier to be aware that there was a message and a larger triangle with exclamation marks in”**
- **“pattern of writing style. It is an emergency should be displayed bigger with read text color and then in new line more description.”**

17. If you could add any one function with this prototype, what would you add?

Majority of participants wanted to have a function that detects the language automatically and those messages should be standardized for frequently occurred situations such as traffic delay and red signals. Implementing QR code that opens website or the same text message followed by contact information to concerned authority was a unique and new feature suggested by one of the participant that can be scanned through passenger’s mobile phone.

- **“Maybe have a few default messages for the driver, to make it easier on him/her. Eks: trafic or delay could be a default message-button.”**
- **“It must recognize languages automatically. Should be based on standard messages instead of detection”**

- **“QR code that opens a website with the same info. Then people can read at their own pace.”**

18. What would you suggest us to improve with this prototype so that, you can get information more easily?

Participants were seeming to be more focused on the notification of message during the travel. They have suggested to us cognitive impairment friendly flash or blinks that notifies and grab the attention of the hearing impaired passengers including other passengers at that time.

- **“Maybe something that blinks or flashes before the message appear on the screen, to get the attention of the passenger that is deaf (and everybody else too).”**
- **“mobile display options maybe on the respective apps such as Ruter”**

19. I will recommend public transportation companies to use this kind of system.

Almost 50 percent of participant has recommended public transportation companies to use such kind of system.

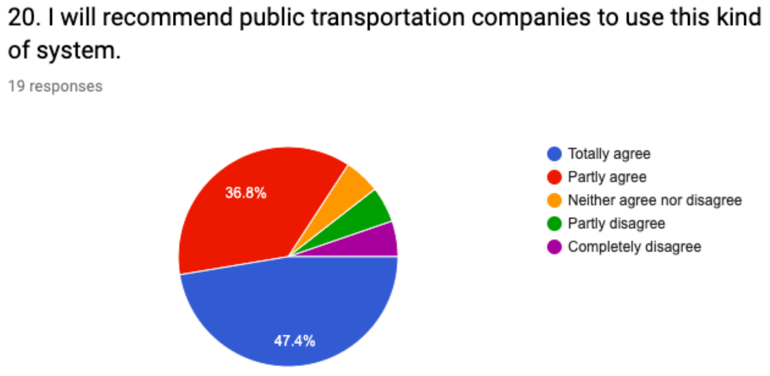


Figure 33: Recommendation of participants for integrating this system into current public transportation

6 Discussion

The resulting prototype was demonstrated to the participants of HLF and some students at Oslo Metropolitan University. The present thesis considers the possibility of implementing system that displays announcement of driver into the display monitor. After completion of all the research approach mentioned above in methodologies section some critical analysis is done in this system.

6.1 Passengers experience during the travel

Excessive handling of delay and other situation occurred during travel implies clarifying the explanations behind it, limiting its effect and giving continuous and precise data. Then again, reduced distribution which is described by an absence of data, no clarification of the issue, and the public transportation company which lacked sufficient amount of resources to provide complete information to the passengers. Just a minority of travelers are able to receive particular announcement made by the driver for situation such as delay, emergencies, traffic congestion, regardless of speaker device available within the transport, hearing impaired and international passengers has to deal with information gap during their travel.

Different sources of information are accessed or available at different travel stages, each driving a different information experience: digital and broadcast media are used before arriving at the departure station and are the best-rated information on any stage of the travel. The key information is understanding its severity for the majority of passengers made aware of the disruption before arriving at the station. Some passengers can receive custom messages from the public transportation company about disruption, including a solution that works for them. Most passengers have been made aware of the station disruption, where announcement and displays are the main sources of information, with few speaking to staff or using digital sources. This is a stressful environment and there is frustration that displays are not always considered to be sufficiently frequently accurate, helpful or updated. There are weaker ratings for ability to find out more here than at the pre-station stage, which ranks the lowest across all public transportation system.

Drivers announcement on the public transportation provide the most information, but they have the lowest rating. Delayed service make passengers feel resigned and anxious, with a loss of control. Passengers want drivers or staff member to provide quick and frequent updates or take personal ownership of the situation. General analysis describes that the drivers are thought to be ‘out of the loop' too often, not having access to the up - to – the - minute information where some passengers have (via smartphones). This is surprising for passengers who do have the information, and they believe that it is likely to hamper the ability of the driver to be helpful when less informed than the passengers themselves. Key areas that are important to passengers and where performance is currently weaker are the frequency, amount, and speed of information and the ability to find out more throughout all travel stages.

During interruption or delayed public transportation, the dominant mindset of passengers is frustration. The experience of hearing impaired passengers is at its worst when a poor information experience aggravates the frustration of the delay. Poor information makes them feel incapable in controlling their travel, changing plans, informing others, or making alternatives. This leads to their feeling as a hostage. Interestingly, response from the announcement did not necessarily identify new needs, but increased emotion and more intense experience. Generally speaking, the most important thing all the passengers want to know is what are the consequences of the delay, rather than the problem's nature. The value of information on the problem and advice regarding alternatives depends on the disruption stage or the situation of the passenger. In general term, a highly focused method of providing a predefined or standard announcement system that suffices, the requirement of what the passenger need to know must be implemented.

Addressing these problems to the CIO of RUTER, -Terje Storhaug he replies that, unfortunately the on-board display-screens are connected to a vendor specific real-time solution. All protocols and interfaces are proprietary to the vendor, and even they have difficulties in getting things changed. It is therefore not easy to “take over” these screens for giving additional info in an ad-hoc manner. However, they are currently developing a new solution and the first buses will be put in ordinary traffic within summer 2019. Everything that is displayed on the screens - or played on a loud speaker is streamed in real-time from their backend. Messages will be put on dedicated information screen display board the right hand side as shown in Figure 34. He addresses the company is keen to experiment with text-to-voice using Amazon’s Polly. Universal design will be considered for front end design but there is always room for improvements. This vital information has influenced on how to proceed in the future improvement of the public transportation system and with the help of this thesis more development of various features can be explored that needs to be implemented taking accessibility into consideration in current public transportation system.

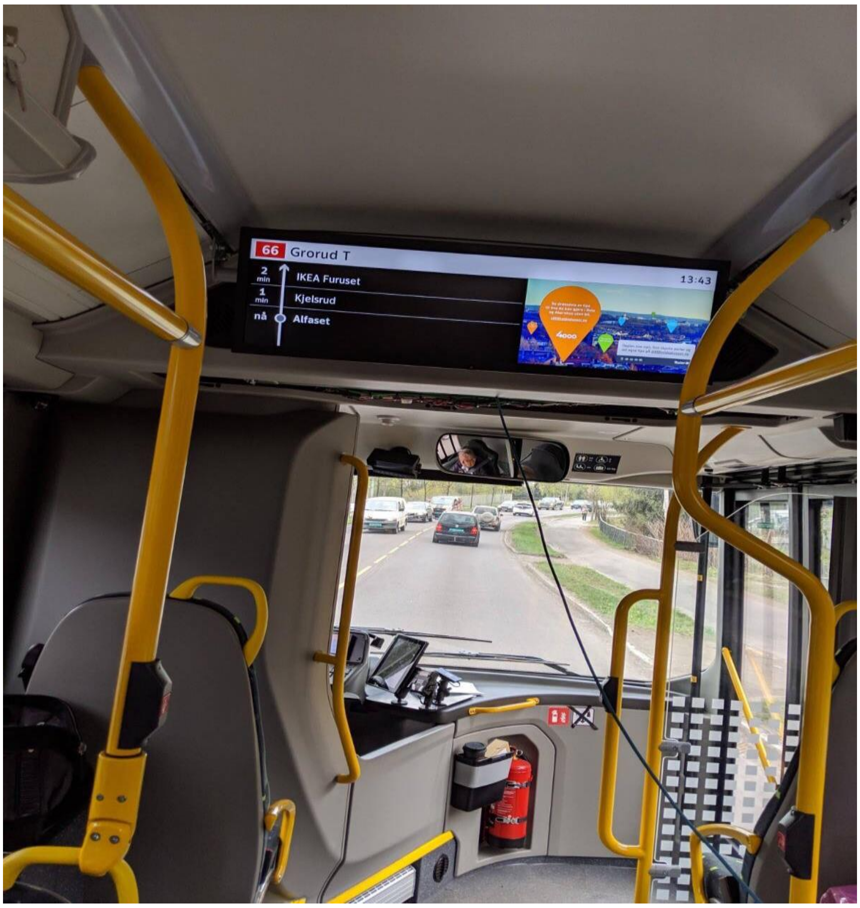


Figure 34:Example of display screen installed on the bus for future public transportation.

6.2 Analysis of proposed system

One of the thing that were most appealing for our participant was the real time announcement display function on both prototype. And during the demonstration, only speech to text display function was presented. Later, functions like semantic similarity and information correction as well as language translation were added. These features were added based on the significant feedback given by participants and the suggestion given by political advisor of HLF – Marte Oppedal Vale.

6.2.1 Radar chart analysis

Figure 35 displays the correlation where participants were required to identify visibility, readability and meaning of the text message displayed on the system. The figure illustrates that the system has provided more meaningful information and more than 60 percent of participant could easily visualize the information.

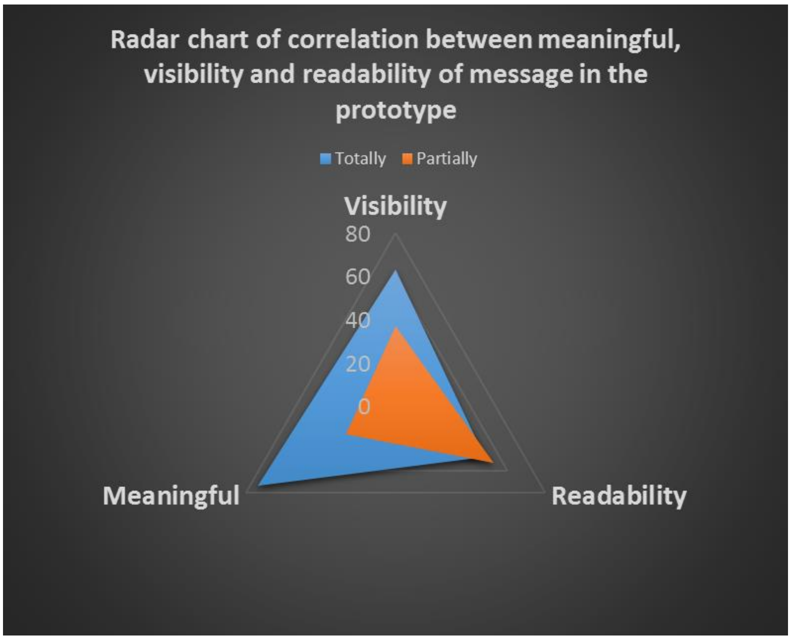


Figure 35: Correlation between visibility, readability and meaning provided by the prototype

Similarly, in Figure 36, participants were asked to choose between prototype A and prototype B based on the overall appearance, where maximum number of participant preferred Prototype B over Prototype A.

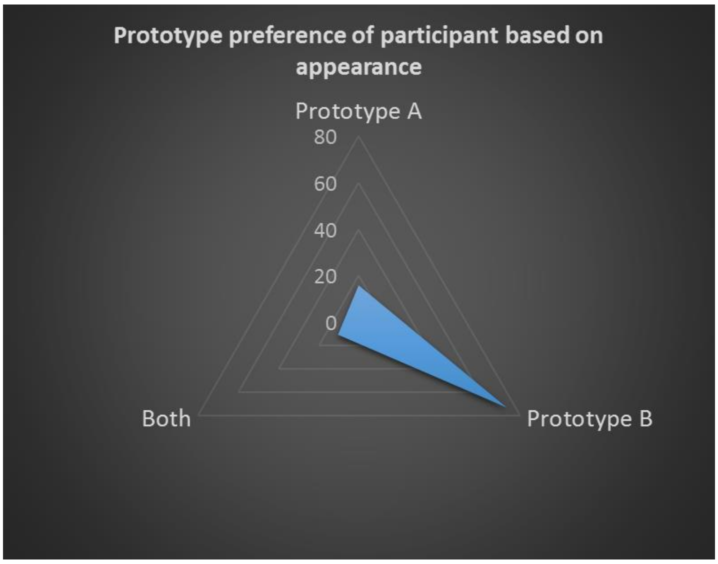


Figure 36: Participants preferences between prototype A and prototype B

6.3 System utility

As analyzed, various public transportation system uses different information display system. Unlike public buses or Tram, T-Bane does not share same route with other modes of transport. This reduces the amount of traffic jam, delay in arrival unless unfortunate environmental factor like bad weather occurs. Therefore, it is very easy for passengers to predict the arrival and departure time of T-Bane. After the study, it was found that T-Banes are mostly equipped with light emitting diode (LED) display that shows the next station information and on the stations same LED displays shows arrival time of the T-Bane as shown in Figure 37.

Figure 37: LED display panel in current T-Bane in Oslo city

However, some buses and trams uses the same route which sometimes creates the problem of traffic jam and uneven traffic flow, and differ the original schedule of arrival and departure of trams and especially buses. All the buses, are equipped with LED display monitor that displays arrival time for the next station. Each bus is equipped with global positioning system (GPS) device which helps to locate current location and helps to determine required time to next destination. Figure 38 represents the LED display for the buses of Oslo city.

Figure 38: Current information display panel in public bus in Oslo city

All the public transportation systems have loud speakers that announces the next station name and drives will manually make an announcement to the passengers about the problems faced during the travel. It was also found that, if there was any problem and passengers has to make any alternative in the middle of the journey, it is the driver who explain the way to get to alternative arrangements. Here, all the announcements are broadcasted through loud speakers and basically in Norwegian language also only once. Therefore, it makes the situation very difficult for international people and especially hearing impaired. Therefore, the proposed system might introduce a new and improved way of information exchange during their travel taking accessibility and universal design into consideration.

Regarding the application of the proposed system, prototype A has a drawback which requires the specific platform to run however, prototype B was designed using cross platform software development method. If carefully improved, prototype can be integrated with the information display panel available in buses. Additionally, if wider and longer display screen are installed in trams and T-Bane, prototype B can be easily executed providing uninterrupted information for the passengers.

The main question raised during the development of this system regarding the requirement of internet connectivity to run the system, section 5.1.2 has described the outcome of the system while connected to mobile network. Similarly, if we can implement a device that connects to mobile cellular network the use of this system can be expanded all over the public transportation system. However, the cost of implementing internet connecting device and display panel for each public transport might be costly but possible.

7 Ethical issues

Public transportation system with reliable information flow definitely has an ability to provide significant benefits to passengers. In contrast to the beneficial aspect, there are bunch of ethical dilemmas due to maximum use of location tracking, sensing and real-time behavior judgment and higher number of technological infrastructure such as:

7.1 Financial issues:

Universally design public transportation technology often peaks infrastructure costs to support spontaneous travelling, participation and increased familiarity among people with disabilities. Installing required technical devices and software, increases the cost of implementation and hiring professional increases additional expenditure. While using already available API, their cost also adds up to the expenditure. As per now, during the prototyping phase the limit of the Google Cloud Speech and Translation API is within free quota. Table 3 describes the price table of the Google Cloud Speech-To-Text which is priced on monthly basis depending upon the amount of successful audio processing by the service. Table 3 also describes that if the audio to process is less than 60 minutes per months the service is free to use.

Feature	**0-60 minutes**	**Over 60 minutes, up to 1 million minutes**
Speech recognition (excluding video)	Free	$0.006 USD / 15 seconds*

Table 3: Google Cloud Speech-to-Text price quota

Similarly, Table 4 describes Google Cloud Translation API pricing where a system can translate up to 500,000 characters for free and just requires $20 to translate 1 billion characters which is reasonable if we increase the amount of characters to be translated.

Feature	**1–500,000 characters**	**500,001–1 billion characters**
Text translation	Free	$20 per million characters

Table 4: Google Cloud Translation API pricing

7.2 Privacy concern:

The expectation level of privacy in public is higher but in regards to public transport, it is limited. Concerning disability, the degree of privacy is completely lost as they rely on caregivers, transit providers or members of society to accompany their task and activities during travel.

7.3 Transparent information:

As providing information during travel is a critical element because it should ensure high quality of service. Whilst obvious scenarios concerning anonymity is crucial due to risk and redistribution of information and data authenticity should be ensured. Intervention warnings should be trust worthy and liable so that warnings targeted for drivers might be misunderstood by riders and could lose trust over public transport information system.

8 Conclusion

This overall review of existing information system carried out in this report states that various barriers of ICT are still needed to be considered as serious issue of accessible information system. Keeping in mind the end goal is to enhance the level of accessibility, by for instance, giving satisfactory data previously and along the way in this way lessening tension and giving genuine feelings of serenity. It is considered important these signs and information guarantee the correct meaning regardless of any location, particularly in connection to significant goals e.g. public buses, real taxi terminal, significant shopping area, distance between modular office, or hospitals. Reinforcement likewise implies that the hard of hearing or in need of a hearing aid do not need to depend on different people to inform about the messages in public transport. Therefore, a system that is capable of displaying information with speech recognition and announcement will help both hearing impaired and visual impaired passengers, which can be autonomous, and leads to independent travelling. As such, they would have the capacity to recognize the right vehicles for their journey and in addition communicate to the driver about their requirements.

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10 Appendices

10.1 Survey questionnaires in English language

Section 1: Survey on public transportation information system for passengers.

Today, the information in public transport is largely provided through speakers in a situation like signal failures, platform change and in emergencies such as fire, evacuation. Such situations are often chaotic, and the driver/conductor/ pilot is reading messages about what happens and what passengers are going to do. This rarely helps the hearing impaired to bring along. This survey is an attempt to understand the problems faced by hearing impaired passengers during the travel.

* Required

1. **What is/are your primary means of transportation?** * *Mark only one oval.*

   - Private
   - Public
   - Other: ____________

2. **How often do you use public transportation?** * *Mark only one oval.*

   - Daily
   - Weekly
   - Monthly
   - Often
   - Sometimes
   - Never

3. **From which method of communication do you usually get information about transport during your travel?** *
   Mark only one oval.

   - SMS
   - Information display monitor
   - Speakers
   - Other: ____________

4. **Have you ever experienced a problem receiving information inside public transportation, if so how often?** *
   Mark only one oval.

   - Always
   - Often

- Sometimes
- Never

5. **Do you agree that the public transportation system has enough resources to provide information for passengers?** *
Mark only one oval.
   - Totally agree
   - Partly agree
   - Neither agree nor disagree
   - Partly disagree
   - Completely disagree

6. **Do you notice announcements made by the driver while traveling in public transportation?** * *Mark only one oval.*
   - Always
   - Often
   - Sometimes
   - Never

7. **Do you need help for understanding the driver's announcement?** * *Mark only one oval.*
   - Always
   - Often
   - Never
   - Sometimes

8. **How satisfied are you with current methods of communication system used by public transportation?** *
Mark only one oval.
   - Totally satisfied
   - Partly satisfied
   - Neither satisfied nor dissatisfied
   - Partly dissatisfied
   - Completely dissatisfied

9. **Mention any problems that you face when announcements are made by driver.** *

10. **What improvement would you like to see in public transportation regarding communication methods?** *

Section 2: Review on the prototype

This is the feedback form for the prototype that records announcements made by the driver and translates them to text on information display monitor.

11. **How informative do you find this new system?** * *Mark only one oval.*

- Very informative
- Informative
- Partly informative
- Not informative

12. **Is the text displayed on the monitors visible?** * *Mark only one oval.*

- Totally visible
- Partly visible
- No, completely invisble

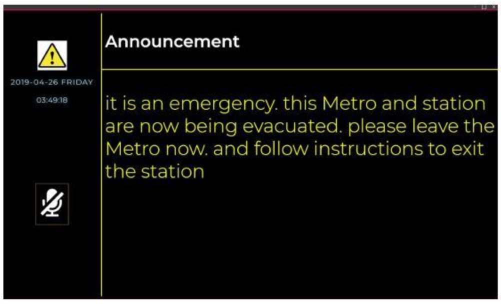
13. **Are the words displayed on the monitors readable?** * *Mark only one oval.*

- Totally readable
- Partly readable
- No, they are completely unreadable

14. **Do you understand the meaning of the sentences displayed on the monitors?** * *Mark only one oval.*

- totally understand.
- partly understand.
- did not understand.

15. **Which prototype has better text and color display?** * *Mark only one oval.*



Prototype A [With bright background]

Prototype B [With dark background]

Both

16. **If you could change one thing with this prototype, what would you want to change?** *

17. **17. If you could add any one function with this prototype, what would you add?** *

18. **What would you suggest us to improve with this prototype so that, you can get information more easily?** *

19. **If you were to review this prototype, what score would you give it out of 10?** * *Mark only one oval.*

1	2	3	4	5	6	7	8	9	10
⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭

2. **I will recommend public transportation companies to use this kind of system.** * *Mark only one oval.*

- Totally agree
- Partly agree
- Neither agree nor disagree
- Partly disagree
- Completely disagree

10.2 Survey questionnaires in Norwegian language

Seksjon 1: Undersøkelse på kollektivtransport informasjonssystemet for passasjerer.

I dag er informasjonen i offentlig transport i stor grad gitt gjennom høyttalere i en situasjon som signalfeil, plattformskifte og i nødstilfeller som brann eller ved evakuering.

Slike situasjoner er ofte kaotiske, hvor fører, leder eller pilot leser meldinger om hva som skjer og hva passasjerene skal gjøre. Dette hjelper sjelden de hørselshemmede. Denne undersøkelsen er et forsøk på å forstå problemene som hørselsskadde passasjerer står overfor under reisen. * Required

1. **Hva er ditt primære transportmiddel?** * *Mark only one oval.*

- Privat
- Offentlig
- Other: ____________________

2. **Hvor ofte bruker du offentlig transport?** * *Mark only one oval.*

- Daglig
- Ukentlig
- Månedlig
- Ofte
- Noen ganger
- Aldri

3. **Fra hvilken kommunikasjonsplattform får du vanligvis informasjon om gjeldende transport under reisen?** *
Mark only one oval.

- SMS
- Informasjon skjermmonitor
- Høyttalere
- Other: ____________________

4. **Har du noen gang opplevd et problem med å motta informasjon i løpet av reisen din med offentlig transport, i så fall hvor ofte?** *
Mark only one oval.

- Alltid
- Ofte
- Noen ganger
- Aldri

5. **Er du enig i at det offentlige transportsystemet har nok ressurser til å gi informasjon til passasjerer.** *
Mark only one oval.

- Helt enig
- Delvis enig
- Ikke enig eller uenig
- Delvis uenig
- Helt uenig

6. **Oppfatter du kunngjøringer fra føreren av transportmiddelet når du reiser med offentlig transport.** *
Mark only one oval.

- Alltid
- Ofte
- Noen ganger
- Aldri

7. **Trenger du hjelp til å forstå føreren kunngjøring?** * *Mark only one oval.*

- Alltid
- Ofte
- aldri
- noen ganger

8. **Hvor fornøyd er du med nåværende kommunikasjonssystem som brukes i offentlig transport?** *
Mark only one oval.

- Helt fornøyd
- Delvis fornøyd
- Verken fornøyd eller misfornøyd
- Delvis misfornøyd
- Helt utilfreds

9. **Nevn eventuelle problemer du møter når kunngjøringer annonseres.** *

10. **Hvilke forbedringer må gjøres for å optimalisere kommunikasjonsmetodene i og på offentlig transport?** *

Seksjon 2: Tilbakemelding av prototypen

Dette er tilbakemeldingsskjema for prototypen som registrerer kunngjøringen gjort av føreren og deretter oversetter tale til tekst på informasjons-displayskjermen.

11. **Hvor informativ synes du dette systemet er?** * *Mark only one oval.*

    - Veldig informativ
    - Informativ
    - Delvis informativ
    - Ikke informativ

12. **Er tekstene som vises på monitorene godt synlige?** * *Mark only one oval.*

    - Helt synlig
    - Delvis synlig
    - Nei, helt

13. **Er ordene som vises på monitorene leselig?** * *Mark only one oval.*

    - Helt lesbar
    - Delvis lesbar
    - Nei, de er helt uleselige

14. **Forstår du betydningen av setningene som vises på monitorene?** * *Mark only one oval.*

    - jeg forstår alt.
    - jeg forstår delvis.
    - jeg forstår ikke.

15. **Hvilken prototype har best tekst- og fargedisplay?** * *Mark only one oval.*

- ◯ Prototype A [Med lys bakgrunn]
- ◯ Prototype B [Med mørk bakgrunn]

- ◯ Begge er like gode

16. **Hvis du kan endre en ting med denne prototypen, hva vil du endre?** *

17. **Hvis du kunne legge til en funksjon ved denne prototypen, hva vil du legge til?** *

18. **Hva vil du foreslå oss å forbedre ved denne prototypen, slik at du kan få tildelt informasjon enklere?** *

19. **Hvis du skulle vurdere denne prototypen, på en skala fra 1 til 10 hvilken karakter ville du gitt den?** *
Mark only one oval.

1	2	3	4	5	6	7	8	9	10
◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

20. **Jeg vil anbefale offentlig transportselskap å bruke dette systemet** * *Mark only one oval.*

- Helt enig
- Delvis enig
- Vet heller ikke enig eller uenig
- Delvis uenig
- Helt uenig