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Evaluating Accessible Pedestrian Signals for Visually Impaired Persons in Copenhagen

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ACCESSIBLE PEDESTRIAN SIGNALS

EVALUATING PEDESTRIAN SIGNALS FOR VISUALLY IMPAIRED PERSONS IN COPENHAGEN

An Interactive Qualifying Project submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science

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May 9, 2010

ABSTRACT

This project, sponsored by Worcester Polytechnic Institute and Dansk Blindesamfund, investigated accessible pedestrian systems that can improve accessibility for people with visual impairments in Copenhagen. Current audible beacons are experiencing audibility, noise pollution, maintenance, and cost issues. We began by familiarizing ourselves with the problems identified, the needs of people with visual impairments, assistive technologies that are available for crossing the street, and related technologies that can be used for accessibility purposes. This was done through extensive literature reviews and numerous interviews with both accessibility experts and identified stakeholders. After identifying and analyzing numerous technological solutions that address the needs of neighbors and the government while maintaining and improving upon high levels of accessibility for persons with visual impairments, we created a set of short-term, near-term, and long-term conclusions and recommendations. Our findings conclude that the audible beacons currently found in Copenhagen can be improved through use of a more effective percussive tone, by implementing a remote monitoring system for improved maintenance, and by working directly with people who are fully blind to ensure the volume is set at an appropriate level above ambient noise. We further suggest that push-button and pedestrian detection activation schemes begin to be implemented to help ensure the audible signals are only produced when needed, and that fully tactile solutions be researched that can help pedestrians cross the street with little or no acoustic help.

ACKNOWLEDGEMENTS

The authors wish to thank everyone who generously contributed their time and efforts, participated in interviews, showed us intersections, responded to our request for comment placed in several local newspapers, aided with translation and assisted us with research or revision. In particular, we wish to thank Mr. John Heilbrunn of Dansk Blindesamfund for his advice, ideas, and logistical support; Prof. Holly Ault for her suggestions for revision, as well as Ms. Evelyn Riley and Ms. Dorte Silver for assistance with our research.

AUTHORSHIP

This section details which author was responsible for each task related to this project. The tasks that needed to be completed were research, writing content, interviewing experts and stakeholders, surveying intersections, editing written material, and finding or producing graphics. Research required group members to look for published sources, examine the content for useful material, and cite appropriately. Content writing required group members to present key ideas in cohesive prose with relevant tables and figures. Interviewing experts and stakeholders required members to create interview plans, schedule meetings, and often send interview summaries to the interviewee in a timely manner. Surveying intersections required group members to visit various locations in Copenhagen, measure details such as the distance at which signals are audible, assisting guides who are visually impaired if present, and documenting comments and measurements on a note sheet. Editing required group members to revise all written material to ensure that all statements made are accurate, all conclusions are defensible, and no syntactic errors are present. Graphics required group members to locate appropriate graphical sources, generate visuals, and cite graphics as needed to explain and enhance the written content. Jeffrey Gorges, Brian Shaw, and Danica Rili each contributed equally to each of these tasks.

EXECUTIVE SUMMARY

For sighted pedestrians, crossing the street is a simple task. For pedestrians with visual impairments, it is much more challenging. Accessible Pedestrian Signals (APS) encompass a variety of technologies aimed at helping people with visual impairments travel safely and independently. They provide information to pedestrians about the location of the intersection, which direction to cross, when to cross and how to get to the other side safely.

Locating the end of a sidewalk at an intersection with APS is currently done by either feeling a detectable warning surface underfoot or following a locator tone. Both indicate that the pedestrian has reached the edge of the sidewalk and must stop. Currently in Copenhagen, the locator tone is a beep at 880 Hz once every two seconds. All APS devices in Denmark also have a tactile arrow which indicates the exact direction of the crosswalk as well as whether or not traffic islands must be crossed.

When the crossing signal light comes on, the pedestrian can be informed through auditory or vibro-tactile means. The current crossing tone in Copenhagen has the same pitch as the locator tone but at a rate of five times every two seconds. Audible beacons are another type of APS device that can alert the pedestrian to cross as well as guide them in the right direction by emitting a highly directional signal. The most common vibro-tactile solution is a vibrator incorporated into the APS device.

Current APS manufacturers make a variety of devices, many of which have similar features such as the ability to emit locator tones with different sounds, tactile arrows, vibrations and adjustable volume capabilities. Prisma Teknik and Swarco provide most of the devices currently used in Copenhagen. Devices have the capability to adjust the volume level of the signal to accommodate changes in the ambient sound level. These devices are consistently located relative to the edge of the crosswalk to allow for easier navigation between signals. They are also located a consistent distance from the curb so the user can be close to both the signal and the intersection. Most intersections are timed in Copenhagen, so most devices do not have a pushbutton.

Even though current devices have the capability to adjust volume based on ambient noise, finding a volume that is loud enough for pedestrians but won’t disturb residents in the area is a problem. Maintaining these systems and trying to develop universal harmonization are further issues. A number of systems such as pedestrian detection and user activation using radio frequency identification (RFID) tags or cell phone Bluetooth signals have been proposed to address these problems.

The goal of this project was to research new and improved Accessible Pedestrian Signal systems for the Dansk Blindesamfund. To accomplish this task, we investigated the needs of our stakeholders: the visually impaired, the community and the government. We also discussed problems with the current system. Furthermore, we identified and assessed solutions to each specific problem. The basic objectives for this project are listed below.

1. Understand the needs of the stakeholders
2. Detail characteristics of existing and related technologies
3. Compare APS systems using criteria based on stakeholder needs
4. Suggest appropriate solutions
5. Recommend possible implementation strategies

To familiarize ourselves with this project, we determined what accessible technologies exist, how they work, and how they help people with visual impairments cross the street. We analyzed each system based on how well it met the needs of our stakeholders.

In order to understand how people with visual impairments cross the street as well as their needs and concerns, we interviewed a mobility specialist and conducted walkthroughs of APS-equipped intersections. We then asked a representative group of actively travelling people with visual impairments about their needs and their opinions on the technologies we were considering. In order to obtain neighbor complaints directly from the community, we placed an advertisement in three local newspapers asking residents for their opinions.

To understand how the government is involved in accessible system installation and the types of devices that are currently installed, we interviewed three traffic engineers working for the city of Copenhagen. They also explained how timed intersections function in the greater Copenhagen area. We also conducted field investigations of specific APS installations and interviewed a representative of Swarco, the company responsible for APS installation and maintenance. Additionally, we studied the Danish Road Rules detailing various requirements for APS devices. During this investigation we learned that the Frederiksberg municipality recently reconfigured their APS system to use a different acoustic signal. We interviewed a member of the Dansk Blindesamfund instrumental in the installation as well as a traffic engineer who worked on the project.

System solutions were identified by analyzing the problems with the current systems and reviewing literature on both available and related technologies. We interviewed representatives from Prisma Teknik and Swarco, two APS manufacturers whose products comprise the majority of the current devices around Copenhagen. Available features were categorized based on how they help pedestrians locate the crosswalk, orient themselves correctly, determine when to cross the street, and do so safely. We used decision matrices and the results of previous studies to analyze different system solutions.

Our conclusions have been divided into those that can be applied in the short term to improve the current system, those that can be applied in the near future using technology that already exists, and those that need further investigation before being implemented.

For short term solutions, the tone used can be improved to maximize effectiveness and minimize noise pollution. We recommend reprogramming the current devices to use the knocking sound that is currently being used in Frederiksberg. Maintenance and error reporting can also be made more effective by standardizing APS configuration methods. A fully blind consultant familiar with APS regulations should be hired to help determine the appropriate volume settings for the acoustic signals. Phone and e-mail hotlines should be set up for interested parties to report malfunctions or complaints, which should be recorded for future reference.

Mid-term solutions are those that can be applied in the near future with existing technology. Noise pollution and appropriate volumes for pedestrians can both be addressed by using a pedestrian activation system. The signal would emit a constant locator or pilot tone. The pedestrian could then request a crossing tone – which would be louder – with a button press. This louder tone would continue for two crossing cycles before the signal returned to the original, quieter locator tone. Recently installed devices have a button on the bottom which can be used. After implementation, people with visual impairments must be educated on how the system works, what to expect and which intersections use the new system. Another recommendation is to improve tactile arrows by indicating the total number of traffic islands to be encountered as opposed to simply indicating the presence of islands.

We also recommend that Detectable Warning Surfaces (DWS) be implemented more widely and more effectively. This will allow pedestrians to better locate the intersection, the signal pole with the APS device as well as any traffic islands. Recommendations for best practices should come from collaboration between Dansk Blindesamfund and local traffic engineers as well as studies of countries with well developed tactile infrastructures, such as Japan and Great Britain.

Our mid-term solution for improving maintenance involves implementing centralized error detection for APS devices. Newer APS devices have the capacity for reporting errors to a centralized system much like the centralized traffic signal error reporting system currently used in Copenhagen. The limitations to implementing centralized error reporting come from the availability of wiring to a control box and any changes that must be made to the current software. Since any centralized error reporting would be an improvement, it should be implemented whenever possible.

Long term solutions are those that best address the needs of all the stakeholders but require more research before implementation. We recommend a system that uses tactile features to convey all the information necessary for crossing the street. This would involve using tactile paths and detectable warning surfaces to locate an APS device with a tactile arrow and vibrating crossing signal. The pedestrian would follow a tactile path to the DWS at the far side of the intersection with DWS at intermediate traffic islands.

The feasibility of this system depends on many factors, such as whether a vibrating APS device and a tactile path can be as effective as an acoustic device, the effect of tactile surfaces on the mobility of other pedestrians as well as installation and maintenance costs. Existing regulations and specific studies have been conducted but more research must be done on the specific application of tactile paths for crossing Danish streets. DWS and tactile paths can be installed at intersections in conjunction with acoustic signals as a method of phasing in the new system. This would also provide an opportunity to test the proposed system's effectiveness before complete implementation.

This project has produced a number of conclusions and recommendations based on an evaluation of the needs of each stakeholder and the current status of accessible systems in greater Copenhagen. Some of these recommendations can be implemented now, some in the near future, while others still require substantial research, testing and verification. It is our hope that our recommendations will lead to improved accessibility for persons with visual impairments while still fulfilling the needs of the community and the government.

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1 INTRODUCTION

For sighted pedestrians, crossing the street is a simple activity: push a button and wait for the signal to cross. For pedestrians with visual impairments, this simple act is much more challenging. Crossing at the wrong time or mistaking the boundaries of an intersection could lead to serious injury or worse. Accessible Pedestrian Signals (APS) encompass a variety of technologies aimed at helping a person with disabilities travel safely and independently throughout a community. Generally, they provide information to pedestrians with visual impairments about the location of the intersection, which direction to cross, when to cross and where to find the opposite side of the crosswalk. This information improves safety, independence, and mobility, but systems can be costly to install and maintain.

In Copenhagen, Denmark installation of APS is mostly the responsibility of the municipal government. Since the City of Copenhagen has a limited budget, the government has prioritized APS installation in the central business district. APS systems have been installed elsewhere at the request of the Dansk Blindesamfund (Danish Association of the Blind). Still, only 72 of the 359 intersections have some type of APS (Bjerremose, Frederiksen and Kreutzfeldt 2010). The independence and mobility of people with visual impairments is limited by this incomplete coverage across the city. Another issue is that many systems are malfunctioning or non-functional. Since there is no way to remotely monitor these systems for proper performance, users and residents must report problems to the appropriate municipality. There are also problems with noise pollution. Some pedestrians with visual impairments say the signals cannot clearly be heard, while residents who live nearby complain about them being too loud.

A variety of interested parties have been continually striving to find the best way to guide pedestrians across the street safely. Orientation and mobility specialists have studied what is the best pitch and tone of auditory signals, how loud they need to be, and how to place them most effectively. Other studies have been done to improve technologies that aid navigation as a whole for people who have visual impairments. The current state of technology still has problems that need to be addressed. It is difficult for municipalities to fully accommodate pedestrian needs due to these noise complaints while keeping costs within budget. A thorough understanding of the different technologies available and the needs of the stakeholders is required to determine which solution or solutions are most appropriate.

2 BACKGROUND

Accessibility for pedestrians is an important part of designing traffic infrastructure. With an expectation of equality for people with disabilities, considerations must be made to meet their needs. Crossing intersections is one of the more hazardous undertakings for pedestrians, more so for people who have visual impairments and cannot detect standard visual signs and signals. A variety of technologies have been developed to aid the visually impaired in this process. However, both the legal aspect of accessibility and the impact of other traffic initiatives must be considered when attempting to improve accessibility.

2.1 DEFINING BLINDNESS

In order to understand the fundamentals of accessibility for pedestrians who are visually impaired, it is important to understand what it means to be visually impaired.

In 1811, an institute dedicated to supporting blind people in Denmark was established. The Royal Institute for the Blind was "the first Danish institute for visually disabled people" (Andersen 2004). Its first students were twelve blind children who studied a variety of subjects including religion, geography and music. Forty-seven years later, a formal definition of blindness was established to determine blind children's qualification for admission to the Institute. Issued from the Ministries of Ecclesiastical Affairs and Education on July 22, 1858, the condition was "that the child is deprived of visual power to such an extent that it cannot follow ordinary schooling" (Andersen 2004).

Four years later, a Dutch ophthalmologist named Hermann Snellen devised what is known as the Snellen eye chart shown in Figure 1.This chart is used to compare and record visual acuity. "…Visual acuity measures only the smallest detail we can see; it does not represent the quality of vision in general" (Watt 2003). The fraction beside every line in Figure 1 is called the Snellen fraction. The numerator in the Snellen fraction is the test distance in feet while the denominator indicates "the distance that the average eye can see the letters on a certain line of the eye chart" (Watt 2003). In short, the Snellen fraction of 20 / 20 means that a person can clearly see a certain size letter that is twenty feet away. If a person has 20/200 vision, this means that the smallest letter they can see twenty feet away, a person with 20/20 vision could see from two hundred feet away. The Snellen fraction (or Acuity) measured in meters is called Metric Acuity, which uses the conversion 20 feet ≈ 6 meters. The measure 20/200 in the Snellen Acuity is 6/60 in the Metric Acuity (Watt 2003).

Figure 1: The Snellen eye chart is used to compare and record visual acuity (Watt, 2003)

In 1888, a Danish ophthalmologist named Gordon Norrie used the Metric Acuity of 6/60 to describe a weak-sighted child's visual acuity. In 1890, some amendments were made and so a child could only be admitted to the Royal Institute for the Blind if he or she could not "…read or write ordinary writing and also that the child is at an age of nearly 10-12 years old" (Andersen 2004). There were often exemptions to this admission rule for children over 12 and adults. Later on, the National Board of Health in Denmark adopted the visual acuity of $^{6}/_{60}$ as its condition for practical/social blindness. In 1955, more amendments were made by the Ministry of Social Affairs to the definition of blindness, one of them being that there was now a definition for visually impaired adults.

> "…children were considered blind if their visual acuity was so reduced that they could not follow teaching in primary school. Adults were considered blind if they could not cope with their occupation or be educated to do another job. As a rule, patients would be considered blind if their visual acuity was reduced to $^{6}/_{60}$ or less" (Andersen 2004).

Regardless of age, these conditions are generally still valid in Denmark. Anderson notes that "…wide individualization is…always necessary in the evaluation of a subject as blind or not blind" (Andersen 2004).

As of 2004, there are different categories pertaining to different levels of blindness. They are organized in Table 1. Category A visual impairment means that only the first three lines of the Snellen chart in Figure 1 are clearly visible. Category B visual impairment, designated as Social Blindness, covers a range of people. People who have 6/60 vision and can only read the first line of the Snellen chart to those with 1/60 vision and can only see details a meter away that a person with 6/6 vision could see sixty meters away are considered socially blind.

Table 1: The classification of visual impairment in Denmark as of 2004 (Andersen, 2004)

Category	***Designation***	***Visual Acuity***
A	Partial Sightedness	Between 6/18 and 6/60
B	Social Blindness	From 6/60 to 1/60
C	Practical Blindness	1/60 to sense of light with projection
D	Total Blindness	No sense of light and sense of light without projection

People with visual impairments who are permanent residents of Denmark have the right to become members of Dansk Blindesamfund. Their visual criteria states that one “must have residual vision of 6/60 or less in better eye or …a residual vision of over 6/60 with complications” (Dansk Blindesamfund 2010). Complications include central field loss, peripheral field loss and a very narrow field of vision.

2.2 CROSSING THE STREET

One of the greatest dangers for the visually impaired pedestrian is crossing the street. Without any special considerations for visually impaired pedestrians, this ordinarily simple task can become very formidable. There are four main problems that a pedestrian encounters when crossing. The four basic steps are listed in Figure 2 and discussed in detail below.

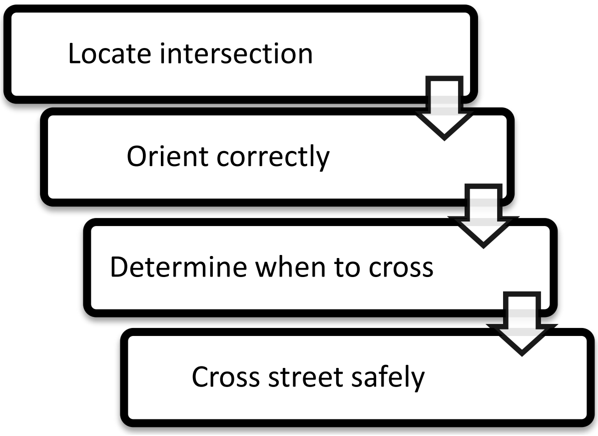

Figure 2: Four steps a visually impaired pedestrian must take in order to cross a street

The first step, locating the intersection, can be done in a variety of ways. It is often done with a combination of methods. The curb at an intersection can be found with a white cane. However, if a portion of the curb has been turned into a wheelchair ramp, there is no guarantee that a visually impaired pedestrian will be able to distinguish where the wheelchair ramp ends and where the street begins. Listening to traffic sounds also plays a very important role. If the pedestrian hears traffic moving perpendicular to their direction of travel, the pedestrian knows they are approaching an intersection. In areas where many buildings are close to the sidewalk, such as Copenhagen, the change in sound between the buildings and the openness of an intersection can be another clue (Harkey, Carter, Barlow & Bentzen, 2007).

After the intersection is located, the pedestrian must orient themselves in the correct direction for crossing the street. Without any accessibility aids, this is done by listening to the sound of traffic. Pedestrians use the sounds from traffic moving parallel to the intended direction of travel as well as the sound of the traffic in lanes they are crossing. These traffic sounds give the pedestrian a mental image of the intersection and allows them to estimate their heading. However, there is no guarantee that the opposing sidewalk is directly across the intersection (Harkey et al., 2007).

Once the pedestrian is facing the right direction, they must determine when it is safe to cross. In order to do so, the user must determine whether a crossing signal must be activated. This can be done by searching the intersection for crossing signal buttons. The pedestrian can then listen to traffic patterns for a few cycles of the light to determine if there is an appropriate time to cross the street. They must also take into account whether traffic signals provide a dedicated period of time for crossing, if they will be crossing with the flow of parallel traffic and whether or not there is a substantial amount of turning vehicle or bicycle traffic (Harkey et al., 2007).

After the pedestrian has determined that it is the correct time to cross, they must be able to safely navigate to the other side of the intersection. People with visual impairments tend to veer to one side or the other while attempting to walk in a straight line. This poses a hazard as the pedestrian may end up in the middle of the intersection or encounter stopped traffic. If there is traffic flow parallel to the direction of travel, the pedestrian can use this as a guide. Another consideration is where the intersection actually ends. Traffic islands or medians may have a separate crossing signal that must also be evaluated when encountered (Harkey et al., 2007).

People with visual impairments face a number of problems when attempting to cross the street. A system that attempts to address these problems is known as an Accessible Pedestrian Signal system. Accessible Pedestrian Signals (APS) are, according to Noyce and Barlow, "a device that communicates information about pedestrian timing in a non-visual format such as audible tones, verbal messages, and/or vibrating surfaces" (2003). An APS system must cater to the senses that the visually impaired use daily for mobility. Auditory signals and tactile systems are frequently utilized in conjunction with each other. This helps to accommodate those who are both hearing and visually impaired.

2.2.1 LOCATING THE INTERSECTION

Various types of audible locator signals can be used to detect intersections. Frequently these audible signals are emitted from the push-button device helping pedestrians locate the button. This type of locator tone not only indicates that the user needs to press a button to trigger the crossing signal but also indicates the location of the button. Many intersections are pre-timed and do not require button activation. For these, there may still be a pedestrian level locator tone device. This device is often incorporated with a directional arrow, discussed in the next section. In order to locate the crosswalk after the signal pole has been found, the pedestrian needs to know where the crosswalk is in relation to the pole. For example, in Denmark the poles with locator tones are within 0.6 meters of the curb and are within 0.3 meters of the edge of the crosswalk (Harkey et al., 2007). This is illustrated in Figure 3.

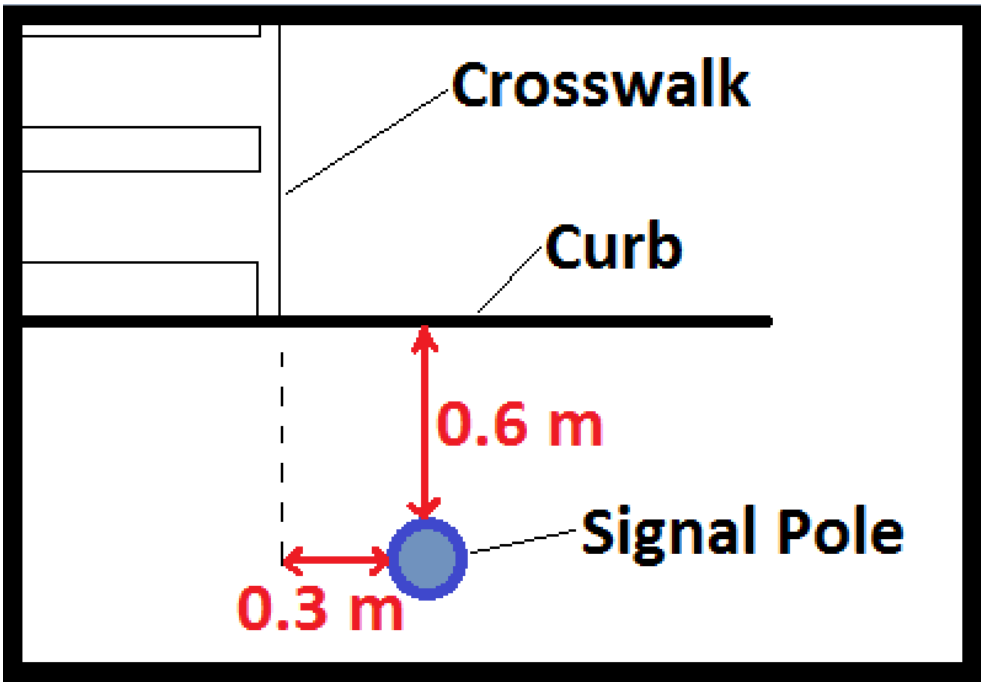

Figure 3: Location of a signal pole in Denmark

A report published in 2006 shows that after installing push-buttons with locator tones, pedestrians with visual impairments were 97% successful in beginning to cross within the bounds of the crosswalk compared to intersections without push-button locator tones for which only 77% started within the bounds of the crosswalk (Harkey et al., 2007).

2.2.2 ORIENTING CORRECTLY

One of the most popular systems used to orient the pedestrian in the correct direction is the tactile arrow. In general these consist of a raised line that is parallel to the crosswalk with an arrow at one end to indicate the appropriate direction of travel. These come in a variety of shapes and sizes. Often, if there is a button to activate the crossing signal, there will be a tactile arrow on the button. A tactile arrow that has become standard in Denmark is a graspable bar shown in Figure 4.

Figure 4: Tactile arrow in Copenhagen

This figure shows a tactile arrow mounted on an APS device in Copenhagen. It has two bumps, the outer bump indicating the direction of travel and the inner bump indicating that at least one median is present (Vejdirektoratet, 2006). This particular picture shows an older APS device that is being replaced with newer ones (Bjerremose, Frederiksen, & Kreutzfeldt, personal communication April 7, 2010), although arrows on newer devices function the same way. The standard dimensions of these arrows are shown in Figure 5.

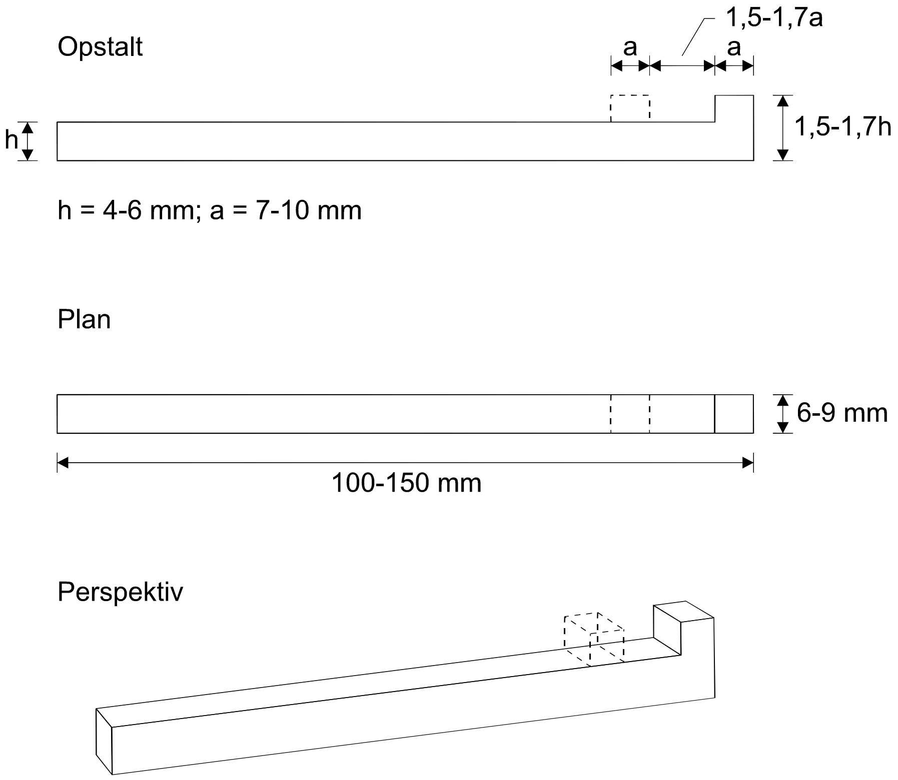

Figure 5: Standard dimensions of a Danish tactile arrow (Vejdirektoratet, 2006)

A study was conducted in 1982 in Denmark to determine the effectiveness of tactile arrows. This study used Danish standard tactile arrows such as those that are currently used on APS in Copenhagen. The study found that there was no actual improvement to orientation at intersections with the arrows installed (Harkey et al., 2007). Two studies in the US show that tactile arrows instead help a user determine whether they are listening to the correct signal or the signal for perpendicular traffic. In Tucson, after familiarization with the tactile arrow system, 100% of participants used the correct activation push-button for the direction they wished to travel (Harkey et al., 2007).

Sometimes pedestrians listen to the locator tone on the opposite side of the intersection when trying to orient. The problem is that locator tones are normally only intended to be heard at a short range to prevent pedestrians from confusing them with one another (Harkey et al., 2007). This means that if the opposing signal is adjusted to the correct volume, it should not be audible from across the intersection. If the volume is louder, the signal next to the user is probably also louder, drowning out the sound of the opposing signal as well as traffic sounds that are vital to navigation. Therefore, it is impractical to rely on locator tones across the street to orient pedestrians before they cross.

2.2.3 WHEN TO CROSS THE STREET

It is important that all pedestrians know when it is safe to cross the street. Pedestrians who cross the street when cars are not expecting them often create hazardous situations that must be avoided. According to a study conducted in 2000 by Martson and Golledge, without any type of APS system, 48% of visually impaired pedestrians began crossing during the “don’t walk” period of the traffic cycle, an action that could prove very dangerous. When these pedestrians had access to an APS, none of the participants started crossing during this unsafe time period (Harkey et al., 2007). APS are therefore very beneficial to improving safety because they tell a person when there is a dedicated time for pedestrians to cross. This does not necessarily mean that it is safe to cross, but rather that it is the designated time for pedestrians to begin crossing.

There are both auditory and tactile solutions to this problem. Tactile indicators tend to be very straightforward. They normally consist of a vibrator that is incorporated in the push-button or the locator housing. The signal vibrates to indicate when to cross. Tactile solutions are important for pedestrians who have both vision and hearing impairments. Tactile signals are also useful during loud traffic conditions to confirm which direction has the walk signal.

There are three main criteria that must be addressed for audible “walk” signals. They must:

- Be recognizable over the sounds of traffic.
- Be easily differentiated from signals during the no-walk interval.
- Be localized to ensure pedestrians know which crosswalk has the “walk” signal.

In order to hear the signal over the ambient noise, the signal type, pitch and delivery must be considered as well as the volume. Crossing signals come in a variety of forms including beeping, percussive “ticks,” bird calls and recorded voices. The waveform of the beeping, the type of percussion, the species of bird, or the wording of a recorded message all affect how easily the signal can be heard and interpreted. Variations on these forms coming from the appropriate direction indicate to the pedestrian when to walk or not walk. Studies have been done to see which is the most effective at being heard over the sound of traffic while at the same time not disturbing the residents of neighboring apartments and houses. Three separate studies by Staffeldt, Hulscher and Poulsen, point to a frequency of 880 Hz or one octave above concert A as the optimal pitch to be heard through ambient traffic noises while being the least disturbing for neighbors (Harkey et al., 2007). An experiment conducted for the National Eye Institute showed that relatively lower frequency percussive tones were the most audible in traffic. The percussive signals also require the least change in volume to be heard over an increase in ambient noise (Harkey et al., 2007).

Once a particular sound or message is determined, the volume must be set. Most current signals have some method of self adjusting to account for ambient noise. The rate at which ambient noise increases in volume is matched by the system. In order to prevent drastic fluctuations, the rate of decrease in volume of the system is slower than the rate of decrease in volume of ambient noise (Bentzen, 2001).

Systems are generally set to be heard at a certain distance or to be a specific decibel range above the ambient sound. It is important that the sound is not too loud. Loud signals will cover up other important sounds that visually impaired pedestrians use to navigate. Another issue with loud signals is echoing off of nearby objects, which could confuse the pedestrian. If a signal is reflected off a surface and is detected by the originating system, the system may mistake the echo for an increase in ambient noise and adjust itself accordingly (Bentzen, 2001). Wind is another factor that has been known to affect the microphone. Because of this manufactures such as Swarco have moved the microphone to the back of the box up against the pole (Pedersen, personal communication, 2010).

Setting the volume to a level that can both be heard and not disturb the neighbors is a continuing debate. The US standard is currently to have a signal no more than 5 dB above ambient (Harkey et al., 2007). This can be a problem for speech based systems because they must be at least 15 dB over ambient for a 90% chance of being intelligible (Harkey et al., 2007).

Determining the effective tone and the volume is only half the problem. Another important factor is where to locate the source of the sound. It is important that signals are spaced far enough apart that the pedestrian does not mistake the signal for one direction with that of the perpendicular direction. This directly depends on the volume of the signal and is another reason why the signal cannot be too loud. Based on a 5 dB sound difference between the signal and ambient, and with the sound coming from a pedestrian level signal box, poles should be spaced at least 3 meters apart (Harkey, 2007). If the signals are posted higher, such as on the pedestrian signal heads, this spacing must be increased.

2.2.4 CROSSING THE STREET SAFELY

The last task for the pedestrian is to actually cross the street. When the signal indicates it is the designated time to cross, the pedestrian determines if it is safe to do so and makes their way across. However, they may need to wait for turning traffic and cars disobeying traffic laws. Two of the main problems, as discussed earlier, are navigating to the opposing curb and understanding obstacles or traffic islands that might be encountered along the way. Understanding the complexities of the intersection is best done through a tactile map.

Danish tactile arrows have a very basic form of tactile map, since they indicate the presence or absence of medians. More detailed tactile maps, such as those featured on Prisma APS shown in Figure 6, indicate the direction of travel, the number of lanes to be crossed, bike lanes, rails, the direction of traffic for each lane and islands that will be encountered. Little has been done to research how effective tactile maps are, but one study was conducted which included a usefulness rating and recorded the number of participants who actually used the map. While participants generally responded that the tactile maps were “useful and easy to understand,” only 9 out of 40 participants actually used them at intersections (Harkey et al., 2007).

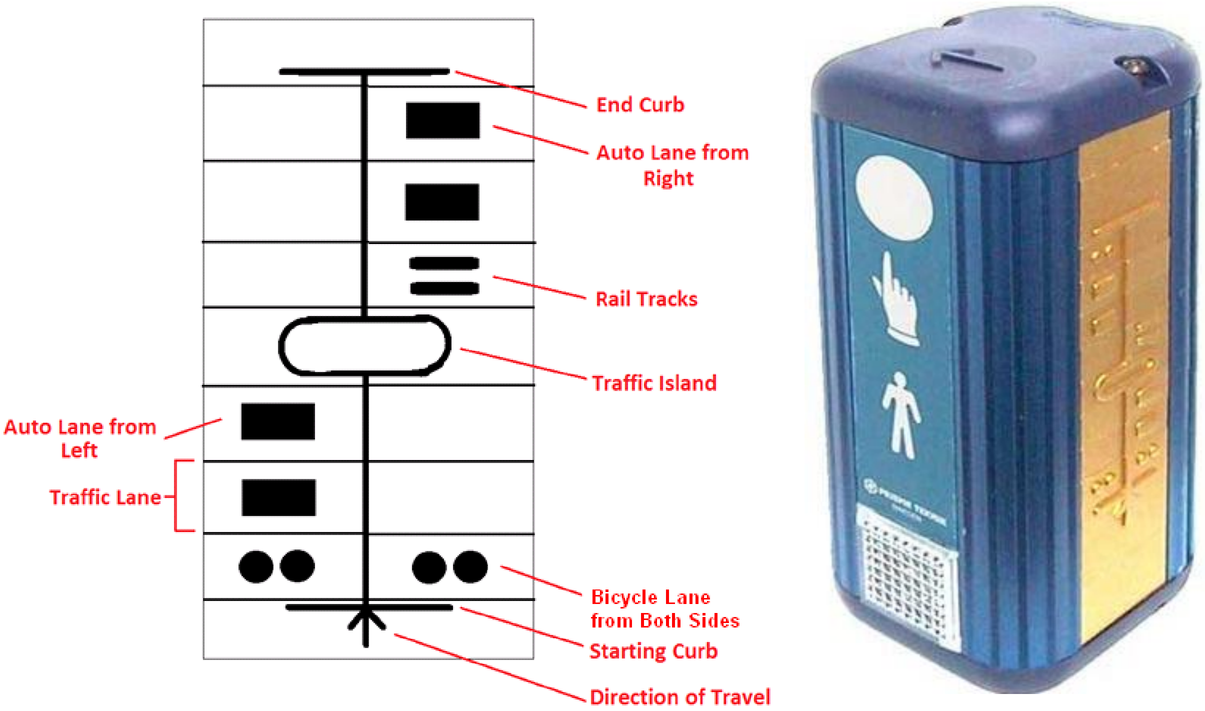

Figure 6: Diagram of a tactile map

The map shown on the left is a drawing by one of the authors. It shows an example intersection. The direction of travel is from the bottom of the map to the top of the map, indicated by an arrowhead at the bottom. The following are the lanes encountered:

- Bike lane from both directions, indicated by two circles on both sides of the center line
- Two motor vehicle lanes coming from the left, indicated by rectangles left of the center line
- A traffic island indicated by an oval halfway through the center line
- Railroad tracks coming from the right, indicated by an equals sign to the right of the center
- Two motor vehicle lanes coming from the right, indicated by rectangles right of the center
- The end curb indicated by a centered flat bar

This demonstrates the tactile map from a Prisma DAPS, shown on the right in Figure 6 (Harkey et al., 2007).

Audible beacons, different than just audible signals, are used to orient the user while they cross. The idea is that a speaker emits a highly directional signal toward the middle of the crosswalk. This way, signals are not drowned out by one another, but this also assumes the pedestrian can make it to the middle of the crosswalk. Audible beaconing only really works if there is enough room to have these directional indicators without interfering with each other. One method that helps to eliminate this problem is an extended button press that causes only the opposing signal from the one being pressed to emit the "walk" tone. This allows the user to focus on the one sound and alleviates the issue of drowning out other signals with the signal overhead (Harkey et al., 2007).

2.2.5 FEATURES OF TACTILE NAVIGATION SURFACES

Currently there are several major types of tactile navigation system designed to assist visually impaired pedestrians when they travel. Hong Kong regulations detail three types of tactile ground surface indicators (TGSI) (Jiang-yan, Michael, & Ping, 2009):

- Danger Warnings
- Directional Indications
- Location Indications

Most countries use TGSI for all three purposes. However, standards vary, from the UK which defines six types of TGSI to the United States which only uses danger warnings (Jiang-yan, Michael, & Ping, 2009).

Detectable Warning Surfaces (DWS) are used to indicate that a pedestrian needs to stop and assess their surroundings. The United States Access Board defines DWS as "a distinctive surface pattern of domes detectable by cane or underfoot… used to alert people with vision impairments of their approach to streets and hazardous drop-offs" (United States Access Board, 2008). All DWS are designed to act as stop signs, where the pedestrian must determine that it is safe to continue before they do so. US guidelines for manufacturing specify a truncated dome shape as shown in Figure 7 (United States Access Board 2008). The color must contrast with the surrounding environment; the DWS shown in the photo is bright yellow. This color contrast is helpful for people who are partially sighted as well as guide dogs (Dansk Blindesamfund, personal communication, April 14, 2010).

Figure 7: White cane on DWS (ADA Solutions, Inc.)

DWS are applied in a number of distinct ways. They are often used at curb cuts to ensure the edge of the sidewalk can be detected. They are also common at train platforms worldwide, though the type of DWS varies by country (Katsumi, Tomomi, Arisa, Kunijiro, and Mayumi 2008). The Copenhagen S-Train uses raised domes that also indicate the safe distance for sighted persons to stand from the platform. Another strategy is to place DWS in an L-shaped configuration to indicate that an intersection is present, and warn pedestrians of the curb cut. A London example of this is shown in Figure 8, on the left. On the right is an example of DWS at the bottom of a staircase, also in London, UK, used to reduce the risk of stairway-related accidents (Katsumi et al., 2008).

Figure 8: Applications of DWS in the UK (Katsumi et al., 2008)

Research has shown that for underfoot detection, a 61cm (24 inch) strip has a 90% success rate in stopping pedestrians before they enter the intersection. A 91cm (36 inch) strip has a 95% success rate. Detection by white cane and successful stopping was much the same as underfoot detection (Bentzen, et al., 1994). This can be compared to wheelchair accessible curbs without DWS which had only a 61% success rate in stopping pedestrians with visually impairments from entering the intersection (Harkey et al., 2007). Japanese standards specify that the individual domes on a DWS strip should be 22mm (7/8 inch) in diameter and 5mm (3/16 inch) high. This standard was developed to maximize the accessibility benefit to people with visual impairments without impeding other pedestrians' movement, though standards differ greatly from country to country (Katsumi et al., 2008 10).

A different form of TGSI is used for helping pedestrians with visual impairments navigate to their destination. Directional blocks constitute tactile paths designed to lead pedestrians to their destinations. Figure 9 shows a tactile path installed on an experimental basis at the Montparnasse train station in Paris, France. It consists of gray metal directional blocks with three parallel ridges arranged in a T arrangement. Four of these directional blocks are combined into a square to indicate the junction of two pathways. One pathway connects the platform with the main door to the station, while another runs parallel to the platform.

Figure 9: Directional blocks forming tactile path in France (Katsumi et al., 2008 9)

Similar systems are used in many parts of Denmark. During our field investigations in greater Copenhagen, the team found DWS at the curb cuts of each intersection visited. However, this usually took the form of concrete tiles that did not have a color contrast with the surrounding sidewalk. Tactile paths are especially common in Copenhagen due to the design of many sidewalks. Cobblestones and concrete slabs are alternated so that the cobblestones provide a tactile path along the entire sidewalk. In many cases, this path leads down the middle of the sidewalk. Figure 10, a picture of a sidewalk in Copenhagen, Denmark taken by one of the authors, shows this form of tactile pathway.

Figure 10: Sidewalk with tactile cobblestone path in Copenhagen

Some countries, predominantly in Asia, use tactile paths to help pedestrians cross the street without veering from the crosswalk. Figure 11, below, shows a Japanese crosswalk where a tactile path directs pedestrians from the DWS on one side of the crosswalk to the other. The DWS is yellow and roughly follows the curve of the street corner; the tactile path is white and straight. The crosswalk is indicated by white lines perpendicular to the tactile path while a bicycle lane to the right uses lines parallel to the path. Truncated domes are used for both DWS and directional blocks though the size and spacing is different.

Figure 11: Tactile path crossing a street in Japan (“Tactile Guiding Line”, 2006)

One important consideration with tactile surfaces, especially those set in a street, is durability. For these systems to be used in climates like North America or Scandinavia, they must be able to withstand snow, snow removal, and frost heave without becoming unusable or incurring prohibitive maintenance costs. Results from a 2000 study conducted by the U.S. Access Board are mixed. In some locations the domes on DWS were sheared off by snowplows, though this issue can be resolved by ensuring the tops of the domes are below street level. Color fading due to sunlight varied. Rotary brushes used for sidewalk snow removal proved effective at cleaning DWS without creating damage. DWS installed in at least one location in Fairbanks, Alaska, USA proved to be in good condition despite severe cold and occasional vehicle traffic (Bentzen, Barlow & Tabor, 2000). Concrete DWS that the authors have observed more recently in Copenhagen appear heavily worn but are nonetheless detectable as we walk over them. Due to improvements in technology since 2000 and the sometimes positive results of the study, it is likely that a DWS or tactile path that is installed and maintained according to its manufacturers’ recommendations can reach its intended lifespan in any climate that it is designed for.

2.3 LEGAL CONSTRAINTS AND STANDARDIZATION IN APS DESIGN

There are many recommended practices with regard to APS design, but few binding legal requirements anywhere in the world. Although APS systems are required to abide by national standards for traffic signals and signage, these standards rarely cover APS comprehensively and do not require APS to be installed. The United Nations passed the Vienna Convention on Road Signs and Signals, an agreement between 67 countries including the United States and Denmark, providing a uniform agreement for road signage (United Nations, 1968). Most of these road signs are directed towards vehicle traffic; pedestrian signs are covered in less depth. However, the Convention does not provide any regulations concerning APS devices intended to assist the visually impaired. The United States has a similar set of regulations called the Manual on Uniform Traffic Control Devices (MUTCD), which covers APS briefly and is discussed in more depth later. It provides a limited set of formal guidelines for APS design and installation, but does not mandate that they be installed. Due to this international lack of mandates, accessible pedestrian signal systems are typically installed when a study recommends one or a third party requests one.

2.3.1 INTERNATIONAL STANDARDS FOR APS

In 2007, the International Organization for Standardization published a new standard specifically targeted to APS devices. It addresses both audible and tactile devices used with traffic signals to help people with visual and auditory impairments (ISO 23600:2007). It allows for a broad range of devices and settings, yet defines the "requirements, technical specifications, and performance criteria" (ISO 23600:2007) of APS devices. ISO 23600 describes the purpose of APS devices, the rate volume and pitch of audible signals, and proper height for installing devices. For example, the pitch of an APS device must be audible to all the users who need to rely on it. A significant portion of the signal needs to be in the 300Hz to 1500Hz band for the beacon to be useful to pedestrians with age-related hearing loss (ISO 23600:2007). The volume of APS beacons should be between 2dB and 10dB above the ambient background noise, with 5dB as the recommended value (ISO 23600:2007). A beacon that is not in compliance with this standard would likely be inaudible or audible too far away, posing a problem for people with visual impairments or the surrounding community. Since crosswalks vary greatly in length, the ISO standard is not as specific when defining the distance at which an audible sound should be heard. Instead, the sound "should be detectable from the entry of a pedestrian crosswalk to the exit" with beacons placed on pedestrian refuges when needed to ensure coverage across long crosswalks (ISO 23600:2007).

2.3.2 *Danish Disability Law*

In the early 20th century, disabled and handicapped Danes lived separate from the rest of society. However, from the 1950s to the 1970s, criticism of the state-run institutions grew both in Denmark and internationally (Wiederholt, 2002). Disability care became increasingly decentralized, and in 1980, the responsibility for caring for persons with disabilities was passed to municipalities. The Danish Disability Council was founded at this time, becoming a liaison between representatives of the disabled and the rest of government (Center for Ligebehandling af Handicappede, 2010).

Three years after the Americans with Disabilities Act in 1990, the landmark resolution B 43 of 1993 unanimously passed the Danish Parliament. The resolution was a statement of principle that declared disabled and non-disabled people deserved equal access to opportunity, setting in motion many of the processes needed to achieve that objective (Wiederholt et al., 2002). While it was not legally binding and offered few specifics about how to achieve that goal, the resolution strengthened the cause of equality and expanded the role of the Disability Council. The act created the Equal Opportunities Center for Disabled Persons under the Disability Council. In addition to taking charge of the Council's secretarial functions, the Center now serves as a watchdog group to ensure progress and provide legal recourse for discrimination (Center for Ligebehandling af Handicappede, 2010).

Another resolution that was accepted by the Danes in 1993 was the United Nations' Standard Rules on the Equalization of Opportunities for Persons with Disabilities (Wiederholt, 2002). It was a similar nonbinding statement of principle with a similar set of rules that provided for equal rights for people with disabilities. However, accessible pedestrian crossings are not explicitly mentioned in the Standard Rules. In fact, the task of funding and implementing APS projects is the responsibility of a loose coalition of local governments and interested parties. Heilbrunn commented that this process rarely follows a logical set of procedures. It is generally the responsibility of blind Danes to request the systems through organizations such as the Dansk Blindesamfund, who then secure funding through local municipalities and an increasing number of private sources (2010).

The Danish legal system today is characterized by dialogue between various interested parties, who form advisory boards to produce recommended practices. As such, Danish laws rarely provide binding resolutions but serve to guide the actions of both national and local governments. This style of government is a Danish cultural phenomenon, and contrasts with the United States' frequent use of legal mandates. For example, after the Americans with

Disabilities Act was passed, the Danes considered a similar legal measure prohibiting discrimination against people with impairments or disabilities. Neither the government nor advocacy groups looked favorably on it, as they felt it might undermine the culture of equality the law was looking to create. While in an American context the prohibition of discrimination was a civil rights victory, in a Danish context such a measure would make too strong a distinction between people without disabilities and those with disabilities or impairments (Wiederholt, et al., 2002). However, the coalition of government agencies and advocacy groups did publish their intent to achieve equality in a later act. This drive for equality amongst all Danes continues to shape Danish legislation.

2.3.3 DISABILITY AND APS LEGISLATION IN THE U.S.

The United States provides a number of formal guidelines for APS installation. Since APS systems are considered part of the transportation infrastructure, the United States government addresses them through transportation bills and commissioned reports on best practices. However, the impetus for these measures comes from disability rights legislation, notably the landmark Americans with Disabilities Act (ADA). The ADA is a binding mandate that requires equal opportunity for people with known disabilities, along with specific mandates on groups such as employers and federally funded institutions. Some of the better-known provisions of the ADA mandate equal opportunity for employment and accessible design in new or renovated buildings. However, APS systems are generally implemented to comply with the “effective communications” clause of Title II of the ADA as they help communicate road conditions to pedestrians (Harkey, et al., 2003). Since they are not explicitly required by the ADA, it is generally acceptable to implement APS systems on an as-needed basis, responding to requests from residents or as determined through studies.

The specific technical requirements for APS systems can be found in the Manual on Uniform Traffic Control Devices (MUTCD), published by the U.S. Department of Transportation (Federal Highway Administration, 2009). This document contains regulations and recommended practices on all forms of traffic signage and signaling. Although the Vienna Convention does not explicitly mention APS, Sections 4D.03 and 4E of the MUTCD are relevant to APS design and implementation. Section 4E explains that APS systems are optional, as many intersections can be safely navigated by the visually impaired by listening for traffic, but that APS are to be installed in particularly difficult situations. The MUTCD advises conducting an engineering study to determine whether or not an intersection warrants APS, and for compliance with other pedestrian safety measures, when the matter is called into question. However, in practice, such studies are often prohibitively expensive and time-consuming. This results in APS systems being implemented in a less structured fashion. The usefulness of the MUTCD is limited in making decisions regarding APS implementation; at best, it provides a set of minimum standards.

More detailed recommendations for APS installation are provided by the United States Access Board, an advisory and research body that develops and supports a wide array of recommended practices. These practices provide specific design specifications that have been shown to effectively assist persons with disabilities (U.S. Access Board 2010). Their primary document on the subject of APS systems is a document known as "Accessible Rights of Way: A Design Guide", often known as the PROWAG or the Public Rights of Way Advisory Guidelines (U.S. Access Board 2010). It is intended to harmonize regulations in the MUTCD with the results of research into APS design and installation. The document dates from 1999 and has most recently released a 2009 edition (Federal Highway Administration, 2009). The Access Board is also known for several other publications and continues to conduct research into available APS technologies and their applications.

While U.S. laws are not binding in Denmark, both countries share similar challenges in attempting to get pedestrians across intersections with faster and more dangerous traffic. As the technical challenges are similar internationally, it is wise to consider recommendations developed for one country and apply them to another when relevant. There is a wide range of street conditions within each country, ranging from small one-way roads to small highways with multiple medians. However, different countries often have similar ranges. This aids efforts to promote international standardization, as similar standards that cover a diverse range of streets can be used in different countries.

2.4 APS INSTALLATION APPROACHES

A variety of approaches have been used to determine whether to install APS at a given intersection. The following approaches have been considered or used by various municipalities:

- Install APS upon a request initiated by residents or advocacy groups
- Install APS at any new or renovated intersections
- Perform engineering studies before installing APS at intersections
- Install APS at all intersections

The most common method is to install APS upon request. This method is used in Denmark and other countries including the United States (Heilbrunn, 2010). Usually this request is put forward by a person who is visually impaired, or by an advocacy group representing such individuals. The formal and informal processes for submitting such a request vary from municipality to municipality. In Copenhagen, residents who are visually impaired often refer the matter to groups such as the Dansk Blindesamfund. These groups represent them to the City of Copenhagen and work with the City to find funding for implementing APS at the intersections that person needs to reach destinations such as the central business district and local transportation hubs.

Another method, installing APS at new or renovated intersections, is inspired by the ADA's provisions regarding other aspects of accessible design. In most cases, the ADA requires accessible design to be implemented in new construction and during substantial renovations. By applying this principle to APS installation, compliance is assured. One example of a municipality that uses a related method is the City of San Francisco. After an advocacy campaign by the California Council for the Blind and the San Francisco Light House, among others, the city adopted a legally binding agreement increasing the number of APS-equipped intersections from 1 to over 80 (Feingold & Lorentz, 2009). The deadline for this installation, as mandated in the 2007 agreement, was December 31, 2009. In addition to the intersections highlighted by the advocacy groups, the city agreed to "make ready" any newly installed or renovated intersections so APS could be easily installed at a later date (Law Office of Lainey Feingold, 2007). This measure substantially reduces the costs of properly installing APS systems upon request, by eliminating any need to lay conduits for signal wires or redesign the intersection to accommodate APS.

Corvallis, Oregon has chosen to install APS at all intersections. This decision, made to reduce the cost of engineering studies and promote a pedestrian-friendly environment, makes the city unique. Corvallis is a small city in the western United States, with an estimated population of just over 50,000 (City of Corvallis, 2010). Over 10% of the population is 65 years or older, an age group with a disproportionate number of visual impairments. Furthermore, the City of Corvallis has made a heavy investment into alternative transportation. In order to reduce Corvallis' environmental impact and improve quality of life, the city has supported infrastructure projects for bicycles and pedestrians. Approximately 97% of the roads in Corvallis provide bicycle lanes, and a 2008 survey showed 22% of residents commuting via bicycle (City of Corvallis, 2010). Changes to the transportation infrastructure have been required to accommodate this investment, such as the addition of bike lanes and redesigns of crosswalks. This led the City of Corvallis to investigate measures for improving pedestrian safety and the flow of traffic. In particular, they discovered that "audible prompts get pedestrians moving faster and are particularly useful in advising persons with cognitive disabilities" (Bentzen, 1998). Given these considerations, the city reasoned that the cost of conducting engineering studies as suggested by the MUTCD was too great and it would be more effective to adopt APS at every intersection with a traffic light.

The Corvallis method highlights a key strategy for achieving universal adoption of APS systems at crosswalks. When an intersection is renovated, the costs associated with installing APS can be combined with the other renovation costs, resulting in a significant financial savings. The most significant cost of installing APS is renovating the intersection so that signal poles and control wires are located where the beacons need to be installed, as this often requires conduits to be laid beneath the street and significant electrical work.

Considering that it is easier to lay the electrical conduits and poles required for APS while an intersection is being renovated than after renovations are complete, San Francisco agreed to make all renovated intersections APS-ready (Law Office of Lainey Feingold, 2007). This substantially reduces the cost of installing APS upon request. Furthermore, since the locations of APS signals have already been determined, proper installation is facilitated. By contrast, installing APS universally as Corvallis did requires a more substantial up-front investment. By not installing the APS devices, thousands of dollars are saved per intersection which can then be spent on other pedestrian safety measures. APS-ready intersections strike a valuable compromise as they reduce the up-front cost of renovations as well as the cost of installing APS signals later on when requested by residents with visual impairments.

2.5 IMPACT OF OTHER PEDESTRIAN INITIATIVES

APS systems are not the only innovation being considered for modern streets. As the transportation infrastructure is reassessed around the world, a number of new initiatives are appearing that potentially affect APS system installation. The overarching trends in transportation design reconsider urban planning from a non-vehicle perspective aimed to improve quality of life, rather than an efficiency perspective aimed to improve the flow of motor vehicles (Barter, 2009). Since Denmark already has implemented bicycle-friendly measures, it is the pedestrian aspect of design that is most relevant to our research. Pedestrian-friendly environments further benefit the community by increasing exercise rates and improving public health. These efforts can potentially affect plans for APS installation and must be considered when advocating solutions for pedestrians with visual impairments.

Pedestrian Friendly Design

A trend towards pedestrian-friendly cities encourages APS systems and accessibility for the blind. Proper APS installation is often encouraged when intersections are redesigned to improve pedestrian safety and traffic flow. One example of this is when midblock crossings are redesigned to help pedestrians cross busy multilane streets. A key recommended practice is to stagger the crosswalks, using the median to separate the street into two separate crossings.

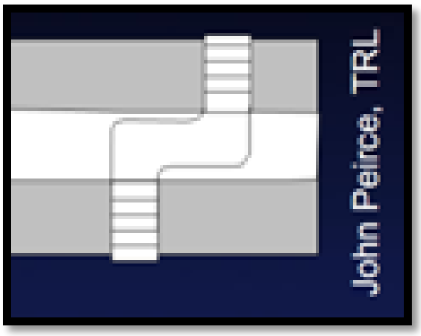

Figure 12: Staggered crosswalk median (Peirce, cited by Baranowski 2004)

The diagram shown in Figure 12 shows how a midblock crossing can be used to route pedestrians around a traffic circle. The crosswalk is placed outside the traffic circle, on the adjoining road. A median is used to divide the crossing into two separate crossings, one for each direction of traffic. This is useful for crossings where the road is heavily used or contains multiple lanes in each direction, because pedestrians do not have to wait for vehicles to stop coming from both directions. The crosswalks for each direction are staggered, providing space in between the crossings for pedestrians to congregate as they wait for the next crossing to become available. This space also provides a visual separation between each crossing. The crossings are staggered in such a way that, while a pedestrian is on the median walking parallel to the road traffic, they face the oncoming traffic of the intersection they are about to cross.

This innovative design is APS-friendly for several reasons. First, by separating the crossing into two separate intersections, the distance between each side of the street is halved. This makes it easier to hear the APS on the other side without increasing the noise emitted, while leaving pedestrians exposed on the crosswalk for a considerably shorter period of time per crossing. The shorter crossing greatly improves the safety of all pedestrians, but especially pedestrians who do not move quickly. Since the large majority of Danish pedestrians who are visually impaired are elderly (Silver, 2010), the safety benefits are compounded. Furthermore, to prevent audible APS from interfering with each other, a 10 foot or 3.3 meter difference between them is recommended (Barlow, 2009). By staggering the crosswalks, this minimum distance can be achieved. This provides a safety benefit as pedestrians will not confuse one signal for another, while reducing the additive noise from adjacent signals. The main disadvantage to this crosswalk design is additional land use and cost. Land must be dedicated to the median, a longer distance must be paved with sidewalk, and two additional APS must be installed per crossing. However, this cost can be easily justified by the safety benefits given to all pedestrians when the vehicle traffic is sufficiently heavy. This configuration is justified when there are two or more lanes for vehicles in each direction, a situation which would not occur unless the road is heavily travelled. However, providing space for a median may be an issue in cities like Copenhagen that have narrow roads.

2.6 SUMMARY

In this chapter, we have covered five main topics: defining blindness, the four steps to crossing the street and how APS technology currently applies to them, legal considerations, installation considerations and how different pedestrian initiatives might affect APS in the future. It is necessary to know the target audience of the technology, what it needs to accomplish as well as the standards and regulations that apply to it. It is essential to understand these different topics before being able to analyze needs, problems and solutions.

3 METHODOLOGY

The goal of this project was to research new and improved Accessible Pedestrian Signal systems for the Dansk Blindesamfund. To accomplish this task, we investigated the needs of our stakeholders and discussed problems with the current system with them. Further, we have identified and assessed solutions to each specific problem that needs to be addressed that can be implemented using existing technologies.

The basic objectives that were met for this project are listed below.

1. Understand the needs of people with visual impairments and the neighboring community
2. Detail characteristics of existing and related technologies
3. Compare APS systems using criteria developed from understanding stakeholder needs
4. Suggest appropriate solutions
5. Recommend methods of testing solutions

Figure 13 shows an outline of these different objectives and how they apply to each of the stakeholders in this project.

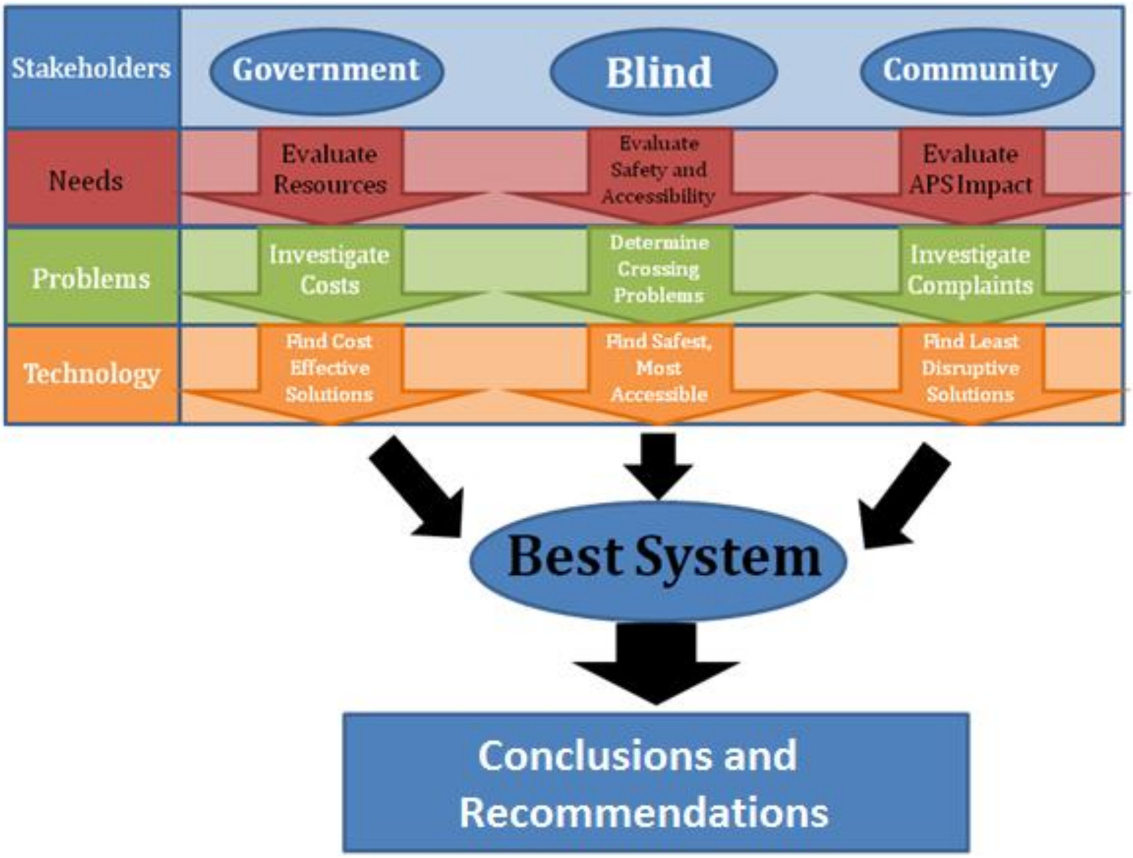

Figure 13: Methodology flow chart

To familiarize ourselves with this project, we examined existing literature detailing what accessible technologies exist, how they work, and how they help people with visual impairments cross the street. We also looked into the standards set for APS in Denmark and the United States as well as various approaches to implementing such a system. We then used a variety of techniques to better understand the needs of each of our stakeholders as well as the solutions used in the greater Copenhagen area. Then, we analyzed each of the available and future systems that can be used. Based on our findings and this analysis, we present our conclusions and recommendations regarding what system or systems should be used and what other changes can be made to address the problems that have been identified.

3.1 INVESTIGATION OF NEEDS

It is crucial to understand the needs of our major stakeholders. APS devices are designed to assist people with visual impairments, so the most important measure of their effectiveness is how much they improve pedestrian safety. Our sponsor, the Dansk Blindesamfund, is deeply tied to these safety interests. In order to ensure that APS systems will be adopted when needed by people with visual impairments, the systems must have minimum negative impact on the surrounding community and any positive aspects need to be emphasized.

The following are the main issues that were addressed in order to understand the needs of people with visual impairments, the surrounding community and the government.

- Understand how the blind cross the street
- Understand the needs of people with visual impairments
- Understand the needs of the neighboring community
- Identify problematic and well functioning intersections
- Understand the needs of the government
- Investigate selected intersections

The core issue of our project was to find a safe method for pedestrians with visual impairments to use for crossing intersections. Although APS systems have been developed to accomplish this task, they are only one class of solutions to this problem. In order to understand the effectiveness of one system over another, we needed a thorough and comprehensive understanding of how pedestrians with visual impairments cross the street.

As all of the members of our team are fully sighted, we needed to improve our own understanding of the issues being addressed before attempting to discuss them at length with our stakeholders. Since the single most important purpose of an APS device is to help pedestrians cross the street safely, we needed to understand this process thoroughly. We interviewed an Orientation and Mobility instructor with the Instituttet for Blinde og Svagsynede and conducted walkthroughs of APS-equipped intersections with various volunteers who have visual impairments to gain a better understanding of the challenges they face. We allowed each volunteer to select the intersections that they would demonstrate. It was important to use a familiar intersection so the added distraction of talking to us would not present a safety hazard.

For each intersection, the volunteer would first lead us to the appropriate corner that he wished to start from. We discussed the intersection: how it was laid out, if there were any special considerations, the type of APS device, if the APS was sufficient or if it had any shortcomings, any historical problems with the intersection and the volunteer's general method for crossing. We would then wait for the next crossing interval and follow the individual as he made his way across the street. During the crossing, we made observations of the individual's methods, attempting to interfere as little as possible so as to better understand how he performed a normal crossing by himself. Also, crossing the street normally takes considerable concentration and we did not want to distract the individual by asking questions while he was crossing. We did provide assistance if there was a possible safety hazard such as unobservant cyclists, road construction or if the volunteer was veering toward traffic. Upon reaching the far side of the intersection or stopping at a traffic island, we asked the volunteer to clarify the observations that we made while crossing. We also asked the volunteer to explain any further thoughts that he had while crossing the street.

In order to continue improving our understanding of the needs of people with visual impairments, we asked a representative group of active pedestrians numerous questions about the technologies being considered and issues we had found. This was done through an interview with nine participants from three different districts of the Dansk Blindesamfund. Our liaison contacted the different districts asking for volunteers to come to the group interview. A room was set up at the Dansk Blindesamfund office where everyone could meet. We developed a list of topics and specific questions to be presented at the interview. This list was given to John Heilbrunn who read the Braille copy during the interview. For each question, he would first read our question in English on his Braille reader and then ask the question in Danish to the group. The group would then discuss the question, providing feedback and building on each other's ideas. Heilbrunn then translated a summary of the key points that were given which we noted. A couple of the participants were very conversant in English and would sometimes answer the questions in English. The reason Heilbrunn presented the questions in Danish was so that we could address a wider group of individuals.

One key stakeholder in accessible pedestrian systems is the general public. Currently, those who live and work near these systems are directly affected by the noise that they make. This could be seen in the number of complaints Københavns Kommune receives about the current APS system. Our original plan for investigating these complaints was to examine formal records of them. We discovered in our interview with three traffic engineers at the Center for Trafik of Københavns Kommune, summarized in Appendix C2, that there was no comprehensive record of formal complaints. Since both DBS and the traffic engineers had heard complaints through informal means, we changed our approach. In order to obtain complaints directly from the neighboring community in a time-efficient manner, we placed an advertisement in three local newspapers asking residents to email or call us with their concerns. Those who opted to call would be directed to an answering machine at the Dansk Blindesamfund where they could leave a message. Both the article and the responses were in Danish, as we did not want a language barrier to limit the potential respondents or the contents of the responses.

In order to focus our research, we needed to determine which intersections were particularly problematic. Not all intersections pose a problem to the neighbors, but we needed to find out which intersections do and what constituted a problem intersection. Rather than surveying every intersection at a variety of times and conditions, we decided that it would be more effective to investigate intersections mentioned in complaints we received from the newspaper article and use those to help us understand what it is about the current system that can be improved upon for the neighbors. Another way we identified problem intersections was from our interview with the three traffic engineers from Københavns Kommune: Anders Kreutzfeldt, Niels Peter Bjerremose and Lars Bo Frederiksen.

After we identified a representative sample of these intersections, we visited each in person and analyzed the features using a checklist that we developed. This checklist is shown in Appendix B. The components of the system present at the intersection were noted, such as Detectable Warning Surfaces, tactile arrows, etc. A map was drawn at the back of sheet and then numbered to show the locations of the various APS devices throughout the intersection. We also took note of the surrounding conditions at the time of observation, such as wind direction and condition, the type of neighborhood and the traffic conditions, among other things. When observing the audible signals, we took note of the type of tone used, the duration of the walking phase and the locator tone, issues with the volume as well as how far away it could be heard from. This was done by walking away from the signal pole until the signal could not be heard. This distance was then measured. This was done by all of us. The 3 distances were then averaged. Issues with the volume of the audible signals were also noted, such as if wind conditions affect the volume.

It is important to understand the needs of the government and their role in the implementation process. For a suggested implementation to be successful, it must meet the needs of the government, which is in charge of selecting and funding the installation of the device as well as in charge of deciding regulations for APS in Copenhagen and Denmark. In addition to conducting a literature review of the Danish Road Rules, we gained a lot of insight from our interview with the traffic engineers from the Center for Trafik at Københavns Kommune. From this, we also gained a better understanding of how the traffic signals system in Copenhagen worked and the types of devices currently installed. There are differences between intersections in different countries and it could not be assumed that our experiences in America would be indicative of every system in Denmark. They also informed us how the subcontractor Swarco is responsible for installation and maintenance of APS devices in Copenhagen.

To better analyze what made an intersection problematic for our stakeholders, we decided to conduct field investigations of two specific locations where APS was installed. Since Copenhagen has 72 signaled intersections with APS, it would have been impossible for us to analyze each one. When selecting intersections to investigate, the following considerations were used:

- Problems identified at the intersection by our stakeholders
- Diversity of intersections and APS devices

To summarize existing APS systems and understand what options are available for us to assess, we made use of a literature review. Much of this review can be found in our background research. After consulting with the Copenhagen traffic engineers, we had a better understanding of which manufacturers' devices are represented in the City of Copenhagen. We contacted the manufacturers producing some of the newer devices currently in use for more information about their products. We interviewed company representatives of the three main manufacturers of APS for Denmark. We also researched published data on some of the newer technologies that have not been implemented in Denmark or are still in research stages.

3.2 IDENTIFY SOLUTIONS FOR ANALYSIS

Solutions have been identified by analyzing the problems identified with the current system and determining which technologies address these problems. In order to do this we listed all the problems that our various stakeholders presented when we investigated needs. We then listed all the possible solutions that had been identified throughout our discussions with manufacturers, traffic engineers and even those systems that were proposed by the pedestrians and the neighbors. By listing out all the various types of solutions for each problem, we were able to develop complete system ideas that met the needs of our stakeholders.

3.3 ANALYZE SOLUTIONS

Analysis was conducted two ways. The first was using a literature review supplemented by information gathered from interviews. This type of analysis allowed us to find the answers to some problems that had been encountered in other places. One example is identifying the optimal tone for an acoustic beacon. This was accomplished by combining both the results of previous studies and the opinions of the stakeholders when we investigated their needs. Because both sources pointed toward the same solution, this was deemed an effective method.

For more controversial or complicated problems, we used a decision matrix to allow us to more effectively weigh the advantages and disadvantage of the possible choices. One example of this was the comparison between verbal and non-verbal crossing messages. Because each system has its advantages and disadvantages, it was necessary to approach this selection in a more methodic way. A list of criteria was developed for comparison. These criteria were divided into three categories based on the whether they came from a need of the pedestrian, the neighbors or the government. Each criterion was given a scoring rubric. These scoring rubric used specific, measurable score definitions that allowed each system to be objectively scored.

Each criterion was also given a weight. The weight of a criterion represents its importance relative to all the other criteria. These weights were assigned based on our understanding of the needs of each of the stake holders. Each stakeholder was given a certain portion of the whole score with which to divide the weights of the criteria that applied. For example, since the pedestrians with visual impairments are the ones who rely on the systems for navigation and to cross the street without being hit by a car, they make up the majority of the total weight.

Each criterion was scored for each choice using the scoring rubric. After the scores were calculated, it could be determined which choices fared better in the comparison. The results of the decision matrix were then analyzed to determine where potential biases or problems with the scoring might lie.

3.4 DEVELOP RECOMMENDATIONS

Based on the results of the analysis, a number of conclusions were developed. Each conclusion was then applied to a recommendation to make to the Dansk Blindesamfund. Since they are the sponsors for this project, the recommendations were made to them. This means that those recommendations that required changes to be made by the municipality were phrased in a way that the DBS could make well reasoned recommendations to the municipalities responsible for installing the systems.

4 INVESTIGATION OF NEEDS

In order to properly select an APS system most appropriate for Copenhagen, we had to understand the needs of our stakeholders. This chapter talks about the results we gathered for our needs-based analysis.

4.1 UNDERSTAND HOW PEOPLE WITH VISUAL IMPAIRMENTS CROSS STREETS

We interviewed an Orientation and Mobility specialist to find out more about how people with visual impairments cross the street, as well as the training they receive before attempting to cross an intersection. We also conducted walkthroughs of various intersections with people with various degrees of visual impairment in order to gain a better understanding of how the current technology is used, the range of strategies people use for crossing the street as well as to investigate more closely some of the shortcomings of the current systems.

4.1.1 ORIENTATION AND MOBILITY SPECIALIST

To help us better understand what it takes for a person with visual impairments to cross the road, we interviewed Lisbeth Hallestad, who is an orientation and mobility (O&M) specialist at Instituttet for Blinde og Svagsynede (Institute for the Blind and Partially Sighted.) A summary of the interview is included in Appendix D.1. She has been working as an O&M instructor for the past twenty years, teaching adventitiously blind adults how to orient and navigate (Hallestad 2010). Adventitiously blind adults are those who have "experienced a loss of functional vision after having had usable vision" (LaGrow and Weesies 1994). Ms. Hallestad explained that there is a big difference between teaching someone who has just become blind and teaching someone who was born blind. An adult who is adventitiously blind may learn to cross the street without making use of APS while someone who has been blind all their life would have trouble visualizing traffic flow and phases, which is an essential tool in crossing the street for adventitiously blind adults (Hallestad 2010).

Being able to cross the street is considered the culmination of O&M training. Because of this, students must first learn how to navigate an indoor environment (Hallestad 2010). This develops orientation and mobility skills. Orientation is defined as "the ability to establish and maintain an awareness of one's position in space and is dependent upon both the gathering and interpretation of available sensory information" while mobility is defined as "the act of moving through space in a safe and efficient manner" (LaGrow and Weesies 1994). Being able to determine what direction traffic is moving in and maintaining the line of direction are only some of the skills necessary to cross a street. The first intersection to be navigated must be simple: two streets at ninety degree angles without traffic islands and APS. Once the curb is located, the traveler must listen and gather information about the present traffic flow such as how much traffic is present, among other things (Hallestad 2010). This information can be auditory, kinesthetic, tactile, thermal and/or olfactory. The traveler must then align his body in relation to available traffic sounds. In the case of parallel alignment, the traveler must track the sound of individual cars into the distance and align himself with that. When the traveler hears a surge of parallel movement, he can start crossing. In order to ensure that there are no cars turning onto the street, the traveler can delay crossing "until the traffic breaks the plane of the center of the intersection" (LaGrow and Weesies 1994). While crossing the street, the traveler must maintain the line of direction. This can be done by acquiring a straight line and then mentally projecting the line across the street (LaGrow and Weesies 1994). These instructions apply to crossing a simple intersection without APS. For more complicated intersections, APS provide more auditory and tactile information to help the traveler navigate safely.

4.1.2 INTERSECTION WALKTHROUGHS

We also asked for volunteers with visual impairments to demonstrate how they cross intersections that have APS devices installed. We had four individuals volunteer to show us intersections that were of particular interest and how they crossed them. These volunteers were all participants in our group interview or were present during our proposal presentation and learned about our project when they were invited by our liaison, John Heilbrunn, to participate in either one. John Heilbrunn and Hans Rasmussen both volunteered to perform a walkthrough upon hearing of our intent. Ulrik Dahl Madsen volunteered when we made the request during our group interview. Christian Bundgaard volunteered to conduct a walkthrough while interpreting for our team at a meeting in Frederiksberg.

The following is a list of the volunteers and the intersections that we walked through. Summaries of each walkthrough can be found in Appendix G.

Hans Rasmussen

- Ryvangs Alle and Hellerupvej
- Hellerupvej and Rugårds Alle
- Kildegårdsvej and Niels Andersens Vej

Ulrik Dahl Madsen

- Rebildvej and Randbølvej
- Bellahøjvej and Sallingvej

John Heilbrunn

- Frederikssundsvej and Hillerødmotorvejen

Christian Bundgaard

- Nordre Fasanvej at Fasanvej Station

The three fully blind volunteers – Rasmussen, Heilbrunn and Bundgaard – used similar techniques when using the APS devices with varying degrees of success based on the complexity of the intersection and the functionality of the devices. The standard method was to first locate the APS device. When the device was loud enough, the individual could walk directly toward the device when he was approaching the intersection. If the individual could not hear the device, he would stop at the curb which could be detected by the white cane or under foot. As the individual was approaching the pole or after he had reached the curb, he would search for the pole using his white cane. When the pole was discovered, the individual would feel for the device on the pole. When the device was found, the individual would move to the correct side of the pole and feel the tactile arrow on the top. After orienting with the curb and the tactile arrow, the individual would wait for the appropriate signal. Upon hearing the crossing signal or feeling the vibration, the individual crossed, moving quickly toward the expected location of the far signal. In almost every instance of a traffic island, the individual would continue crossing without stopping at the island to reorient. Also in almost every instance, the individual would not hear the opposite signal in time to redirect himself toward it before reaching the opposing curb. Therefore, when they reached the curb, each would move along the curb in the direction from which the locator signal was coming or in the direction they believed the APS was located. The individual would then confirm his location by finding this opposite pole.

The partially sighted volunteer – Madsen – used the audible signal primarily for knowing when to cross because he could not see the light. He could locate the device and the crosswalk as well as navigate to the far side without the use of the APS. He did indicate that he preferred to travel at night when he could better see the signal lights.

We learned a few particular things about the crossing process, the types of devices, how the devices are installed and how they have been modified to meet certain needs. The following is a summary of these different topics:

Crossing

1. If the opposite signal is too quiet, it cannot be used for directional assistance when in the middle of the intersection. This means that the pedestrian must rely on his or her ability to walk in a straight line. Since this is often very difficult, the pedestrian will sometimes intentionally veer toward the stopped traffic, away from the intersection until they reach the far side.
2. Crosswalks that are not perpendicular to the sidewalk are much harder to cross because the pedestrian cannot use the sidewalk to orient and must instead rely on the tactile arrow to have the correct orientation.
3. Ramps at corners can make it difficult to detect where the street begins. This is especially true for guide dogs which are trained to stop for drop-offs or step-ups but not slopes. They are also often trained to stop at drastic changes in color. Brightly colored DWS could be used to act as a stop sign for pedestrians and guide dogs.
4. Sharp changes in direction at a traffic island were often confusing. There were examples of where one device had a bent tactile arrow and examples of where the traffic island had multiple devices for each different direction of travel. This proved confusing and potentially dangerous for the individuals who were accustomed to crossing through islands without checking the APS device or tactile arrow.

Devices

5. The devices encountered included Swarco and Prisma devices. These had the standard beeping sound in Copenhagen, the knocking sound standard to Frederiksberg as well as the modified vibrating sound in Hellerup. The Frederiksberg devices also had a pushbutton that could extend the “walk” period.
6. There is a common misunderstanding about the bumps on tactile arrows. There is one bump to indicate the direction of the opposite curb – one on either end if located on an island – and one extra bump that indicates when there are also islands that need to be crossed regardless of the number of islands. When the problem presented itself, the volunteers stated that they would expect the number of extra bumps to reflect the number of islands to be negotiated.

Installation

7. Many intersections equipped with APS have them installed for all but one of the crossings. This can be seen as an inconvenience to pedestrians who must cross three or more APS equipped intersections to get to the opposite side of the non-equipped crossing. However, this not only saves on the cost of the installation but also provides another point of reference for an intersection that might otherwise be symmetric. By having distinctive corners, the pedestrian can keep better track of his or her location.
8. Two intersections in Gentofte were equipped with APS devices that were turned off completely.
9. Two devices in Hellerup had the beeping sound of the signal turned down or off while the vibrating device was attached to the pole to create a metallic buzzing sound instead of the beeping. This was in response to neighbor complaints about the beeping sound.
10. A number of tactile arrows in the Hellerup and Gentofte areas were installed such that the arrow could easily be turned by hand. This meant that there was no guarantee that the arrow pointed in the correct direction and thus posed a great safety risk.

4.2 UNDERSTAND THE NEEDS OF PEOPLE WITH VISUAL IMPAIRMENTS

It is very important to understand what people with visual impairments need from an APS system as they are the targeted users. To help us with this understanding, we conducted a group interview with the help of our liaison at Dansk Blindesamfund, John Heilbrunn. A detailed summary of the group interview can be found in Appendix E. The following is a summary of the topics that were discussed and the reactions of the group.

Demographics

To begin with we wanted to know some of the demographics of the people that we were interviewing. It is important to keep the answers in the perspective of the background of the individuals providing the answers. In this case, there was an even distribution geographically. Of the nine participants, three were from the Copenhagen district of DBS, three were from the Frederiksberg district and three were from the northern suburbs of Copenhagen. Representing a wide geographic distribution was important because APS vary by area and municipality.

We also wanted to track the age distribution of interviewees. However, this was not necessarily representative of the age distribution of those people who spend the most time independently navigating. While a sample size of nine people that were not randomly selected is not necessarily representative of this population, it was also important to know the age distribution to allow us to keep a perspective of the answers given. For example, during our background research, we discussed with both Bentzen and Raymond that older people might be more hesitant to adopt new technology. Therefore answers to questions about new technology would have to be taken into perspective based on the age distribution of the interviewees. Of the nine individuals, five were between 25 and 44 years old, three were between 45 and 64 and one was over 65. This age distribution is not representative of that of blind people in Denmark because the majority of people with visual impairments are older. However it still covers a wide range.

We also wanted to know how mobile our interviewees were. Every person present used a white cane. Three people used guide dogs to navigate. Each one was a well experienced independent traveler who often navigated the city on foot, by bus and by train. Many traveled for work as consultants for the DBS. The interviewees well represented the blind population that would use APS the most frequently and might often travel in unfamiliar areas. However, this did not cover the entire spectrum of potential users of the system.

Crossing the street

Everyone who was interviewed said that they benefit from using APS when they are functioning correctly. Many problems make crossing more difficult such as crossing streets that do not intersect at right angles. Wind can play havoc on crossing for many reasons. Wind can make sounds drift away from the pedestrian. Also, if there is wind in the pedestrian's ears, the sound can cover up important sounds that are used to determine when it is safe to cross. Often, if the intersection is deemed too hazardous, due to either it being a complex intersection with no APS or if the APS is not functioning correctly, the pedestrian may ask for help from a sighted person at the intersection. Danish law allows 15 hours of guide time per month for a variety of purposes, such as when they must go to an unfamiliar area. This is an important part of Denmark's social service program.

DWS and tactile pathways

Of the nine interviewees, eight found DWS to be helpful where it was present. The ninth interviewee had diabetes which prevented him from feeling textures under his feet and therefore did not find the DWS helpful. The most common type of tactile path in Copenhagen is the line of cobblestones found in the center of a most sidewalks, which can be seen in Figure 14. These can be differentiated from the regular cement pavers on either side of the cobblestones. Specific tactile paths are used frequently around train stations or for crossing large open squares. At least one interviewee found that bars were much easier to feel than dots or truncated domes. One problem with tactile paths that do exist is that sometimes hotdog stands or other street vendors will park right over the top of the path. Also, some places in the city have historical restrictions that prevent the installation of the rubber or metal tactile pathways.

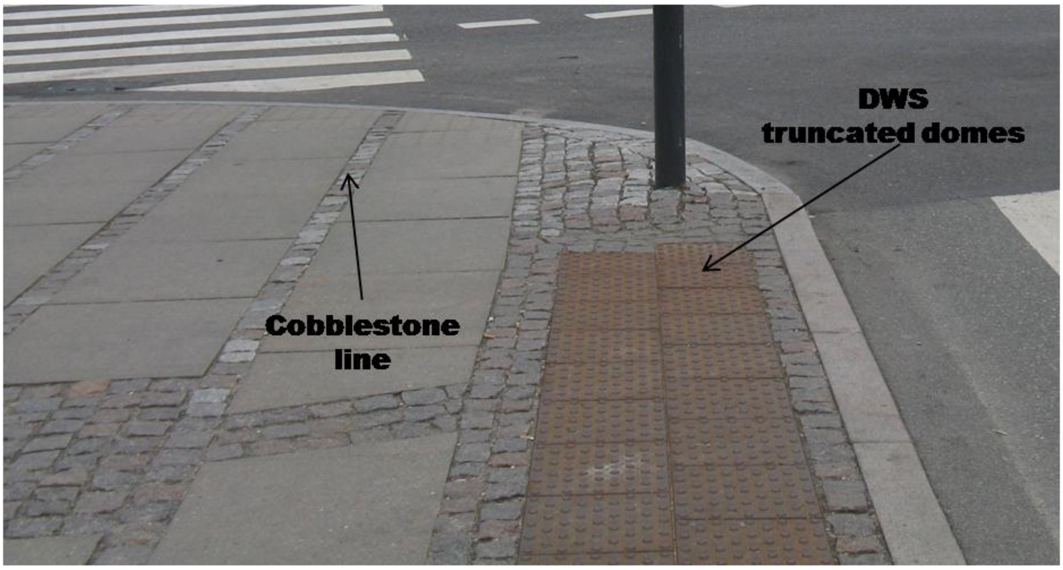

Figure 14: A typical Copenhagen sidewalk outfitted with Detectable Warning Surfaces (DWS)

APS

Everyone found the APS signals to be very helpful when they can be heard. Some examples of unhelpful implementations include some places in Norway where the locator signal is turned off and only the crossing signal plays. This is not helpful for pedestrians trying to find the APS device before crossing. Another problem is with devices that do not have a locator tone and require a button press to either activate the APS or even to activate a pedestrian phase. Without any locator tone, there is no guaranteed way to find the device to push the button. In Frederiksberg, one intersection must be activated by a button press, but there is a constant locator tone. Also, the interviewees understand that sometimes it might be appropriate to turn down the volume of a signal during the night, but they all agreed that turning off a signal was unacceptable as this meant they were limited to travelling only during the day if they were not comfortable crossing streets without the signals to guide them.

There were many opinions on what was best for the sound of an APS. Most people agreed that the knocking sound used in Frederiksberg was easier to hear over the noise of traffic. There was also an interest in spoken messages because of the extra information that they would provide, but it was also realized that excessive amounts of information could take away from the concentration necessary to guarantee a safe crossing. Some people believed that a sound with more frequencies would be easier to hear for a wider variety of people and can improve people's ability to locate the source of a sound.

Tactile arrows are a very important part of the whole system and are very helpful for orientation if they are installed correctly. If one cannot hear the opposing signal to navigate toward, the tactile arrow is the only means of orienting in the correct direction for crossing. If the arrows can be moved, they actually pose a safety hazard. Tactile maps had been heard of by a few, but only one had been encountered near Copenhagen. Some people believed it would be nice to have more information, such as whether or not there is a bike lane. However, it was also noted that information would have to be concise and easily understood to prevent confusion.

Maintenance has been a constant issue with the devices. Malfunctioning systems are reported quickly by the people who use them. However, the interviewees said that the response time varied from a few days to weeks. There were also experiences of conflicts with neighbors where the neighbor might call to have the signal turned down which would be followed by the blind pedestrian calling to have the volume increased.

The main comment on user centered systems was that pedestrians should not be required to use another device. Many people with visual impairments describe a "gadget hell" in which there is a specific device to help with each of a number of specific tasks. Carrying around many different devices for many different tasks becomes more difficult as the user must keep track of where the device is, identify it in relation to other devices, and keep track of which devices need charging.

Suggested solutions

For those who are both deaf and blind, the vibrator on a cell phone could be used to indicate crossing signals. Traffic islands could also be more identifiable to let users know that they are in a safe location. For example, the cut in a median could be slightly raised or use a different material than the rest of the crosswalk. Another solution proposed would be to have a Bluetooth based system incorporated in the user's cell phone. A program on the cell phone would be able to trigger the APS device and indicate any special needs that the particular individual might need. Examples of needs might be a higher signal volume, different frequencies that are easier to hear, or a longer crossing period.

4.3 UNDERSTAND THE NEEDS OF THE NEIGHBORING COMMUNITY

The visually impaired pedestrians are not the only ones affected by malfunctioning APS systems. The neighboring community can also be strongly affected in a negative way, as evidenced by complaints to Københavns Kommune. It is important to understand needs of the neighbors because the APS signals not only affect their daily life, but the community is responsible for the taxes that pay for the devices. Since Københavns Kommune had no record of formal complaints, we decided to obtain opinions by placing an advertisement in three local newspapers, inviting readers to voice their thoughts. A copy of the advertisement can be seen in Figure 15.

Støjende lydsignaler i fodgængerovergangene

Bliver du irriteret over metalbokse, der udsender lydsignaler i fodgængerovergange? Holder de dig vågne om natten?

Forhindrer disse bip-toner dig i at nyde freden og en kold øl på en varm sommeraften?

Hvis du kan svare ja til et eller flere af disse spørgsmål, vil vi meget gerne høre fra dig.

Vi er tre studerende, som undersøger lydsignaler ved lyskryds for Dansk Blindesamfund. Formålet er at finde frem til et system, som kan hjælpe personer med et alvorligt synshandicap at komme sikkert over vejkryds og samtidig sikre, at lydsignalerne ikke er generende for omgivelserne.

Vi har derfor brug for at høre fra dig om dine erfaringer med de eksisterende lydsignaler, og om du kender til lyskryds, hvor lydsignalerne er særligt generende.

Hvis du har tid og lyst, må du meget gerne skrive en email til os på følgende email-adresse tfs.undersoegelse@gmail.com. Du kan ringe til os på tlf.nr. 3814 8806.

Figure 15: Our Danish advertisement inviting readers to share their thoughts on APS

These opinions were collected via email or phone message in Danish, then translated and categorized based on the type of complaint and the location referred to. Copies of the original messages can be found in Appendix F. On April 16, 2010, John Heilbrunn extended the same invitation on the radio. We received eighteen emails and five phone messages. Ten messages were complaining about the signal volume. Some volunteered problem intersections or the area where they lived. Six respondents offered suggestions on either what type of sound the signal should be or a different method of activating the system. Four emails came from company representatives pitching their solutions or offering their expertise with sound to Dansk Blindesamfund. One email and one phone message were from people who said they had complaints and then left their contact information. Only one phone message was left by an individual who said that the signals did not really affect her. In Figure 16, these results are illustrated by means of a bar graph.

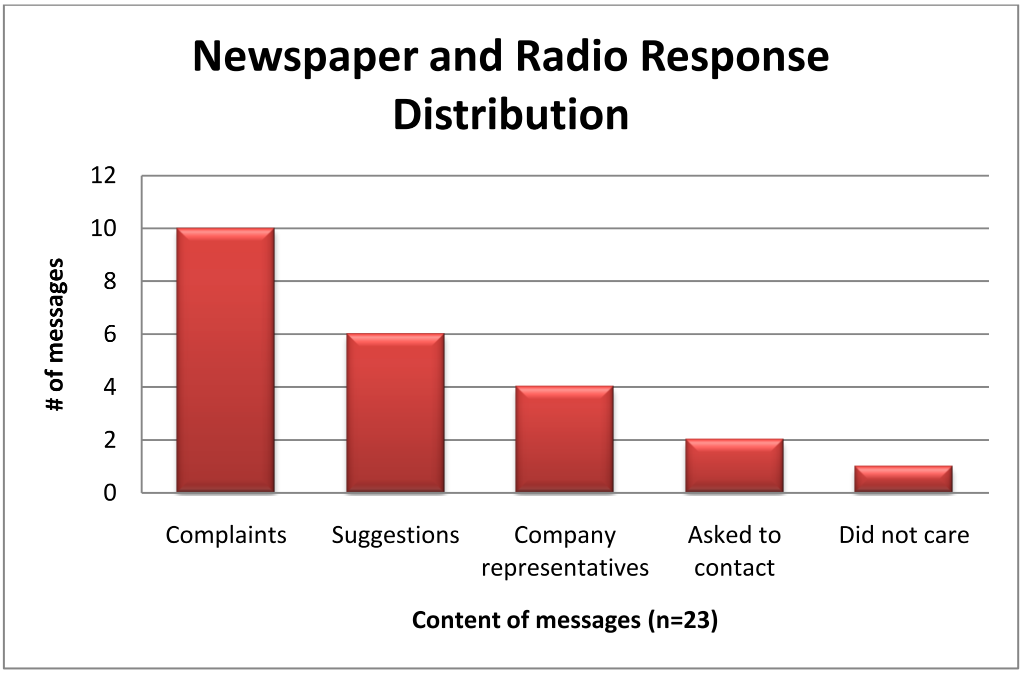

Figure 16: All responses to the newspaper advertisement and radio interview categorized

4.4 UNDERSTANDING THE NEEDS OF THE GOVERNMENT

We contacted traffic engineers to gain a better understanding of how the traffic system in Copenhagen works and the types of devices that are currently installed and consequently, the level of involvement of the government. We interviewed traffic engineers Niels Peter Bjerremose, Anders Kreutzfeldt and Lars Bo Frederiksen, who are all with the Center for Trafik at Københavns Kommune. Their job entails applying the rules established by the Vejdirektoratet (the Danish Road Directorate) and existing technologies to intersections in Copenhagen. They are also responsible for hiring contractors to install and maintain these traffic control systems (Bjerremose, Frederiksen and Kreutzfeldt 2010).

The city's motivation for installing APS is for safety, not convenience. Its top priority is to enable pedestrians with visual impairment to navigate safely by equipping intersections with assistive technology that is cost-effective. Københavns Kommune has the authority to request a specific manufacturer's system over another, but specifying a different system from those currently installed would cost more due to compatibility issues (Bjerremose, Frederiksen and Kreutzfeldt 2010).

The cost of purchasing and installing APS devices in an intersection can be from twenty to one hundred thousand Danish kroner ($3500 - $18 000). There are around 360 signaled intersections in Copenhagen, and approximately 20% of these have APS devices installed. A large part of the cost is due to the need to dig up an intersection in order to install the necessary cables to wire the APS device. When there is enough funding to purchase and install APS devices, Københavns Kommune consults with Dansk Blindesamfund, especially on where to install these devices.

Each year, Dansk Blindesamfund submits a list of intersections organized from highest to lowest priority (Heilbrunn, 2010). Once it is determined what intersections will receive APS devices, traffic engineers have to figure out how to outfit an intersection with fewest number of APS devices. This is due to the rules established by the Vejdirektoratet, which specify that APS installations occur at locations where there is a special need. Therefore, not all sides of the intersection are outfitted with APS devices.

When an intersection is being redesigned, urban planners contact the signals engineers for that area, who then consult Dansk Blindesamfund if APS devices are part of the installation. This sometimes leads to conflicts with project managers because including APS devices reduces funding available for other aspects of the project.

The traffic engineers appreciate collaborating with the blind community with regards to changing existing systems and installations of new systems. All they ask is that the blind community report problem intersections and know what routes are accessible (Bjerremose, Frederiksen and Kreutzfeldt 2010).

4.5 IDENTIFY PROBLEMATIC INTERSECTIONS

Identifying what made an intersection problematic was done based on insight gathered from interviews with the three traffic engineers from Københavns Kommune. This was important to know to help us determine how solving the problem should be approached.

In general, intersections should be as simple as possible because pedestrians need to understand how to navigate the intersection. The same applies to APS devices because pedestrians need to easily understand what the signals mean as well as be able to use them without difficulties. The challenging part is ensuring that a pedestrian will easily understand the signal and interpret it correctly. All traffic signals must stay on all hours of the day, instead of being shut off and using a flashing yellow light signal, as is sometimes done in the US. This is according to the Danish Road Rules. To accommodate this, detectors are used to adjust the timings based on traffic. There are four different timing programs used in a day: morning rush hour, midday, evening rush hour and nighttime.

Other Danish standards include having islands of no less than two meters long as well as all APS devices being on the same side of the crosswalk, as can be seen in Figure 17. This is done so pinpointing the direction the signal is coming from is easier. Danish APS standards also require that APS devices emit a beeping sound as opposed to the knocking or hammering sound, which is used in Sweden. Despite this, the most recent installation of APS devices in Frederiksberg makes use of the knocking sound (Dansk Blindesamfund, personal communication, 2010). This was done to reduce complaints about the system being on all hours of the day.

Figure 17: All APS devices are along the same side of the crosswalk.

The municipalities try to accommodate the needs of the blind and the neighboring community. Generally speaking, complaints about APS devices happen more during the summer, when people want to keep their windows open. It has been observed by the traffic engineers that the signals travel upwards and are carried by the wind very well. It does not help that the automatic volume adjustment feature sometimes does not work as it should. Wind blowing into the microphone or the microphone picking up the signals from the other APS devices in the intersection can cause the system to increase the volume of the signal because it considers those sounds to be background noise as well. Another possibility for volume malfunctions is if the signal is reflected by a building surface nearby. The device thinks it is hearing another signal and thus increases its volume when it is only hearing itself. Instances of the APS device being sabotaged provide an example of how some people have taken the issue of noise pollution into their own hands. An example of this occurred near the Ålmholm train station, where the speaker wire was cut. The device was repaired but the automatic volume adjustment feature was disabled. Traffic engineers can have the APS devices disabled from late at night until early in the morning but before this happens, Dansk Blindesamfund is consulted. While this is very effective at appeasing residents in the area, it restricts the activities of the blind community.

Maintenance checks of an intersection equipped with APS require that all APS devices be either all functioning correctly or all turned off. This is done so that pedestrians do not get stranded halfway through an intersection if one signal gets them to the middle of a street but no other signal is there to guide them the rest of the way or back the way they came. Simultaneous shut down also occurs when a device fails its self-test. In this situation, the entire batch of devices is replaced to ensure reliability. In general, APS devices have a lifetime of approximately ten to fifteen years. Corroded or vandalized devices may be replaced earlier. The traffic engineers mentioned that Swarco was the main supplier of the APS devices here in Denmark. We later learned in an interview with a Swarco representative that they are also responsible for installation and maintenance of all APS devices in Denmark as well manufacturing most of the APS devices in use (Pedersen 2010).

Adjustment of the APS devices has become less expensive and less difficult in newer systems. For most of the older systems, the volume was adjusted by using a screwdriver to manipulate the potentiometer. This required an electrician adjusting each device by hand. This made maintenance time-consuming and expensive. Newer systems can be adjusted through a computer. For example, RTB devices can store various settings. Another problem with the way the old systems are adjusted is that volume is determined solely by the electrician doing the repair without necessarily using any sound measuring equipment. RTB manufactures a special device that is able to differentiate the sound of their APS from the ambient sound allowing the technician to set the relative volumes more precisely (Schulte 2010).

We conducted field observations of intersections identified as problematic by responses from our newspaper advertisement, identified by traffic engineers working at Københavns Kommune, walkthroughs and by observation. This was done in order to understand how the intersection was designed and why it presented a problem. A list of quantitative and qualitative criteria was developed in order to compare intersections. This allowed us to draw conclusions about what the actual problems were with each installation. The checklist we used can be found in Appendix B.

Folke Bernadottes Allé & Oslo Plads

The first intersection we investigated was that of Folke Bernadottes Allé and Oslo Plads. This intersection was by the Østerport train station, which we took note of as the sound of trains coming and going could affect audibility of the signals. We also took note of the near-90 degree angle of this intersection. In Figure 18 below, we used the Google satellite overhead image to show the complexity of this intersection. We also labeled and numbered the locations of each APS device in the intersection so they can be referred to for this discussion.

Figure 18: An overview of the Folke Bernadottes Alle and Oslo Plads intersection (Google Maps, 2010)

This intersection was selected for multiple reasons. We had formulated a checklist for analyzing intersections and needed to test it. We chose to do so with this intersection because it was fairly large, with multiple car lanes and bicycle lanes as well as traffic islands for each road, with Oslo Plads having two islands. We noticed that every corner and island was outfitted with APS devices, which emit signals that we have heard walking to and from Østerport station. This intersection can be considered a problem intersection, because during this test of our methodology we noticed that three of the APS devices present were nonfunctional.

We observed this intersection on a mildly windy Friday at 14.00. Traffic during this hour was moderate, with everything from bicycles to trucks going through the intersection. This was a commercial neighborhood but there were residences nearby. There were thirteen APS devices for this intersection, two for every corner and one on every traffic island, all of which were manufactured by Swarco. Nine of the devices were installed in 2006, while the remaining four were installed in 2009. This information can be seen in the chart in Appendix F. All corners of the intersection had Detectable Warning Surfaces (DWS) present as well as cobblestones.

All devices in the intersection were timed (as opposed to relying on a push-button) and emitted a beeping signal except for devices two, three and five. The details for each device in the intersection can be found in Table 2. We do not know if these devices were turned off or malfunctioning. This is an issue because pedestrians with visual impairments depend on these signals to guide them in the right direction. Despite the audibility of some signals in the intersection, not all of them could be heard halfway across the crosswalk. This could be due to the device being unable to increase volume quickly enough to be heard over ambient noise. This is an issue because pedestrians with visual impairments rely on these signals to guide them in the right direction. Another problem was the corroded cases of devices five and eight. Whether this affected the lack of signal being emitted from device five and the soft signal emitted from device is something we cannot say. Regardless, more regular maintenance is needed to avoid some of the problems this intersection has.

Table 2: Notes on the APS devices available at Folke Bernadottes Alle and Oslo Plads

Device	Ave. Distance Heard From	Volume Comments	Device Comments
1	6.7 m	Loud	Walk signal played even when green man phase ended
2	-	No signal	
3	-	No signal	
4	14.7 m	Constant volume change possibly due to wind conditions	
5	-	No signal	Corroded case
6	1.5 m	Soft	
7	3.7 m	Loud	
8	-	Very soft	Corroded case
9	2.5 m	Loud	
10	7.2 m	Very loud	
11	-	Loud	
12	-	Loud	
13	-	Loud	Tactile arrow pointed in wrong direction

Jagtvej & Østerbrogade

The second intersection we surveyed was that of Jagtvej and Østerbrogade. This was in a neighborhood that was part residential and part commercial. We again labeled and numbered a Google satellite overhead image to show the location of the APS devices in the intersection.

Figure 19: An overview of the Østerbrogade and Jagtvej intersection (Google Maps, 2010)

We were told about this intersection by Mr. Niels Peter Bjerremose, one of the traffic engineers. He mentioned that older model APS devices were installed there. There were twelve APS devices manufactured and installed by Swarco present, two on every corner and one on every island, as shown in Figure 19. In this system, a small microphone is used to pick up background noise. Doing so would then trigger the system to raise the volume of the signal. The problem with this was that it would mistake signals from other devices in the intersection for background noise and thus, the volume would increase unnecessarily. Because this area is partly residential, this proved to be a great nuisance especially at night. Fixing this problem required removing the lid and then adjusting the potentiometers for both the microphone and the speakers with a screwdriver (Bjerremose, Frederiksen and Kreutzfeldt 2010).

Beeping signals were emitted from all twelve APS devices but we were only able to measure the distance from which these were heard for devices located on corners. Therefore, we did not comment on signal volume for devices two, five, eight and eleven. At least half of the devices in this intersection were very clearly heard over the sounds of traffic. It was evident why this was cited as a problematic intersection by Mr. Bjerremose. Table 3 shows the devices along with distances heard from and comments on volume.

Table 3: Notes on the APS devices located at Jagtvej and Østerbrogade

Device	Ave. Distance Heard From	Volume Comments	Device Comments
1	10.4 m	Loud	Sticker on front
2	-	-	
3	-	Not audible from middle of crosswalk	
4	3.0 m	Loud	
5	-	-	
6	-	Not audible from middle of crosswalk	
7	7.5 m	Very loud	
8	-	-	
9	-	Soft	
10	6.1 m	Very loud	
11	-	-	
12	-	Very loud	

4.6 SUMMARY OF NEEDS

Pedestrians with visual impairments have one request: that they are able to cross safely. In turn, they need whatever APS system is available at the intersection they are crossing to work well. This means that if there is a locator tone, it must be audible above traffic noise and other ambient sounds. The signal must also always be on, even at night at a reduced volume. This is because the locator tone helps them locate the intersection, and consequently, the APS device. They also need to know where the edge of the sidewalk is, whether they are alerted by the curb or by DWS. If there are tactile paths present, they must not be covered by stands or vendors. While they are waiting to cross, they need to know the direction of the crosswalk. This is accomplished by a tactile arrow pointed in the right direction. They then must be alerted to when to cross the street, which means that the walk signal must also be clearly audible. If the APS device has the vibrating option, it can be used in conjunction with the audible signal but not by itself. While the pedestrian is crossing, they must continue to cross in the correct direction. A walk signal clearly audible along the entire crosswalk can help with this as it provides directionality. They also need to know exactly how many traffic islands will be encountered before they reach the opposite side of the street. Last but not least, if devices in the intersection malfunction, maintenance must be prompt. A pedestrian unaware of a malfunctioning system can be in serious danger.

Residents who live near these APS systems only request that they not hear it, especially at night when traffic sounds do not muffle the signal and they are trying to sleep. The government needs a system that is easy and inexpensive to maintain and install.

5 EXISTING, AVAILABLE AND RELATED APS TECHNOLOGIES

Currently there are a number of technologies that address the various travel problems that visually impaired pedestrians encounter when they travel. APS systems rely on electronic devices attached to a pole at the intersection, which monitors the traffic phases and produces some form of indication when it is the designated time to cross. Tactile systems are typically surfaces on the ground that can be detected by pedestrians as they pass through the area. These are used to indicate potentially dangerous areas, points of interest, and travel pathways. Some features of APS systems are also tactile in nature. Related technologies are other technologies which may or may not have been applied to crossing the street, but are nonetheless helpful to consider. They have potential applications in accessibility, such as helping APS devices understand the needs of the intended user or making APS installation cheaper and more flexible.

5.1 FEATURES OF APS SYSTEMS

APS systems have a variety of features designed to help visually impaired pedestrians cross streets. Each of the four main challenges that must be overcome while crossing the street is listed, along with each of the APS features that have been developed to assist with them.

5.1.1 TRAFFIC SIGNALS IN COPENHAGEN

Most signaled intersections in Copenhagen are equipped with pedestrian walk indicators. These consist of a standing "red man" located directly above a walking "green man" such as in Figure 20 below, although women are sometimes shown to add variety. The presence of two red light signals also does not change its meaning. This is done mostly to catch the attention of pedestrians waiting to cross at streets with multiple lanes and traffic islands while providing a backup light bulb.

Figure 20: Pedestrian Walk Indicator

When the green man is lit, it is the designated time to begin crossing. The red man indicates that it is not safe to begin crossing. A "safe red" phase is provided as well, where the red man is shown but pedestrians already within the crosswalk have time to reach the next sidewalk or pedestrian refuge. Sweden and Norway use a flashing green signal instead of the safe red phase (Bjerremose, Frederiksen and Kreutzfeldt 2010).

When designing the intersection, the engineer's goal is to have a pedestrian walking at normal speed be able to cross the entire intersection in one cycle. The average pedestrian is estimated to have an estimated speed of 1.5 m/s, though a speed of 1.35 m/s is used for determining the length of the safe red phase. Pedestrians who move slower make use of traffic islands and are advised to wait for the next cycle. Due to the large amount of pedestrian traffic in Copenhagen, most crosswalks have dedicated pedestrian-only phases that occur once per traffic signal cycle. Since traffic flow in Copenhagen is very consistent from day to day, many traffic signals are timed depending on the hour of the day. Unlike America, cyclists and auto drivers are not allowed to turn right on a red light. Despite this, most cyclists continue to do so. This presents a problem because a pedestrian with visual impairment could be crossing when the cyclist decides to turn right (Bjerremose, Frederiksen and Kreutzfeldt 2010).

5.1.2 APS IN DENMARK

Copenhagen currently has 359 intersections with traffic signals. Seventy-two of these are outfitted with acoustic accessible pedestrian signals (Heilbrunn, 2010). Copenhagen uses a combination of technologies to provide safer crossing for pedestrians who are visually impaired. These systems involve both an auditory and a tactile portion. Three different models of audible signals are used across the city, depending on when they were installed. The most current devices being installed are manufactured by Swarco (Bjerremose, Frederiksen and Kreutzfeldt 2010).

The audible signal produced consists of a locator tone and a walk tone. A pedestrian level locator tone emits a constantly pulsing sound at 30 pulses per minute with each pulse lasting around 400 milliseconds. Copenhagen uses a pitch of 880 Hz or one octave above the standard concert *A* pitch, which is the current standard for Denmark (Vejdirektoratet, 2006). In Frederiksberg, they opted for a percussive “knocking” sound. Most crossing signals in Copenhagen are timed so most systems do not need to be activated with a button press (Bjerremose, Frederiksen and Kreutzfeldt 2010). For intersections that do require button activation, the button is located on the device emitting the locator tone. This allows the user to easily find the button. When it is time to cross, both the Copenhagen and Frederiksberg tones switch to different signals. In both cases the pitch is the same as the locator tone, though the pulse rate of the walk indicator is five times that of the locator tone or 150 pulses per minute. Each pulse is half as long or 200 milliseconds long (Harkey et al., 2007). Figure 21 shows how the length and frequency of pulses changes with respect to the signal, although the length each tone is played for has been shortened for clarity.

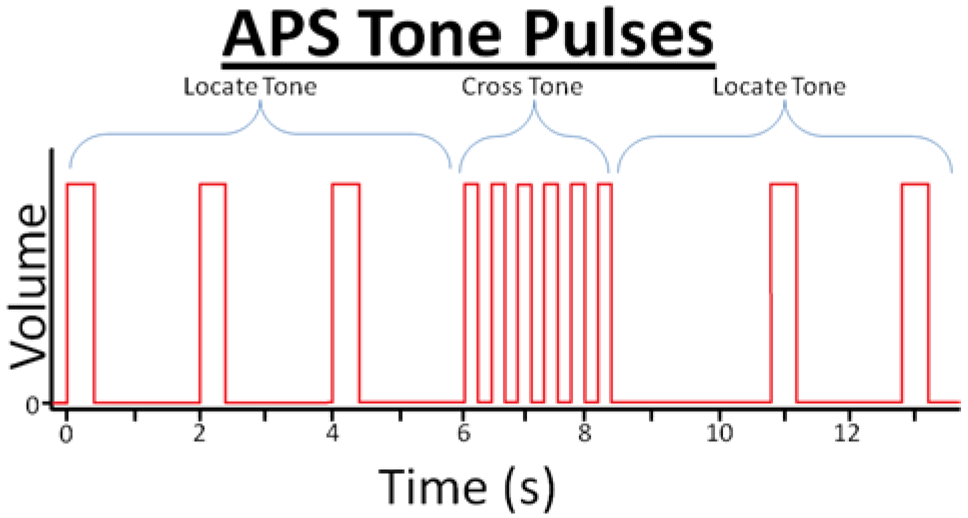

Figure 21: Different APS tone pulses (Harkey et al., 2007)

The volume of these signals adjusts to accommodate changes in the ambient sound level unless they are set to a constant volume. The volume is normally set to be heard at a range of 3 meters over a wide range of ambient noise levels. As shown in Figure 3, these signals are consistently located relative to the edge of the crosswalk to allow for consistent navigation between signals. They are also located a consistent distance from the curb so the user can be close to both the signal and the intersection. Some auditory walk signals in Copenhagen are located higher up the pole on the pedestrian signal-head (Harkey et al., 2007).

There are a number of tactile devices that are used in Denmark to make navigation easier for pedestrians who are visually impaired. The tactile device a pedestrian might encounter first is a textured detectable warning surface in a one foot strip on the edge of the sidewalk. When the user has followed the locator tone to the signal pole, there is a tactile arrow that points in the correct direction of travel (Harkey et al., 2007). This is especially helpful for intersections in Copenhagen that tend to be at a variety of odd angles with which it is more difficult to orient.

In combination, the auditory and tactile systems in Copenhagen work in the following manner: the pedestrian uses the locator tone to find the corner of the intersection. There is often a locator tone near each crosswalk, and so the pedestrian would find the correct locator tone for the desired direction of travel. The pedestrian can then push the button to activate the walk signal if user input is necessary. The next step for the pedestrian is to orient in the correct direction and become familiar with the intersection. They can then prepare to cross by approaching the detectable warning surface. When the signal indicates, the pedestrian would then walk across the intersection. Although the volume levels are not intended for this purpose, the pedestrian can use the sound of the walk signal on the opposing corner to guide them in the correct direction (Harkey et al., 2007).

5.1.3 COMPARISON OF APS DEVICES AND FEATURES

One option that needs to be considered is the choice between different APS devices, for system configurations that rely upon them. This choice primarily affects the feature set that is available, but also affects the cost. Existing devices that are currently being considered for new installation in Copenhagen use come from Prisma, Swarco, and RTB. Prisma has recently released a new APS device that includes features such as RFID activation (M. Lidhed, personal communication April 14, 2010). Furthermore, Swarco and RTB are co-developing a new APS device that is currently undergoing durability testing. We did not possess accurate price information or full specification sheets for each of these devices, so a full cost comparison was not possible. However, the company installing these devices has indicated that Prisma devices cost the City of Copenhagen more than Swarco devices (T. Pedersen, personal communication April 19, 2010). All of these APS devices share a variety of common features. These are:

- A choice between 10 or more different locator and walk tones
- Sound levels adjusted based on ambient noise
- Available vibro-tactile walk indicator
- Tactile arrows for orientation
- The ability to be configured using a laptop, PDA, or other handheld device

Table 4 shows the features that differentiate each device. An "X" indicates that the feature is present. A "?" indicates that we did not have enough information to determine whether or not the feature is present. Product lifespan is a rough estimate, given either by the MTBF (mean time between failures) or information we received during an interview with a representative of the company. This is an important cost and maintenance issue, as devices that have to be replaced more often need to be purchased and installed more often.

Company	**Product**	Tactile Map	Verbal Recording	Speech Countdown	RFID Activation	Bluetooth Activation	Expected Lifespan
Prisma	DAPS	X	X				8 years
	(new)	X	X	X	X	?	?
Swarco	(existing)		X				10 years
Swarco/RTB	(development)		X	?	X	X	?
RTB	Berlin		?				5-15 years

Table 4: Selected Differences between APS Devices

The information shown in Table 4 was obtained through literature reviews and contacting manufacturer representatives. We learned about Prisma's device from product briefs, specification sheets, and an interview with Prisma Teknik CEO Marcus Lidhed (M. Lidhed, personal communication April 14, 2010). We learned about Swarco's current and in-development devices from speaking with Swarco Denmark Service Manager Tonny Pedersen (T. Pedersen, personal communication April 19, 2010). We learned about RTB's device from product briefs and an email interview with Sales Representative Christian Schulte (C. Schulte, personal communication May 4, 2010). Summaries of all manufacturer correspondence can be found in Appendix D.

5.2 RELATED TECHNOLOGIES

A number of technologies exist that are very closely related to the problems that must be addressed for APS systems. General navigation technologies for the blind, pedestrian detection and wireless communication have made dramatic improvements since APS technology was originally developed over 30 years ago. Studying related technologies provides an opportunity to explore solutions that differ from current approaches to the problem.

In general, there are two different approaches to aiding navigation for people with visual impairments. One is to add technology to the crosswalk to reduce the tasks for the user, a passive detection system. The other is to have the user carry a camera phone, Bluetooth or some other accessible technology that requires them to play an active role. Both have merits and shortcomings, but more importantly, investigating these technologies provides ideas for alternative solutions to the current system. The following sections will discuss alternative navigation techniques, pedestrian detection technologies, as well as wireless control devices that are being used in some newer traffic control systems.

5.2.1 ALTERNATIVE NAVIGATION TECHNIQUES

Navigation technology for the blind has taken many forms. The white cane has been a standard for advanced warning of surface topology and has the added benefit of being lightweight and inexpensive. One drawback is that it takes over 100 hours of training to become proficient at using a white cane for navigation. Some alternatives that have been explored include electronic travel aids or ETAs. These often use a laser or ultrasonic beam to detect obstacles. The location of obstacles is communicated to the user in a variety of ways. The *Mowat Sensor* is a handheld device that vibrates faster as it is pointed at an approaching object. The *Nav Belt* is an array of sensors worn around the waist that transmit signals into stereo headphones depending on the optimal direction of travel. The *Guide Cane,* as seen in Figure 22, uses a similar array of sensors but is connected to a wheeled cart at the end of a cane that steers itself to avoid obstacles (Shoval, Ulrich and Borenstein 2001). There are advantages and disadvantages to each of these systems when compared to the white cane. For example, while the Nav Belt and the Guide Cane might reduce the cognitive load for the user, they would be very expensive, bulky and would only detect large obstacles rather than the surface detail that white cane feedback provides.

Figure 22: Guide cane (Shoval, Ulrich, Borenstein, 2001)

Other navigation technology focuses on using devices that are already commonly used by the average person. For example, a system has been made for camera phones to detect color markers and estimate distance. The idea is that the color markers could be placed in key locations and users would use their phone to detect the markers. (Chan, Manduchi and Coughlan 2007). A more ambitious project using a cell phone camera is known as the Bionic Eyeglass. It uses real-time video recognition to communicate certain things to the user. A recent study focused on crosswalk recognition using algorithms to distinguish crosswalk patterns and communicate their presence to users (Radvanyi, Pazienza and Karacs 2009).

5.2.2 *PEDESTRIAN DETECTION*

Pedestrian detection technology has been developed for the general population to help prevent "pedestrian-vehicle conflicts" (Hughes, et al. 2001). A focus recently has been how these detection devices are being used to accommodate people with vision, mobility and physical impairments (Steindel 2008). The idea is to detect the pedestrian as they approach the intersection and activate the signal automatically. This would allow an APS to turn on the locator signal only when there is a pedestrian present. For signals that are pre-timed, this would also eliminate the walk signal being activated when there is no one at the crosswalk. Both of these reductions in sound would cut back the noise pollution caused by current APS systems. Various methods of accomplishing this have been developed including microwave-radar, infrared, piezoelectric, video image processing and laser scanners. A number of countries have implemented these systems to some degree including the US, Canada, Australia, England, Japan, Sweden and the Netherlands (Steindel, 2008).

Each different type of system has its own advantages and disadvantages depending on a number of variables including the type of intersection, what is being detected and how the system is installed. Microwave or radar systems can be implemented in a number of ways but generally work on the principle of an antenna transmitting radio waves and a receiver detecting variations in the reflected signal. These variations would be caused by a moving object such as a pedestrian. One example of implementation of a microwave radar system is in Tucson, Arizona where the detectors monitor the crosswalk. If the crosswalk is still occupied during the normal end of the "walk" sequence, the time is extended by 33% to give more time to the pedestrian to clear the crosswalk. In Ottawa, Canada at least two intersections have replaced pushbutton activation of the crossing signal with microwave-radar systems that also detect whether pedestrians are still in the intersection, similar to the system shown in Figure 23. One disadvantage with this particular system is that they must be finely tuned to only respond to people on the sidewalk or in the crosswalk (Hughes, et al. 2001).

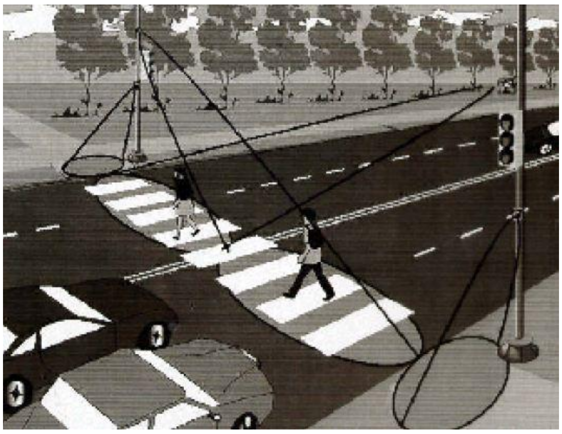

Figure 23: Detection areas for an infrared or microwave pedestrian detection system (Hughes, et al. 2001)

Infrared pedestrian detection systems work much like the microwave-radar systems, most often detecting movement to trigger the crossing signal. One of the largest installations of this type of system is in Sydney, Australia which includes about 20 intersections. This particular system uses infrared signals to detect pedestrians remaining in the crosswalk near the end of the crossing sequence. The system has now been in place for a few years, but further installations are unlikely because the current system has issues with both false calls and justifying the costs in relation to the minimal benefits that are realized (Steindel 2008).

Another type of system that has been used for many years in a variety of traffic applications is the piezoelectric sensor. This works on the principle of a particular material changing its electric properties when a pressure is applied. In this case, the piezoelectric sensors are placed under a mat or the paving at a corner and detect when a pedestrian is standing in the correct location. The United Kingdom and Australia have used these sensors for a number of intersections as shown for an Australian intersection in Figure 24 (Shoval, Ulrich and Borenstein 2001).

Figure 24: Piezoelectric sensor under painted area at a curb cut (Stiendel, 2008)

The last main technology that is used for pedestrian detection is video image processing. This uses a camera to capture images and has a computer that then interprets these data into useful information. This detection has the potential to be the most accurate by using shape recognition to tell the difference between pedestrians and other moving objects like cars and debris (Steindel 2008).

Pedestrian detection has successfully been implemented in the United Kingdom, as part of a new pedestrian crossing system known as the Pedestrian User Friendly Intelligent Crossing or PUFFIN. This system does not specify technology but rather an approach that increases pedestrian safety and the efficiency in the flow of traffic. The system works using a pushbutton activated pedestrian cycle. A near side signal, meaning that the appropriate “walk” and “don’t walk” lights are on the same side of the intersection as the pedestrian, allows the pedestrian to look at both the signal and oncoming traffic at the same time. When the button has been pressed, the “walk” signal will turn on at the next appropriate phase in the traffic. Often though, after the button has been pressed, a pedestrian will see a gap in the traffic and cross before the “walk” sign is illuminated. Ordinarily this would mean that traffic was then later stopped when there was no pedestrian present. The PUFFIN system instead detects if the pedestrian crosses early and cancels the push button call (Routledge 2006).

There are two innovations with this system that can be applied to accessible pedestrian signals. The first is having the signal on the near side of the intersection. As the British Department of Transportation says the near-side pedestrian signals allow the user to observe approaching traffic while looking at the signal and that “pedestrians with sight impairments also should find it easier to see…compared to the farside pedestrian signal (Routledge 2006).” The benefits of having a clear signal at eye level directly next to the pedestrian could assist many people with visual impairments.

The second innovation has been used for years and takes many different forms. The Puffin uses “kerbside detection to monitor when pedestrians are present and cancel demands when pedestrians cross in gaps in traffic.” (Routledge, 2006) Canceling crossing demands does not have much application in Copenhagen because according to several Copenhagen traffic engineers, most intersections are timed and the pedestrian phase is automatically incorporated in the parallel traffic phase (Bjerremose, Frederiksen, & Kreutzfeldt, personal communication, April 7, 2010). However, the widespread success of pedestrian detection in the UK makes the Puffin a good example of what is possible.

Pedestrian detection is also used in Copenhagen but because most intersections have dedicated pedestrian cycles, it is not needed as much. This setup is more common in the countryside. Copenhagen has two examples of pedestrian detection already installed. One is outside the Danish Royal Library the mid-block crossing of Christians Brygge. This crossing requires a pushbutton to activate the pedestrian signal. This is used when there is no dedicated pedestrian cycle, although few Copenhagen intersections are configured this way. Since few APS devices with pushbuttons are installed, pedestrians often forget to push the button and activate the cycle. A RADAR system was installed to detect pedestrians at the crossing, ensuring that the signal is still be triggered even if the button was not pressed. Pedestrian detection is also used outside the main gates of the Tivoli amusement park. When there are large numbers of pedestrians, the detector allows the crossing phase to be extended so all of the pedestrians will be able to cross (Bjerremose, Frederiksen, & Kreutzfeldt, personal communication April 7, 2010).

Passive pedestrian detection for APS has advantages and disadvantages. If there are no pedestrians present at the intersection, the APS system can be safely shut off. Once a pedestrian with vision impairments reaches the detection area, the APS system is re-enabled satisfying the need for accessibility. This could reduce or eliminate nighttime noise pollution in areas where pedestrian traffic is uncommon during night hours. However this type of system cannot distinguish between pedestrians who require the APS and those that do not. The noise pollution produced will not decrease as much as it would for a system that can distinguish APS users, particularly during busy hours.

5.2.3 RFID

Another technology that has become more popular in recent years uses radio frequency identification (RFID). This consists of using tags to label objects and readers that can read the labels. This technology has been used for both indoor and outdoor navigation. By placing tags in key locations, the user can receive information about their location. One example of how RFID is currently being used is Ispra, Italy. Over 1200 tags were placed in the ground around the city. The user has a white cane outfitted with an antenna that sends signals to the user's smart phone as the tags are detected (Peck 2008).

In the context of APS devices, a tag can be carried by APS users while the tag reader can be a feature of the APS device. This arrangement permits the user to send data to the APS device, identifying them as an APS user. Passive RFID tags can be retrofitted to white canes and guide dog harnesses, items a visually impaired person may already have and is unlikely to leave behind. This retrofit is simple and affordable, as passive tags can be mass-produced for less than 1 Danish Krone (18 cents) each and do not require batteries (Bondsor & Keener, 2010). Prisma Teknik currently sells an APS device equipped with an RFID reader, though this device is a very new product (M. Lidhed, personal communication April 14, 2010).

RFID technology can allow information to be stored regarding the user's preferences for various APS settings. For example, an RFID tag can indicate that its owner needs an additional 5 seconds to cross safely and finds bird calls easiest to hear. This information could be invaluable, especially if the person has frequency-selective hearing impairments or mobility issues. In an interview with John Heilbrunn he emphasized that the tag information should only be able to be set by a recognized authority (2010). Write-Once Read-Many (WORM) RFID tags could be used for this purpose (Bondsor & Keener, 2010), though there is the added labor cost of determining what the individual user needs and authorizing an RFID tag that contains this information.

5.2.4 BLUETOOTH

Bluetooth wireless communications technology permits the APS device to communicate with a user's cell phone or other device. This two-way wireless communication allows each device to provide real-time information. Essentially, Bluetooth beacons are installed at key locations such as information kiosks, busy bus stops or in this particular case, intersections. The cell phone detects the specific beacon and can provide information accordingly. For an intersection, the beacons would be integrated with the normal pedestrian signals so that the user could check the status of the signal. It would also have the ability to describe the topology of the intersection specific to the corner that the user is standing on (Bohonos, Lee, et al., 2007). The following is a list of potential applications for Bluetooth technology at APS intersections:

- Activation
- Customization
- When to Cross
- Intersection Information

Like RFID, Bluetooth can be used to activate an APS device and request custom settings that are tailored to the user's needs. This can be done at a range of 10 meters (33 feet) (Bluetooth SIG, 2010). Unlike passive RFID, the user's Bluetooth device must be powered and therefore portable devices can run out of batteries. Another possible problem with expanding this device to continuous navigation is that in that application it exerts a fairly heavy cognitive load on the user. Care must be taken to ensure Bluetooth navigation devices do not distract them from important tasks such as listening to traffic sounds.

Bluetooth technology has been used to tell a user device what intersection it is near and whether or not it is the designated time to cross. One particular study done in 2008 describes a complete hardware and software system that was used to provide information to the user concerning the names of the streets of an intersection, the topology of the intersection as well as real-time data on the status of the traffic lights. The Universal Real-Time Navigational Assistance (URTNA) was developed using Bluetooth beacons incorporated into the signal system transmitting to the user's cell phone. The cell phone then translates the signal into an appropriate spoken message for the user (Bohonos, Lee, et al., Cellphone Accessible Information via Bluetooth Beaconing for the Visually Impaired 2008). Since the user device is responsible for communicating this information, the way it is communicated can be very flexible. Verbal indications, vibration and Braille can all be used as needed without any changes to the APS device.

According to Tonny Pedersen, the Service Manager for the Danish division of Swarco, a new device that is being developed for production in the next year has the capacity for Bluetooth communication (T. Pedersen, personal communication April 19, 2010). With this capability installed at APS intersections, the only other infrastructure required for Bluetooth accessibility to be tested and used is an appropriate software program for a cell phone to communicate. URTNA has proven that the appropriate software can be developed. Although no more recent research was found, one can expect that advancements in Bluetooth communication in the last two years can also be applied to pedestrian crossing systems. As cell phones have become more popular and as the majority of them have Bluetooth capabilities, it becomes more reasonable to be able to expect more pedestrians to be able to use a system that has this type of functionality.

5.2.5 COMPARISON OF USER DETECTION SCHEMES

Many options exist for mitigating the noise from acoustic signals through user detection. After the APS device or intersection controller has determined that an APS user has arrived at the intersection, it can enable features that provide important benefits to that user but would have a strong detrimental impact if enabled all the time. Some of these benefits include louder acoustic signals and longer pedestrian walk phases. Adjusting the volume of the beacon when a user is detected may allow for a lower volume at all other times. This is an important noise mitigation strategy, especially if verbal walk indications are desired.

There are a variety of technologies that can be used to trigger the APS system. These include pedestrian detection, pressing an auxillary button, using an extended button press, and having a user device detected using either Bluetooth technology or RFID.

The benefits of each of these solutions can be discussed based on the types of users they detect. Pedestrian detection technology will trigger the APS device whenever any pedestrian visits the crosswalk. This ensures that the device will be triggered whenever a pedestrian with visual impairments is present, but limits the noise mitigation benefits as other pedestrians will also activate the device. Both button press schemes will trigger the APS device whenever a pedestrian who knows how to use the device visits the crosswalk and presses the button. This eliminates most unintentional activations, but requires APS users to know where to look for the button and how it operates. Another advantage of the button press is that it can be completely integrated into existing APS devices. RFID and Bluetooth detection schemes require pedestrians to carry a specific user-centered device to benefit from device activation. This solution limits potential users to those with the correct devices, although there may be other benefits such as using a Bluetooth device to help know when to cross. A combination of these systems can be used, although there may be additional cost and complexity.

5.2.6 WIRELESS TRAFFIC SIGNALS

One emerging technology is the use of wireless networks to replace physical wiring. This could be applied to traffic signals and APS systems to bypass under-the-street electrical conduits and their related costs. In order for traffic signaling devices to work, the traffic light controller must quickly and reliably send electrical signals to each component of the intersection. APS devices are either connected to the controller or share signal wires with other devices, such as traffic lights and flashing "Walk"/"Don't Walk" pedestrian signal heads (National Cooperative Highway Research Program, 2010). High-quality weather-resistant wires are expensive to produce and install. By replacing these wires with wireless devices and alternative power sources such as solar panels, the signal wires can be eliminated, thereby saving material costs and installation expense.

These wireless systems are already in use in the United States for connecting traffic signals from different intersections together. Introducing wireless technology has saved Los Angeles $7 million across over 500 intersections, plus hundreds of thousands of dollars per year in telephone line leasing costs (Leavitt, 2009). Cost savings is much greater when connecting distant intersections than when connecting devices located in the same intersection, but wireless technologies can still be used for within-intersection connections. Figure 25 shows a pedestrian signal pole placed up the road from the intersection, used to give drivers advance warning of pedestrian activity. A pedestrian crossing sign is mounted on the pole along with a caution light wirelessly connected to the intersection up ahead and powered using a solar panel.

Figure 25: Wireless pedestrian warning sign (Northwest Power Co., 2010)

This technology’s relevance to APS depends on the intersection. If an APS beacon is being installed where traffic control signal wires already exist, wireless capability is not needed. However, if these wires would have to be installed or relocated, it is possible that a wireless system would be cost-effective. A standard APS unit from any manufacturer relies on standardized signal wires for power and communication with the intersection controller (Pedersen, personal communication, 2010). Although current systems use wires buried in conduits under the street for this purpose, wireless devices and solar panels could be used instead. This would eliminate the need for additional wire conduits for APS-equipped poles in isolated locations, such as stub poles on medians. Our research does not indicate that this form of wireless capability has been tested for use with an APS device at an intersection.

6 AVAILABLE SOLUTIONS

In this section, we identify and categorize various system solutions that can be used by people with visual impairments to navigate an intersection. There are four different broad approaches that can be used to resolve the problems that have been identified. These four categories are generally separated by the time frame in which the solutions could be implemented.

- Retrofit or reprogram existing systems
- Install devices or systems that already exist on the market
- Plan to install and pilot test devices or systems that are currently being developed and can be implemented within 1-2 years
- Plan to research, install and test solutions that have not been developed

Our solutions will focus on the first three categories. Long term ideas that still require extensive research and development are not practical solutions for the relatively near future and do not have enough existing research to be able to effectively compare them.

6.1 SOLUTION IDENTIFICATION

To identify the solutions that are available, we examined the problems that we identified with the current system. These problems were identified both by our liaison, John Heilbrunn, and confirmed while investigating the needs of our stakeholders. The following problems were identified:

1) Acoustic signals are insufficiently audible
2) Acoustic signals create noise pollution
3) APS devices are malfunctioning and not being repaired in a timely manner
4) The current APS solution costs too much
5) There is no standardized system that can be found in all municipalities and countries

Different types of solutions have been identified for the first 4 problems. They are shown in Figures 26, 27, 28 and 29.

Figure 26 shows our solutions to the problem of audibility. There are four broad solutions: increasing the signal volume, using a tone that is easier to hear in traffic, using tactile solutions that do not need to be heard, and ensuring that installed systems comply with ISO standards that have been developed to ensure proper audibility. Although the signal volume can be increased permanently, another option is to temporarily increase the volume when an APS user requests it.

Figure 27 shows our solutions to the problem of noise pollution. Signals can be set to a lower volume or turned off, users can activate the signal only when needed, silent tactile solutions can be used, or a different tone can be chosen that has better noise characteristics. User-activated signals can attempt to detect pedestrians in general or APS users. APS users can identify themselves through button presses or carry a device that identifies them to the APS device.

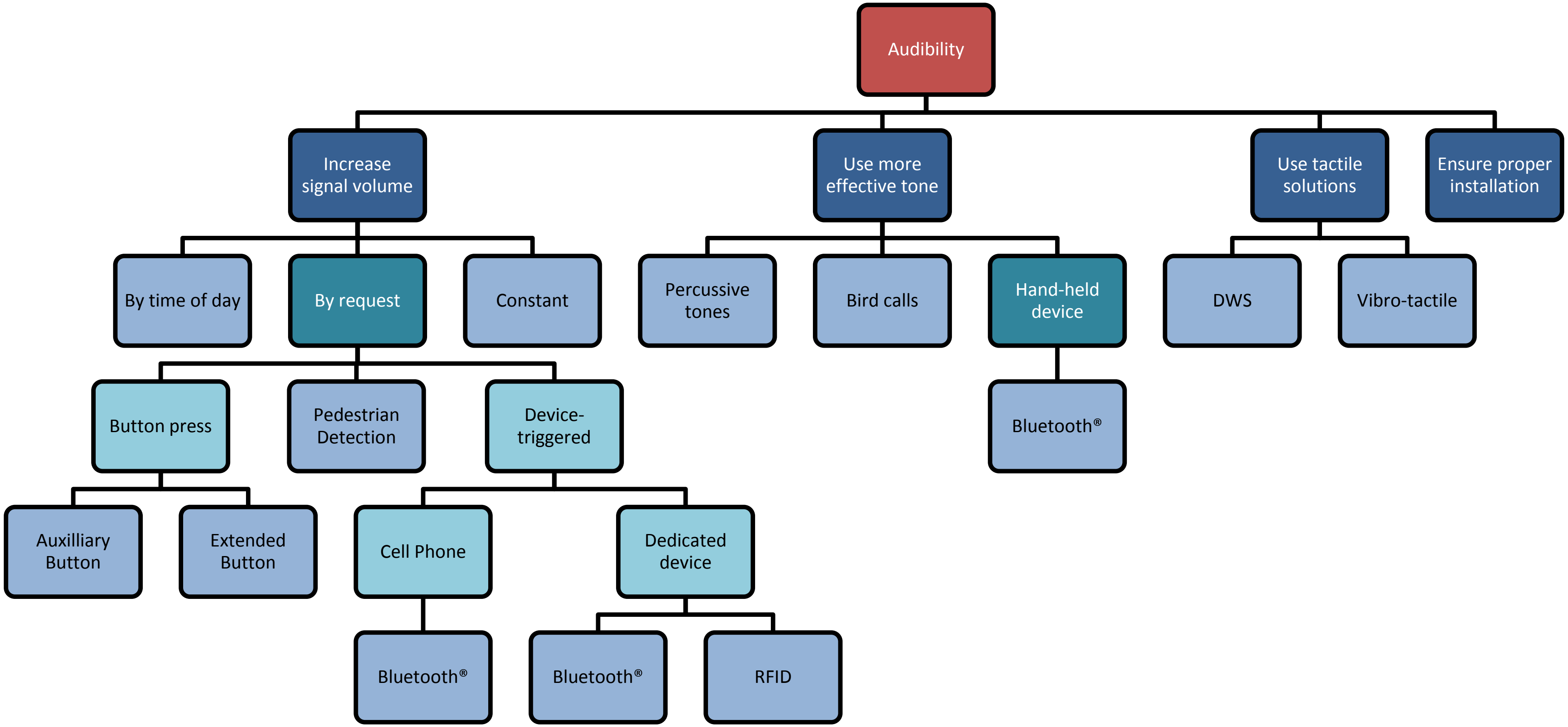

Figure 26: Audibility solution tree

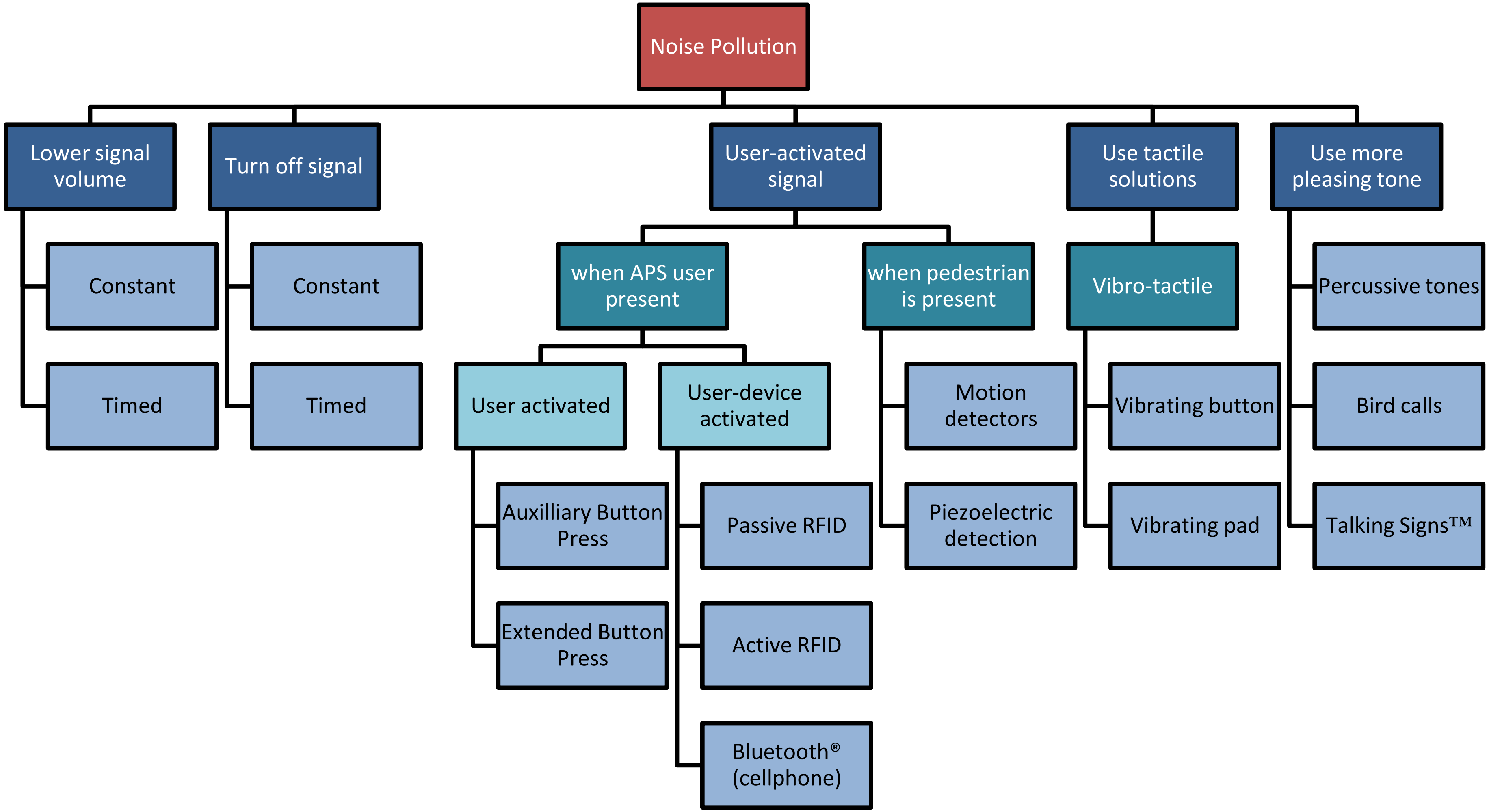

Figure 27: Noise pollution solution tree

Figure 28 shows our solutions to the problem of malfunctioning devices. Many APS devices support automated error reporting mechanisms that allow them to detect errors and report them to the municipalities responsible for maintaining them. Systems can be tested more regularly, or efforts can be undertaken to improve users' ability to report problems.

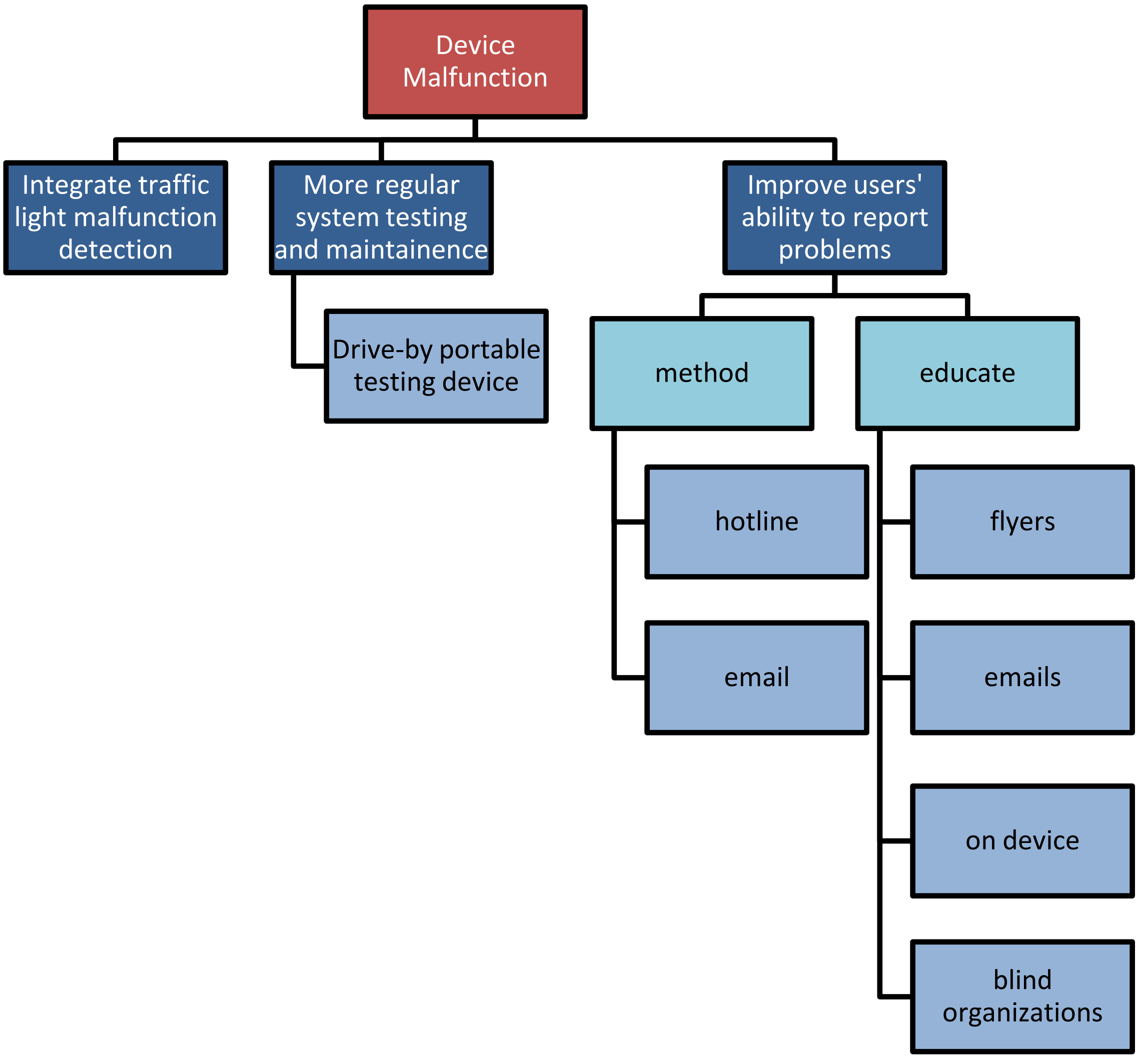

Figure 28: Device malfunction solution tree

Cost is also an issue, as money is needed in order to establish more accessible systems. Figure 29 shows that money can be freed by making new systems cheaper to install and maintain, or additional funding can be acquired. Universal design is another option for funding, increasing the need for accessible system solutions for the blind by enabling people with other disabilities to use them for their needs as well.

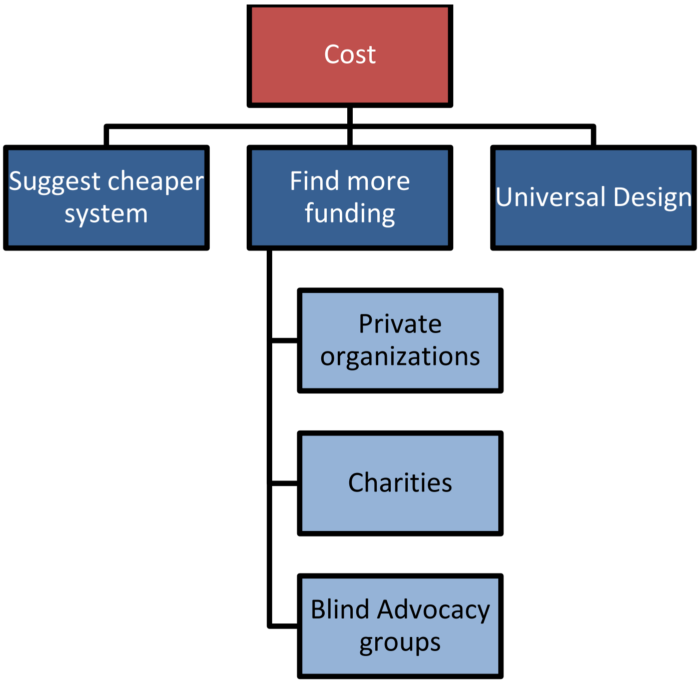

Figure 29: Cost solution tree

We have separated our discussion of these solutions based on when they can be implemented. Some of these solutions can be implemented immediately while others can be implemented beginning when the next APS intersection is scheduled to be upgraded, while others need to wait 1-2 years for product development to produce a system that is ready for a test site or widespread installation.

6.2 RETROFIT SOLUTIONS

There are several approaches that can be used to improve systems that are already in use in the greater Copenhagen area.

- Reprogram acoustic APS devices to use a better sound.
- Improve APS maintenance.
- Change timer and button activation settings on devices that support these features.

6.2.1 USE A BETTER SOUND

Recent-model Swarco and Prisma APS devices support a wide variety of acoustic sounds. Prisma's DAPS supports 16 different tones plus 3 recorded sounds (Prisma, 2006). The Swarco device supports many sounds and can be programmed for a wide variety (Pedersen, personal communication, 2010). Therefore, it is possible for municipalities such as the City of Copenhagen and Frederiksberg to spend available resources changing the sounds used with their APS devices. Currently, Copenhagen uses an 880Hz beep and Frederiksberg uses a percussive “knocking” sound.

When determining the best sound to use, many options exist. However, the types of messages fall into two categories, verbal and non verbal. The two signals are not mutually exclusive, for example a device can use a non-verbal locator tone and a verbal crossing indicator, but it is important to decide which is more beneficial.

Existing research has identified a number of criteria regarding what the best sound is for an APS device. Any sound used must be easily detected by pedestrians, including those with some degree of hearing impairment. The sound must also be easily and accurately localized to a specific crosswalk and APS device (Harkey et al., 2007). Also, the sound must clearly indicate whether it is a walk indication or simply a locator tone.

Additionally, existing research has studied the relative merits of different nonverbal sounds as APS indications as well as the nature of the traffic noise that must be overcome. “The sound produced by vehicular traffic is concentrated in the low frequencies, especially for vehicles that are accelerating from a stop” (Harkey et al., 2007). However, higher frequencies tend to be hard to hear as they attenuate in traffic noise. In one 1997 study, the average noise produced by accelerating traffic was 89 dB (Harkey et al., 2007). This is 11dB less than the maximum APS volume permitted by Danish standards (Vejdirektoratet, 2006). The ISO recommended volume is 2-10dB above ambient while the Danish standards recommend 10-12dB. Therefore this 11dB margin is barely enough for average noise let alone particularly noisy traffic. This can be an issue with Prisma devices that have a maximum volume of 90dB (Prisma, 2008).

The Danish standard “beep” sound is an 880Hz square or saw tooth waveform (Vejdirektoratet, 2006). Other available tones include click trains, percussive “bink” and “tok” sounds, melodies of a variety of frequencies, bird chirps, and cuckoos. These were assessed in an unpublished experiment sponsored by the National Eye Institute (NEI), with the results indicating that lower-frequency percussive sounds were the easiest to hear over traffic noise (Harkey et al., 2007). Furthermore, all of the people we contacted who were familiar with the Frederiksberg percussive tone preferred it to Copenhagen’s “beep” or expressed no preference. When speaking with a traffic engineer from Frederiksberg who worked on the project during which the signals were changed, he cited no complaints about the type of noise. He did say that there were many complaints about the volume when the systems were first installed until the different devices could be adjusted appropriately, but no complaints about the type of noise.

One method of configuring an APS is to use a knocking sound for the locator tone with human speech for the walk tone. This method allows the system to provide more information to a user, such as the name of the street. However, it has been noted that such a message should not imply that it is definitely safe to cross the street (Harkey et al., 2007). This is consistent with what we learned from speaking to an Orientation and Mobility specialist (Hallestad, 2010). One example of an appropriate message in English may consist of:

> "Lincoln Avenue. Walk sign is on to cross Lincoln Avenue." (Harkey et al., 2007)

This sort of message provides an English speaker with the name of the street being crossed, Lincoln Avenue, while indicating it is a walk tone. Another possible feature of this kind of signal is that it could provide a countdown of how much time remains in the pedestrian walk cycle. This type of signal was observed by Hans Rasmussen (2010). There are also some important drawbacks to voice-oriented walk tones. A 1999 study found that speech had to be at least 15dB louder than ambient noise to be 90% intelligible, noticeably louder than a beep or knocking sound (Harkey et al., 2007). Not only is this higher than current Danish standards permit, it could create a significant problem for the neighboring community. However, the noise is only produced during the walk cycle, making noise mitigation schemes such as user detection and push-button activation especially effective. Furthermore, the effectiveness of a walk indication given in a language that the user does not speak is currently unknown. Copenhagen is frequented by tourists and visitors, a significant number of whom do not speak Danish. Due to the complexity of these issues, a much more exhaustive analysis is undertaken in Section 7.1.

6.2.2 IMPROVE APS MAINTENANCE

We have identified 3 main courses of action to improve the maintenance of existing APS systems.

1) Increase the frequency of routine maintenance
2) Utilize automated systems for error reporting
3) Improve the current system of responding to user complaints

Currently, routine inspection and maintenance of APS devices is conducted once per year (Pedersen, personal communication, 2010). In order to ensure that devices are fixed within a few days of device failure or malfunctioning using nothing but routine maintenance, the amount of maintenance would have to be increased so much that it would likely become cost-prohibitive. Even doubling the frequency of maintenance visits would result in a 6-month worst-case response time, which is not acceptable for people who must rely on the devices every day.

Many existing systems permit the APS devices to be monitored remotely for detected errors. This feature can be enabled by connecting one wire between the APS device and an intersection controller which supports error reporting, such as any of the controllers installed in Copenhagen. After an error has been reported, the City is notified and Swarco can take corrective action without any further intervention. When this feature is used for APS, a response time can be achieved that is comparable to that of broken traffic lights. Although this method is limited to errors that the APS device itself can detect, this solution has a clear and invaluable benefit for the blind community when errors are detected. Problems with nonfunctional and failing devices can be eliminated quickly, easily, and without relying on any intervention from the intended users. Although the government encounters additional costs associated with monitoring system installation and upkeep, these costs are limited. In some locations additional wiring may be required. The cost associated with responding to problems would likely be reduced. When a community member reports a problem, employees of the City of Copenhagen must interpret and respond to their communication and then notify Swarco of the problem. When an automated system successfully reports a problem, this labor cost and delay can be eliminated as Swarco can respond to the problem without any effort from the City. There is a cost associated with repairing an APS system that has malfunctioned, but this cost must be paid regardless of how the malfunction is reported (Pedersen, personal communication, 2010).

The benefits of well-designed automated error reporting clearly outweigh the costs to each of our stakeholders, so we recommend that APS devices be connected to the central error reporting system whenever practicable. The technical difficulty of enabling error reporting at a particular intersection and the importance of that intersection to the blind community should both be considered when prioritizing which existing intersections to upgrade with available funds.

Additionally, improvements could be made to the way problems are reported by members of the community. This can be done in conjunction with automated error reporting, since there are issues that cannot be detected automatically. For example, automated systems cannot determine whether the volume of a beacon is set incorrectly or when a tactile arrow is pointing the wrong direction. In order for these types of problems to be reported, community members must understand how to report the problem and the contact being relied upon for problem reporting must efficiently forward this information to technicians at Swarco. Any communications must take into consideration both the needs of APS users who are fully blind and neighbors who are fully sighted, and provide instructions that are simple to understand. A discussion of which communication methods are most effective is beyond the scope of this investigation, although we can offer some suggestions regarding what options could be evaluated:

- Awareness campaigns within the DBS membership and throughout the community.
- Braille and Danish messages on APS explaining how to request maintenance.
- Phone and email hotlines for requesting repairs, managed either by the City of Copenhagen or Swarco.

6.2.3 CHANGE TIMER SETTINGS FOR APS DEVICES

Some of the existing APS devices are controllable using timers. Four of the 72 APS equipped intersections are turned off at night, typically from 23:00 (11 pm) to 07:00 (7 am). One intersection simply has the volume turned down from 23:00 to 06:00. Experts on the needs of people with visual impairments, as well as these people themselves, have made it quite clear that it is unsafe for APS to be completely shut off at night (Heilbrunn, 2010). However, the blind community does consider it a marginally acceptable solution for devices to be turned down to reduced volume settings during this time period (Heilbrunn, 2010). Currently installed devices require the installation of a timer to the device which can make this solution cost prohibitive. Because of this, the timing device is only installed at problematic intersections when there are a number of complaints and necessary funds.

6.3 CURRENTLY AVAILABLE SOLUTIONS

As APS devices reach their end of life and funding becomes available for new installations, the City of Copenhagen will be faced with a number of choices regarding what systems to install. The available solutions are limited to technologies that are available at the time of publication.

There are several types of scenarios for a new system installation:

1) Upgrade of existing installation
2) Upgrade of non-accessible intersection
3) New installation at intersection

When an APS-equipped intersection undergoes an upgrade, there is an inherent cost advantage to using accessible systems that use the same infrastructure. APS mounting poles and electrical connections are already in place, though there is no guarantee that an extra wire is available for configuring automatic error reporting. Due to the age of the APS devices that are nearing end of life, there are rarely records of how the devices were configured. This will become less of an issue since many of the newer devices currently in use do have digital configurations that can be stored on Swarco's server (Pedersen, personal communication, 2010). Tactile pathways and DWS that already exist can remain in place, unless they are worn out. However, if the crosswalk itself needs to be replaced along with the DWS then the intersection can be considered a new installation.

Other times, intersections that currently lack any features that improve accessibility for people with vision impairments may receive an overhaul designed to make them accessible. This type of installation has a very different set of installation costs associated with it compared to an intersection that already has accessibility features. The poles on which APS are mounted may not already exist or may need to be repositioned to comply with Danish standards. Electrical conduits for these devices may not exist either, though one benefit of a new conduit installation is that installers can ensure that there is enough wire for adding automatic error reporting features. The current RTB device uses an intelligent field bus which allows the device to be powered and controlled by the same wire, reducing the need for excavation. Any APS devices will need to be configured. All of these concerns significantly affect the costs of installing APS devices, which can be as much as 100,000 Danish kroner per intersection (Pedersen, personal communication, 2010). One feature with most Danish sidewalks that we have observed is a row of cobblestones that can be used as a tactile path. This provides an advantage to solutions that use tactile pathways, though there may be a benefit to configuring pathways differently near the crosswalk itself.

Occasionally, new intersections are installed and all the accessible features can be designed into the intersection itself. APS poles and wires can be located according to standard, although there is a cost benefit to combining them with other signal poles that are required. Although there is a cost benefit to installing underground electrical conduits during the same installation as the street itself, the cost associated with installing APS is still higher than when poles and wiring already exist. Tactile paths and DWS will not already exist near the intersection, though considerable freedom exists for placing them where they can be most helpful for people who are blind. Additionally, the intersection design can accommodate pedestrian detection systems that are used for APS or other purposes. This scenario offers the highest level of flexibility for accessible system installation.

Although these various installation scenarios are vastly different, Dansk Blindesamfund has identified a need for a single standard for accessible system installation throughout Denmark and internationally (Heilbrunn, 2010). Since it is theoretically possible to treat every intersection as a completely renovated intersection by requesting additional funding for full renovation, the key difference between these situations is the cost required to install each kind of accessible system. Therefore, our analysis assesses the value of each accessible system solution at all three types of installation, making a distinction between each when evaluating the cost associated with each solution.

Funding availability is heavily tied to the potential sources of the money. Currently, the City of Copenhagen uses leftover APS maintenance funds and one-time special project funding to install APS devices as requested by DBS. Additional funding is associated with specific projects that are intended to have other benefits for specific areas, and simply include accessible design (Heilbrunn, 2010). Due to the nature of politics and the relatively small size of the blind community in Copenhagen, it is unlikely that the cost of APS can be resolved by simply increasing the maintenance budget. However, other options exist for addressing this concern. Devices that are cheaper to purchase, install, and maintain encourage more widespread APS installation because more devices can be installed for the same amount of money. This possibility is considered in our analysis of each system solution through our discussion of cost. Frederiksberg managed to obtain a substantial amount of project-oriented funding by launching an Accessibility Plan, detailing how to make the municipality accessible to people with all forms of disabilities over the 2005-2015 time frame (Nikolajsen, 2010). Additionally, Frederiksberg obtained project funding from the Frederiksberg City Council for upgrading traffic lights to energy-efficient LED models. This renovation, while not conducted for accessibility reasons, included installation of APS at 17 of the 21 intersections that are equipped in Frederiksberg (Nikolajsen, 2010)

6.4 SUMMARY OF EXISTING SOLUTIONS

Any accessible system being considered must effectively help blind pedestrians cross the street. Each available feature is categorized in Table 5 based on whether it helps pedestrians locate the crosswalk, orient themselves correctly, determine when to cross, or cross the street safely.

Table 5: Summary of existing technology

Locate	**Orient**	**When to Cross**	**Cross Safely**
Curb	Curb and Traffic	Parallel Traffic	Parallel Traffic
Tactile Path and DWS	Tactile Path (possible solution)	Vibro-tactile APS	Tactile Path and DWS (research needed)
Acoustic Locator Tone	Acoustic Signal at Destination	Acoustic APS	Acoustic Signal at Destination
	Tactile Arrow	Bluetooth (in development)	Tactile Map

The first option listed for each shows what a pedestrian who is blind uses to cross an intersection that has no specially designed accessibility features. All of the other options are an assistive technology that can be installed at the intersection. Each of these solutions already exists and is available for use as an accessible device unless otherwise noted. Further discussion of each can be found in Chapter 2, Background. No option excludes any of the other options, and any combination of one or more of the options listed for each category can be used. This creates a wide variety of possible solutions. We will assess several of these possible systems, each chosen to represent a possible accessibility strategy.

6.4.1 *SOUNDS AVAILABLE FOR ACOUSTIC SIGNALS*

Many different sounds are available for the acoustic signals produced by APS devices. For example, 16 preconfigured sounds come with Swarco's APS devices and several recordings can be used to store custom sounds. Copenhagen uses the Danish standard 880Hz beep, Frederiksberg uses a percussive "knocking" sound, and other municipalities around the world use everything from click trains to bird calls to verbal signals indicating what road is being crossed. This sound is played either from a speaker within the APS device or a dedicated beacon mounted higher up on the same pole. These beacons are often used to produce directed sound intended to improve audibility on the crosswalk while reducing noise pollution nearby, though there is an added cost of using a separate electronic device.

6.4.2 *USER DETECTION SCHEMES*

Many options exist for mitigating the noise from acoustic signals through user detection. After the APS device or intersection controller has determined that an APS user has arrived at the intersection, it can enable features that provide important benefits to that user but would have a strong detrimental impact if enabled all the time. Some of these benefits include louder acoustic signals and longer pedestrian walk phases. Adjusting the volume of the beacon when a user is detected allows for a lower volume at all other times. This is an important noise mitigation strategy that can be employed, especially if verbal walk indications are desirable.

Pedestrian detection will activate the device if a pedestrian is present. Button press solutions activate the device if the button is pushed, presumably by an APS user. Bluetooth and RFID detection activate the device when an APS user carrying an appropriate user-centered device, such as an RFID tag or specially programmed cell phone, is at the intersection.

6.4.3 NEAR FUTURE SOLUTIONS

As mentioned in Chapter 2, RFID and Bluetooth technologies can be used to activate APS devices and provide additional functionality. This activation requires that a user-centered device be present, such as an RFID tag or Bluetooth enabled cell phone. However it also permits the user-centered device to request custom settings, such as a different sound or an extended walk period. Bluetooth technology also allows the APS device to communicate the walk phase to a handheld device, allowing for further customization as well as noise reduction capabilities. Although RFID technology has been implemented in new-model Prisma APS devices and Bluetooth capability is offered in Swarco/RTB devices currently under pre-release testing, the RFID codes and phone software has not been sufficiently standardized to permit widespread non-experimental use of these technologies.

7 ANALYSIS OF SYSTEM SOLUTIONS

There are many different features, activation schemes and accessibility strategies that can be combined to form a large number of possible solutions. These were broken down into features and systems that could be evaluated separately. For example, instead of listing all the possible solutions that use verbal messages and then listing all the solutions that use non-verbal messages, we instead compared verbal and non-verbal independently. The one that seemed to rank better would be suggested as the solution which would be used for all the other system comparisons that use an acoustic signal. This was also done to determine the best non-verbal sound to use. After this simplification, fourteen unique systems remained for comparison. The following sections describe the criteria that were used for each analysis, how the analysis was conducted and what the results were for each one.

7.1 COMPARISON OF VERBAL AND NONVERBAL MESSAGES

Verbal messages and non-verbal messages are both used for indicating when to cross. They each have advantages and disadvantages. The following is a summary of the comparison between the two. A complete analysis can be found in Appendix H

The criteria that were used to determine if verbal or non-verbal signals are better were split into three main categories based on the three stakeholders.

Blind

1. Know what street is being crossed – Knowing which street is being crossed can help with navigation by keeping people who cannot read street signs from getting as lost.
2. Cannot confuse with other sounds – It is important that the pedestrian does not mistake a traffic sound or other ambient noise for the crossing signal.
3. Greatest understanding for the most people – The more people that can understand the signal is indicating to cross or not, the better.
4. Length of time to understand – If a crossing signal takes too long to understand, the pedestrian may be delayed in entering the intersection and may therefore not be able to finish crossing the street in the given amount of time.
5. Amount of information to comprehend – Too much information can distract a pedestrian from other important navigational things such as listening for turning cars.

Neighbors

6. Minimum volume necessary to be understood – The pedestrians need a signal that is loud enough to understand. The louder a signal needs to be, the more likely neighbors are to be annoyed.

Government

7. Requirements for installation – A signal that is more complicated to setup or install will be less likely to be adopted by the municipality in charge of installations.

These different criteria were weighted according to their relative importance. Categories that had would directly affect the ability of a person to safely cross the street are given a higher weighting than things that are simply helpful or related to cost.

Scores were given to each criteria based on a specified rubric from one to five. The rubric and definitions can be found in Appendix H.1. Table 6 shows the weights and the scores that were given for each criterion.

Table 6: Comparison of verbal and non-verbal messages

Criteria	**Weight**	**Verbal**		**Non-Verbal**	
		Raw	**Weighted**	**Raw**	**Weighted**
What street is being crossed	5	5	25	0	0
Cannot be confused with other sounds	25	5	125	3	75
Greatest understanding for the most people	25	3	75	5	125
Speed message is understood	12	3	36	5	60
Amount of information to comprehend	13	3	29	5	65
Minimum volume to be understood	10	2	20	4	40
Requirements for installation	10	1	10	5	50
Total Score	100	**Final**	320	**Final**	415

As can be seen by the table, non-verbal messages outscored verbal messages. This is almost independent of the weighing because the non-verbal message scored better for all but two criteria. Of these two criteria, the one with the greater disparity – knowing what street is being crossed – is less important than many of the other criteria for which non-verbal had an advantage.

7.2 COMPARISON OF DIFFERENT TONES

The Danish standard “beep” sound is an 880Hz square or saw tooth waveform (Vejdirektoratet, 2006). Other available tones include click trains, percussive sounds, melodies of a variety of frequencies, bird chirps, and cuckoos. These were assessed in an unpublished experiment sponsored by the National Eye Institute (NEI), with the results indicating that lower-frequency percussive sounds were the easiest to hear over traffic noise (Harkey, Carter, Barlow & Bentzen, 2007). Furthermore, all of the people we contacted who were familiar with the Frederiksberg percussive tone preferred it to Copenhagen’s “beep” or expressed no preference. When speaking with a traffic engineer from Frederiksberg who worked on the project during which the signals were changed, he cited no complaints about the type of noise. He did say that there were many complaints about the volume when the systems were first installed until the different devices could be adjusted appropriately, but no complaints about the type of noise.

Although the Vejdirektoratet has produced standards for APS in Denmark and the ISO has produced international standards, full compliance is not required for a system to be considered. For example, although the Road Rules specifically require the audible tone to be a square or saw tooth wave at 880Hz, the Vejdirektoratet has not disapproved the use of a non-compliant “knocking” sound for use in Frederiksberg (Nikolajsen, 2010). Standards compliance has been evaluated as a need of the government, where more compliant systems obtain a higher score.

7.3 COMPARISON OF APS SYSTEMS

The following is a summary of the analysis that was done to determine the best system to use. A complete description of the systems, scoring rubric, weighting and scores can be found in Appendix H.3.

Fourteen unique APS systems were selected for analysis that each used a different combination of activation methods and features. Each of the systems is idealized to address all the needs of pedestrians who have visual impairments. This means that at a minimum each system has a DWS to find the intersection, a tactile arrow with which to orient and a vibro-tactile indicator to know when to cross. Table 7 shows the fourteen systems.

Table 7: APS systems compared

	Constant Cycle			Pedestrian Detection		Button Press			RFID			Bluetooth		Bluetooth user decive output
System	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Tactile Path	X	X		X		X	X		X	X		X	X	X
Locator Tone		X	X	X	X		X	X		X	X	X		

Fourteen criteria were developed to compare these systems. They are divided into those that apply to the visually impaired, the neighbors and the government.

Pedestrians with visual impairments

1. Ease of use for first time user - It is important that a first-time user who is totally unfamiliar with the system, can easily activate the system. If they cannot do so easily, they may not obtain the benefits associated with activating the APS such as longer walk times and increased signal volumes. It can be assumed that if a user-centered device is included in the design, this person has obtained one.
2. Ease of use for visiting user – Not all potential users will have the correct user-centered device, even if one is required by a standard. For example, international travelers may come from a place that does not use the same system and therefore would not have the correct device. Also, other people may be able to benefit from the APS and so would need to be able to be activated by anyone.
3. Ease of use for frequent user – It is important that a resident who relies on the device every day can activate it easily and reliably. It can be assumed that if a user-centered device is included in the design, this person has it and the device is functioning.
4. Similarity to other existing systems – This is a harmonization issue; users see more of a benefit when the systems in use are similar from municipality to municipality while visitors can know what to expect.
5. Cannot be confused with other directional indicators – Orientation is very important for pedestrians crossing the street. It is important that a pedestrian does not get confused by other indicators in the intersection. This is judged by how easily a user can distinguish which direction to go while they are standing at the crosswalk ready to begin crossing.

6. Can be followed across the entire intersection – It is important that the pedestrian can make their way across the intersection and know where they are headed at all times. If a pedestrian becomes disoriented on their way across the intersection, they may not reach the appropriate location. The different scores for this criterion are based on where in the intersection the pedestrian is receiving feedback on which direction to go.
7. Can be used by deaf-blind – It is important not to alienate a portion of the blind population due to hearing loss. In order to score the full points in this category a blind-deaf person must be able to navigate the entire intersection. The middle score is for systems that can point them in the right direction and tell them when to cross or systems that only help pedestrians who are hard of hearing.
8. Reliability of user-centered device – If the user-centered device runs out of battery or is accidentally left behind, it is useless. This criterion discusses how likely the user device is to become inoperable. It is assumed that the user will always bring their cane and/or guide dog with them, occasionally forget their cell phone, and more frequently forget a dedicated device.
9. Personalization capacity – One feature of user oriented devices is that the user can specify something that they might need for crossing. For example a pedestrian who is hard of hearing might request a tone that is either louder or a different frequency. Someone who needs a longer time to cross the street might request an extra two or three seconds for the walk portion. This criterion is graded based on how many options the user would potentially have.
10. Cost for user – This criterion reflects the cost that is added to a design by incorporating user detection. It reflects the additional costs incurred when purchasing user-based systems, delivering them to their intended recipients, and ensuring they are configured properly.

Neighbors

11. Volume of signal – Neighbors need to be considered when a system is used. It is important to try and minimize negative effects on any of the stakeholders. This criterion is measured by where the sound can be heard, since most complaints by neighbors are noise related.
12. When the signal is audible – This criterion describes when the device is actively making noise. A signal that makes noise all day and all night is worse than one that only produces noise when a pedestrian who needs it is present.

Government

13. Cost per intersection – In order for a system to be widely adopted, it is important that the government can provide the necessary funding. This includes the cost of the system components, the cost of installation and the cost of maintenance. Since there is no ready way to make the comparison directly, this criterion is judged on the number and complexity of the components at an intersection. For example, many electrical components are more expensive and require more expensive maintenance than material components.
14. Cost per user – This criterion is interested in the cost to the government of distributing devices or programs to users. While programs for phones can be downloaded easily off the internet, writing the program incurs a cost.

The weights of the criteria are based on how much invested interest each of the stakeholders has. People with visual impairments hold the greatest stake in the system because they are the customer and would use the device in day to day life. It is also these pedestrians who have the greatest interest in how reliable the system is and how safe it is to use. An unreliable or unsafe system could cause direct harm to the user. The blind were therefore given a total weight more than the other two stakeholders combined with 65%.

The government was given the next most priority. Since they are the ones responsible for purchasing, installing and maintaining systems, they receive more priority than the neighbors. Splitting the remaining percentage, the government was given a 20% stake.

The neighbors only have an interest in keeping the overall noise minimized. Therefore the neighbors are given only 15% of the stake.

For each individual criterion, more weight was given to those that were important for safety considerations such as being able to follow a navigational guide all the way across the intersection. Less weight was given to less important things, such as the cost for the user, since most costs would probably be covered by the government to some degree.

Table 10 shows the weighting and scores for each different system.

Table 8: Comparison of APS systems

Criteria	**Weight**	**System Analyzed**													
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1. Ease of use for first time user	5	4	5	5	5	5	2	2	2	2	2	2	1	1	1
2. Ease of use for visiting user	4	5	5	5	5	5	5	5	5	1	1	1	1	1	1
3. Ease of use for frequent user	8	5	5	5	5	5	4	4	4	4	4	4	5	5	5
4. Similarity to other existing systems	4	1	3	5	3	3	1	3	3	1	1	1	1	1	1
5. Cannot be confused with other directional indicators	9	5	5	3	5	3	5	5	3	5	5	3	5	3	3
6. Can be followed across the entire intersection	10	5	5	3	5	3	5	5	3	5	5	3	5	3	5
7. Can be used by deaf-blind	7	5	5	3	5	3	5	5	3	5	5	3	5	3	5
8. Reliability of user-centered device	10	5	5	5	5	5	5	5	5	4	4	4	3	3	3
9. Personalization capacity	4	1	1	1	1	1	3	3	3	5	5	5	5	5	5
10. Cost for user	4	5	5	5	5	5	5	5	5	3	3	3	1	1	1
11. Volume of signal	6	5	3	1	3	1	3	3	1	3	3	1	3	1	5
12. When the signal makes noise	9	5	1	1	3	3	3	3	3	4	4	4	4	4	5
13. Cost per intersection	12	3	3	4	1	2	3	3	4	3	3	4	3	4	3
14. Cost per user	8	5	5	5	5	5	5	5	5	3	3	3	1	1	1
weight for blind	65														
weight for neighbors	15														
weight for government	20														
Total	100	**439**	**404**	**360**	**398**	**346**	**399**	**407**	**355**	**366**	**366**	**314**	**335**	**283**	**338**

Of the 14 systems that were compared, the system that seems to cost less, require less maintenance and annoy neighbors the least while still meeting the needs of the pedestrians is a purely tactile solution. This system would use a tactile path to locate a DWS from which the APS device could be easily found by hand or with a white cane. The device would have a “don’t walk” and a “walk” vibration signal that would continuously cycle as appropriate. The device would also have a tactile arrow. When the vibration indicated, the pedestrian would follow a tactile path to DWS at subsequent islands or the far side of the intersection. The reason this system fared well in the analysis is because it scored well for every criteria except for the similarity to the existing system and the personalization capacity.

The replacement of locator tones and opposing crossing tones with tactile paths and DWS needs to be more thoroughly investigated. DWS and tactile paths have been used around the world, most notably in Japan for the last 40 years. This length of implementation has created a body of knowledge on the best practices for installation and use. Research needs to be conducted specifically for Denmark including what the best shapes and materials are for paths and DWS. Another consideration is the type of material that is used. If a tactile path crosses a road, it must be made of a material that can withstand heavy wear, not interrupt the flow of traffic and still be able to be detected underfoot or by cane. Another point that was brought up was the effectiveness of underfoot detectable surfaces for people who may not have feeling in their feet such as people with diabetes. It is important then that the tactile paths and DWS must be easily detectable with a white cane. Lastly, it is important to consider the effects of snow and ice on how well the surfaces can be detected as well as how snow removal might affect them. Much of this research can be done by conducting a closer literature review of successful implementations such as those in Japan. Because of the further research that must be done, this solution is considered a long-term solution.

If the tactile paths are found to be problematic, difficult to implement or do not somehow meet the necessary needs, a different set of systems can also be considered. Of the systems that do not use the tactile paths to aid with navigating the crossing, the top three scores were within 14 points. Such a close score is not conclusive. A robustness test indicated that the relative ranking of the scores depends on the weighting of stakeholders.

When the pedestrians are favored in the weighting scheme, the high scoring system describes the ideal implementation of the current system in Copenhagen. This is an interesting observation to make. This means that of the currently available technologies, the current implementation is the best for pedestrians. However, if the neighbors need more consideration, then this is not the ideal system for using existing technology. Instead, a button triggered system or pedestrian triggered system would be better to use.

One interesting observation to make about the outcomes of this comparison is that the user centered devices did not score well. The systems tended to score high in such categories as ease of use for the pedestrian and personalization capacity. However, these advantages were countered by the problems associated with user centered devices such as the potential to forget the device or having it run out of battery and the problem with not being able to accommodate people who do not have a specific device or program. In terms of the neighbors, these systems did have some advantage over other systems, but not significant enough to make much of a difference in the comparison.

Increasing the use of tactile surfaces would prove advantageous to all three stakeholders. However, this will require more investigation into the how to implement tactile surfaces most effectively. If investigations should prove that increased use of tactile surfaces is not a viable solution, than the next best thing would be to either improve the current system or to implement a system that is activated by a button push, depending on whether the needs of the pedestrians or those of the neighbors should be considered more. Systems that require user devices were found to be the least useful for all stakeholders.

8 CONCLUSIONS

The analysis of APS covered a variety of topics, discussing short-term, mid-term, and long-term solutions. Each of the available options for a best system was separated out according to topic. We compared a nonverbal walk signal with a verbal walk signal, concluding that nonverbal signals are more ideal.Then we identified various types of locator tones could be used for APS systems, compared them, and concluded that the Frederiksberg percussive “knocking” tone is the best audible signal for use in greater Copenhagen. We then compared 14 different systems representing different combinations of activation schemes, tactile surfaces, and user-centered devices and concluded that purely vibrotactile solutions are the most ideal. A comparison between the current system, pedestrian detection activation, and button press activation yields inconclusive results. Additionally we conclude that all APS devices would benefit from improved maintenance practices that include automated error reporting, better community awareness, and improved problem documentation.

The most ideal long term solution that we determined from our analysis is a completely tactile system. It was found that a solution that focused on tactile technology was better for all the stakeholders. Silent devices do not produce noise pollution, ensuring it cannot disturb neighbors who are trying to sleep at night with their windows open. Loud traffic noise cannot cover up vital information. Simpler systems have fewer electronic devices and are easier to maintain. There is also a benefit to users who have both auditory and visual impairments, as they can use all of the systems rather than just those which have been outfitted with extra tactile features. Additionally, systems that do not require the pedestrian to consciously activate them are easier to use.

Since an entirely tactile system is untested in Denmark, we also analyzed solutions that could be implemented more immediately. These short-term and mid-term solutions involve improvements that can be made to the current system. The type of message that is used to convey the information about an intersection is very important because it directly affects how easily a pedestrian with visual impairments can cross and how much neighbors are bothered by the sound. We determined that a non-verbal message should be used since verbal messages require a greater volume for the message to be understood and the words to be recognized. Also, having a crossing signal in a specific language may not be useful for people who do not speak the language that is being used. Verbal messages can provide more information such as the street being crossed and the amount of time left on the timer, however these features are not as necessary as unambiguously indicating when it is the designated crossing time.

Once it was established that verbal messages should not be used, we determined the best tone for the signal. We found that a knocking sound is the best sound to use. Since the knocking sound cuts through the ambient noise from the traffic easily, the volume does not need to be as loud to be understood by the pedestrian. This means volume settings can be used that are less bothersome to residents who live near the acoustic device.

We determined during this analysis that systems requiring the user to carry a separate device or chip to activate the system are not advantageous. They add an extra burden to the user, require more specialized equipment development and can only be used by people with the particular activation device. The advantages of the user being able to trigger the system only when it is needed and possibly not making any sound are tasks that can be accomplished through other, more robust systems that only rely on established technologies such as pushbuttonsand quieter systems such as those that rely more on tactile paths and vibro-tactile crossing indicators.

9 RECOMMENDATIONS

Our recommendations have been divided into those that can be applied in the short term to improve the current system, those that can be applied in the near future using technology that already exists, and those that need further investigation before being implemented.

For short term solutions, the tone used can be improved to maximize effectiveness and minimize noise pollution. We recommend reprogramming the current devices to use the knocking sound that is currently being used in Frederiksberg. Maintenance and error reporting can also be made more effective by standardizing APS configuration methods. A fully blind consultant familiar with APS regulations should be hired to help determine the appropriate volume settings for the acoustic signals. Phone and e-mail hotlines should be set up for interested parties to report malfunctions or complaints, which should be recorded for future reference.

Mid-term solutions are those that can be applied in the near future with existing technology. Noise pollution and appropriate volumes for pedestrians can both be addressed by using a pedestrian activation system to increase the volume of the crossing tone temporarily. This activation system could use a push-button or a pedestrian detection system, as our analysis does not conclusively indicate which is better. Recently installed devices have a button on the bottom which can be used. After implementation, people with visual impairments must be educated on how the system works, what to expect and which intersections use the new system. Another recommendation is to improve tactile arrows by indicating the total number of traffic islands to be encountered as opposed to simply indicating the presence of islands.

We also recommend that Detectable Warning Surfaces (DWS) be implemented more widely and more effectively. This will allow pedestrians to better locate the intersection, the signal pole with the APS device as well as any traffic islands. Recommendations for best practices should come from collaboration between Dansk Blindesamfund and local traffic engineers as well as studies of countries with well developed tactile infrastructures, such as Japan and Great Britain.

Our mid-term solution for improving maintenance involves implementing centralized error detection for APS devices. Newer APS devices have the capacity for reporting errors to a centralized system much like the centralized traffic signal error reporting system currently used in Copenhagen. The limitations to implementing centralized error reporting come from the availability of wiring to a control box and any changes that must be made to the current software. Since any centralized error reporting would be an improvement, it should be implemented wherever possible.

Long term solutions are those that best address the needs of all the stakeholders but require more research before implementation. We recommend a system that uses tactile features to convey all the information necessary for crossing the street. This would involve using tactile paths and detectable warning surfaces to locate an APS device with a tactile arrow and vibrating crossing signal. The pedestrian would follow a tactile path to the DWS at the far side of the intersection with DWS at intermediate traffic islands.

The feasibility of this system depends on many factors, such as whether a vibrating APS device and a tactile path can be as effective as an acoustic device, the effect of tactile surfaces on the mobility of other pedestrians as well as installation and maintenance costs. Existing regulations and specific studies have been conducted but more research must be done on the specific application of tactile paths for crossing Danish streets. DWS and tactile paths can be installed at intersections in conjunction with acoustic signals as a method of phasing in the new system. This would also provide an opportunity to test the proposed system's effectiveness before complete implementation.

During our investigation, various people with visual impairments offered suggestions for new APS features and suggestions regarding installation. Several of the APS manufacturers we contacted expressed an interest in hearing these suggestions for possible implementation in future products. However, suggestions for how these devices should be installed or configured need to be directed towards municipalities. We recommend that interested parties who have ideas for new device features contact APS manufacturers after reviewing the capabilities of current products.

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GLOSSARY

ADA – Americans with Disabilities Act

APS – Accessible Pedestrian Signals

DB – Dansk Blindesamfund

DWS – Detectable Warning Signal

MUTCD – Manual on Uniform Traffic Control Devices

PPB – Pedestrian Push-Button

PROWAG – Public Rights of Way Advisory Guidelines

APPENDICES

A. CURRENT APS – DEVICE DESCRIPTION

Campbell Company is known for its accessible pushbuttons for pedestrian crossing signals. The “Advisor” shown in Figure 30 is a pedestrian-level mounted system. A locator tone (800 Hz for 0.1 seconds every second) guides the user to the pushbutton to activate the signal. When the button is pushed, another tone is sounded that indicates that the button was successfully pressed. By pressing the button for an extended period of time the walk signal period can be extended and a message tells the user the location of the intersection. When it is appropriate to cross the street, an audible signal is played and the tactile arrow vibrates. The audible signal can be a chirp, a cuckoo or a message that says, “(Street name) walk sign is on to cross.” The volume of both the locator tone and the walk signal adjust to match the ambient sound (Campbell, 2008).

Figure 30: Campbell Company "Advisor" APS (Campbell, 2008)

Novax makes a number of different models of APS. The one discussed encompasses almost all the features that Novax offers in their different systems. The Novax “SoundSafe™” shown in Figure 31 emits a locator tone for the pedestrian to find the activation button. When the button is pushed a message will say “Wait,” a different tone will play, or the button will click to indicate that it has been pressed. When it is appropriate to cross, the tactile arrow vibrates and a walk signal is played. Different sounds and messages can be played for the walk signal, but the defaults include a chirp for east/west directions and a cuckoo for north/south or a verbal message saying, “Walk sign is on.” Special sounds or messages can also be played to indicate trains, emergency vehicles or other alerts. The volume can be adjusted from 0-90 dB at one meter. After initial adjustment, the signal automatically adjusts to stay 5 dB above the ambient noise level. The different features of the APS can be programmed from a wireless, handheld device (Novax, 2005).

Figure 31: Novax "SoundSafe ™" (Novax, 2005)

The Bob Panich Consultancy has one system that has been installed around the world shown in Figure 32. A locator tone comes from the push-button. When the button is pressed an audible “demand indicator” (Panich, 2009) is played to give feedback to the user that their request has been submitted. When it is appropriate to cross the street, a “walk” tone is played while the tactile arrow vibrates. This system also adjusts to ambient noise levels (Panich, 2009).

Figure 32: Panich APS system (APS Guide, 2010)

The Polara “Navigator” shown in Figure 33 has a wide variety of programmable options. The device uses a locator tone and has a tactile arrow on the pushbutton. There is also an optional message that can be played when the activation button is pressed that indicates the direction of travel, i.e. the street name and any other information that might need to be indicated. When it is appropriate to cross, the arrow vibrates and a “walk” signal is played. The “walk” signal can consist of a variety of tones or a customizable verbal message. Near the end of the crossing phase, a countdown tone is played or a countdown message. All of these verbal messages can be recorded in up to three languages that can be chosen. All sounds adjust to the ambient noise levels, but a maximum and minimum can be set (Polara, 2005).

Figure 33: Polara "Navigator" (Polara, 2005)

Prisma Teknik, a Swedish manufacturer whose products have been used in Copenhagen, has a number of models. The one with the most features is the “Digital Acoustic Pedestrian Signal” or DAPS shown in Figure 34. This system has a locator tone. A tactile map on the side indicates obstacles that may be encountered as seen in Figure 34. The tactile arrow is mounted on the top of the housing making it possible to point in the exact direction of travel, rather than pointing up to indicate forward. The tactile arrow vibrates and an auditory signal is played when it is appropriate to cross the street. The locator tone and the “walk” signal can be selected from a wide variety of different sounds or can be prerecorded voice messages. The volume is automatically adjustable to the ambient sound, but the maximum and minimum volumes can be preset. Programming to the system can be done through a wireless handheld device (Prisma Teknik, 2008).

Figure 34: Prisma Teknik "DAPS" (Prisma Teknik, 2008)

RTB is a Berlin-based APS manufacturer who has also supplied Denmark with some of its products. Their system, the “Berlin”, is comprised of two components: the pushbutton box and the acoustic signal transmitter. The pushbutton box has many models, and one of them is designed specifically for the visually impaired. It has an actual press point, as compared to the other models, which only have a sensor. With this model, the walking phase may be extended and a special signal may be activated. The word “Info” is written in Braille above the pushbutton. On the underside of the box is a vibrating tactile arrow. It must be noted that the features of this model may be combined with other models (RTB 2010).

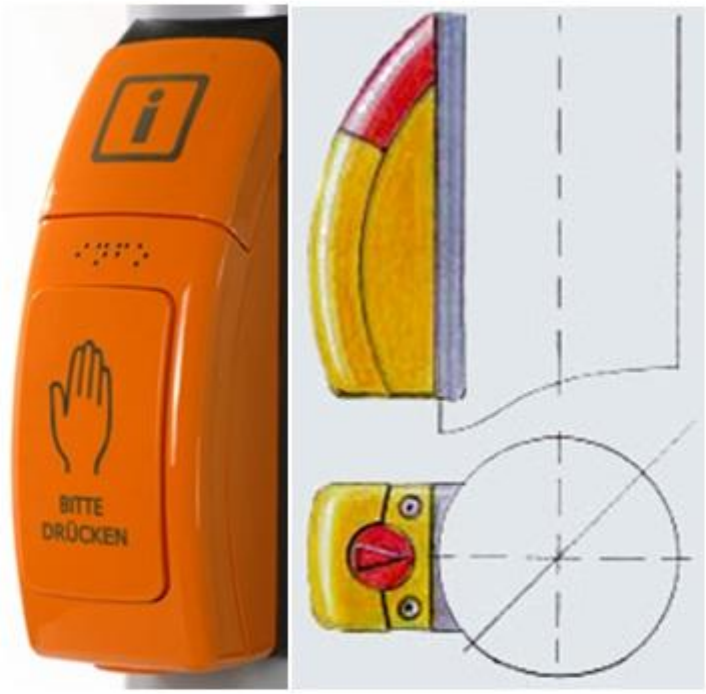


Figure 35: RTB "Berlin" Pushbutton (RTB 2010)

RTB's acoustic signals may be used in conjunction with the pushbutton box or by itself. There are various models to choose from in two general forms: either the 2 speaker form or the 1 speaker form. The 2-speaker form means that one speaker emits the locator tone while the other speaker emits the walk signal. The 1-speaker form emits both the locator tone and the walk signal from one speaker. The volume of the system is self-adjusting and dependent on the ambient noise level in the surrounding area. The direction of the signal beam for both forms can be changed to accommodate various street widths and the presence of surrounding buildings. For maintenance, a remote control is available in order to adjust the volume as well as determine the volume level with a microphone installed on the control (RTB 2010).

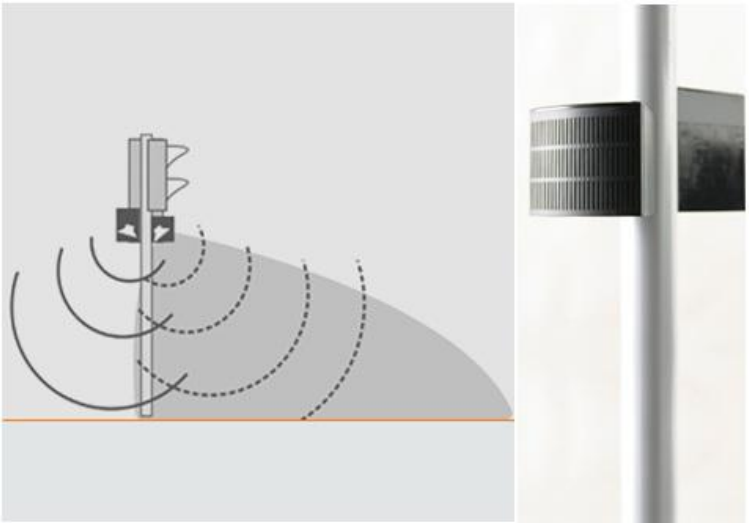
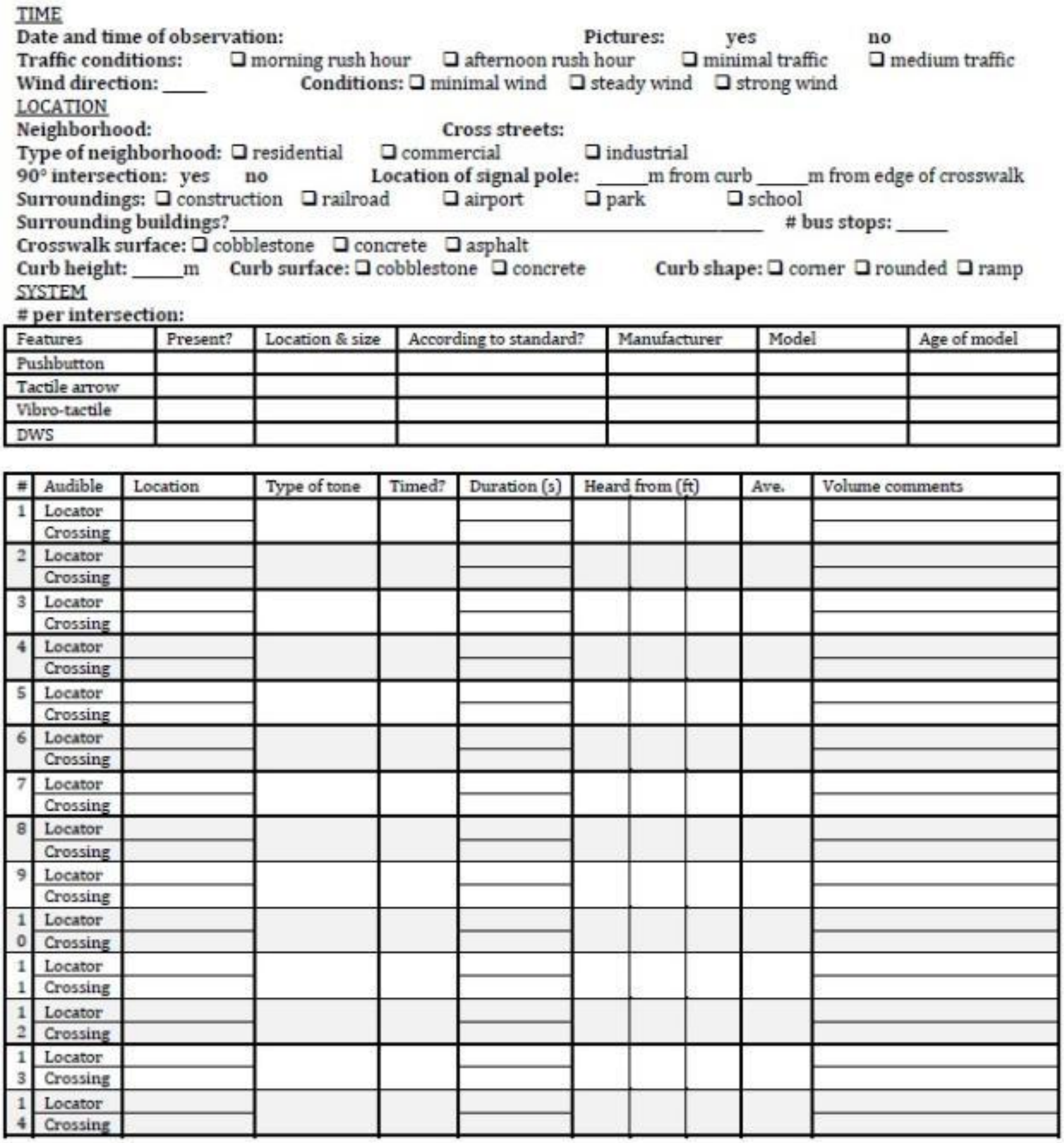


Figure 36: RTB "Berlin" Acoustic Signal Transmitter (RTB 2010)

Wilcox makes a relatively basic audible signal. This particular device, shown in Figure 37 is mounted on the pedestrian signal head. When it is appropriate to cross the intersection, two different signals are played, a cuckoo for north/south travel and a peep-peep for east/west travel. The volume level is approximately 90 dB at one meter. This device is prevalent in dozens of cities around the world including Boston, Massachusetts (Wilcox, 2008).

Figure 37: Wilcox APS (Wilcox, 2008)

B. INTERSECTION CHECKLIST



TIME

Date and time of observation: **Pictures:** yes no

Traffic conditions: ☐ morning rush hour ☐ afternoon rush hour ☐ minimal traffic ☐ medium traffic

Wind direction: ____ **Conditions:** ☐ minimal wind ☐ steady wind ☐ strong wind

LOCATION

Neighborhood: **Cross streets:**

Type of neighborhood: ☐ residential ☐ commercial ☐ industrial

90° intersection: yes no **Location of signal pole:** _____m from curb _____m from edge of crosswalk

Surroundings: ☐ construction ☐ railroad ☐ airport ☐ park ☐ school

Surrounding buildings?________________________ **# bus stops:** _____

Crosswalk surface: ☐ cobblestone ☐ concrete ☐ asphalt

Curb height: _____m **Curb surface:** ☐ cobblestone ☐ concrete **Curb shape:** ☐ corner ☐ rounded ☐ ramp

SYSTEM

 # per intersection:

Features	Present?	Location & size	According to standard?	Manufacturer	Model	Age of model
Pushbutton						
Tactile arrow						
Vibro-tactile						
DWS						

#	Audible	Location	Type of tone	Timed?	Duration (s)	Heard from (ft)			Ave.	Volume comments
1	Locator									
	Crossing									
2	Locator									
	Crossing									
3	Locator									
	Crossing									
4	Locator									
	Crossing									
5	Locator									
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10	Locator									
	Crossing									
11	Locator									
	Crossing									
12	Locator									
	Crossing									
13	Locator									
	Crossing									
14	Locator									
	Crossing									

C. TABLE OF INTERSECTIONS WITH APS IN COPENHAGEN

Table 9 indicates all the intersections in Copenhagen with APS devices as of May 22, 2009. The table includes the known information for if a pushbutton is used, the number of devices, the date of installation as well as the manufacturer. The table is adapted from a larger table provided by Mr. Bjerremose with the city of Copenhagen *Oversigt over anaeg m. lydsignaler og fodgaengertryk* (2010).

Table 9: Intersections with APS in Copenhagen, number of devices, manufacturer

#	Date of latest row update	Internal traffic controller group #	Intersection name	# of pushbutton installed	# of APS installed (22-5-2009)	Date of APS established (dd-mm-yyyy)	Latest update	Manufacturer
1	24-04-2006	41.20	Amager Strandvej - Svend Vonveds Vej	4	6	17-8-2005		TTS
2	20-07-2006	41.13	Amager Strandvej - Øresundsvej		5	3-5-2006		Swarco
3	24-04-2006	36.02	Amagerbrogade - Englandsvej		8			DSI
4	24-04-2006	06.07	Amagerbrogade - Holmbladsgade		10			Prisma
5	24-04-2006	36.04	Amagerbrogade - Oxford Alle	4	4			DSI
6	24-04-2006	36.05	Amagerbrogade - Sundbyvester Plads		16			DSI
7	24-04-2006	33.04	Artillerivej - Njalsgade - Ørestads Boulevard		3			Swarco
8	24-04-2006	02.02	Bernstorffsgade - Tietgensgade		8			Swarco
9	24-04-2006	02.03	Bernstorffsgade ved Tivoli		4			Swarco
10	02-06-2006	09.02	Borgergade - Sølvgade		7			Swarco
11	24-04-2006	22.01	Brønshøj Torv		6			Swarco
12	24-04-2006	07.01	Christiansborg Slotsplads - Holmens Kanal		10			Swarco
13	24-04-2006	06.03	Christianshavns Torv		7			Swarco
14	24-04-2006	25.13	Dybbølsbro - Ingerslevgade		5	8-2-2006		Swarco
15	06-06-2006	31.09	Enghavevej - Tranehavevej		4	6-6-2006		Swarco
16	24-04-2006	09.08	Fredensgade - Blegdamsvej		8			Swarco
17	24-04-2006	17.04	Frederiksborgvej - Emdrupvej		7			Swarco
18	24-04-2006	17.09	Frederikssundsvej - Borups Alle		16			Prisma
19	24-04-2006	22.12	Frederikssundsvej - Islevhusvej		9	27-9-2006		Swarco
20	22-05-2009	22.12	Frederikssundsvej - Islevhusvej Frit fodgængerfelt		3	16-3-2009		Swarco

21	24-04-2006	19.06	Frederikssundsvej - Lygten		10	7-4-2005		Swarco
22	22-05-2009	19.08	Frederikssundsvej - Mågevej		6	27-3-2009		Swarco
23	24-04-2006	23.07	Grøndals Parkvej - Apollovej		14			DSI
24	24-04-2006	04.05	Gyldenløvesgade - Farimagsgade		13			Prisma
25	24-04-2006	04.02	H. C. Andersens Boulevard - Jernbanegade		10			Prisma
26	24-04-2006	04.01	H. C. Andersens Boulevard - Vesterbrogade		11			Prisma
27	06-06-2006	23.03	Hulgårdsvej - Hillerødgade / Godthåbsvej - Sallingvej		13			Swarco (4) Prisma (9)
28	24-04-2006	12.03	Jagtvej - Vennemindevej	4	8	5-1-2006	6-6-2006	Swarco
29	24-04-2006	26.08	Jernbane Alle - Vanløse Alle		5			Swarco
30	24-04-2006	24.03	Jyllingevej – Sallingvej	?	10			DSI (7) Swarco (3)
31	24-04-2006	08.03	Kongens Nytorv - Gothersgade		4	27-3-2006		Swarco
32	24-04-2006	08.12	Kongens Nytorv - Lille Kongensgade		11			Swarco
33	24-04-2006	29.10	Landlystvej – Veststien	?	2			DSI
34	24-04-2006	15.05	Lersø Parkalle - Haraldsgade		15			DSI
35	24-04-2006	14.01	Lyngbyvej - Emdrupvej		12			DSI
36	24-04-2006	07.11	Nytorv - Gammeltorv		2			Swarco
37	24-04-2006	05.02	Nørre Voldgade - Frederiksborggade		11			Swarco
38	24-04-2006	05.01	Nørre Voldgade - Gothersgade		12			DSI
39	24-04-2006	05.03	Nørre Voldgade - Vendersgade		9			DSI (6) Swarco (3)
40	22-05-2009	19.14	Nørrebrogade - Cykelruten		2	10-3-2009		Swarco
41	24-04-2006	19.12	Nørrebrogade - Hillerødgade		4			Swarco
42	24-04-2006	18.06	Nørrebrogade - Jagtvej		9			Swarco
43	22-05-2009	19.05	Nørrebrogade - Lundtoftegade		10		4-3-2009	DSI (7) Swarco (1)
44	24-04-2006	10.04	Oslo Plads - Kristianagade		3			DSI
45	24-04-2006	10.03	Oslo Plads - Østbanegade		5			Swarco
46	24-04-2006	10.02	Oslo Plads - Øster Voldgade		13			Swarco
47	24-04-2006	26.02	Roskildevej - Ålholm Plads		9	1-10-2005		Swarco
48	24-04-2006	26.14	Roskildevej ved Ålholm Station, fodg. felt		4	2004		Swarco
49	24-04-2006	35.09	Røde Mellemvej - Peder Lykkesvej	?	10		2004	
50	24-04-2006	04.10	Rådhuspladsen - Vester Voldgade		9			Swarco (1) Prisma (8)

51	24-04-2006	23.06	Sallingvej - Åbakkevej		2	27-3-2006		Swarco
52	24-04-2006	12.09	Strandvejen – Tuborgvej		8			Prisma
53	22-05-2009	16.05	Tagensvej - Jagtvej		6	9-1-2009		Swarco
54	24-04-2006	17.13	Tagensvej - Tuborgvej		9			Prisma
55	24-04-2006	28.04	Toftegårds Alle - Lyshøjgårdsvej		6			Swarco
56	24-04-2006	28.05	Toftegårds Alle - Valby Langgade		6			DSI
57	24-04-2006	28.03	Toftegårds Plads - Gammel Køge Landevej		11			Swarco
58	24-04-2006	17.07	Tomsgårdsvej - Birkedommervej		7			Swarco
59	24-04-2006	17.08	Tomsgårdsvej - Frederikssundsvej		9			Swarco
60	24-04-2006	10.06	Trianglen - Østerbrogade		11			Swarco
61	24-04-2006	28.10	Valby Langgade - Dronning Dagmars Alle		8			Swarco
62	24-04-2006	02.07	Ved Vesterport		8			DSI (5) Swarco (3)
63	24-04-2006	21.02	**Vejdirektoratet** - Bispeengbuen - Borups Allé		11			
64	24-04-2006	21.04	**Vejdirektoratet** - Borups Alle - Hulgårdsvej		11			
65	24-04-2006	02.04	Vesterbrogade - Hammerichsgade		9			DSI
66	24-04-2006	29.01	Vigerslev Alle - Ramsingsvej		5			Swarco
67	24-04-2006	29.02	Vigerslev Alle - Vilhelm Thomsens Alle		5			DSI (4) Swarco (1)
68	24-04-2006	12.10	Østerbrogade - Jagtvej		12	2005		Swarco
69	24-04-2006	12.05	Østerbrogade - Svanemøllesløjfen		3			Swarco
70	26-07-2007	20.05	Ågade - Jagtvej		8	7-2-2007		Swarco
71	24-04-2006	21.10	Åkandevej - Ruten	3	9	2003		Swarco
72	25-09-2007	26.05	Ålholmvej - Grøndals Parkvej		19			Swarco (5) Prisma (14)

D. KEY INFORMANT INTERVIEW SUMMARIES

1. ORIENTATION AND MOBILITY SPECIALIST

Type of Interview: Key Informant Interview
Where: Institute for the Blind.
When: April 9th, 2010 (Friday) at 11.00am CET
With who: Lisbeth Hallestad, Orientation and Mobility specialist
How: In person

Lead Interviewer: Brian Shaw
Note taking: Jeffrey Gorges, Danica Rili
Summary: Jeffrey Gorges

What do you do as an Orientation and Mobility specialist?

- Teach people how to orient and navigate
    - Mostly adults who have lost their sight recently
- Besides orientation and mobility, also teaches problem solving skills
    - Must use landmarks and information
        - Landmarks are things that stay the same such as the location of an intersection.
        - Information comes from dynamic things such as what traffic is doing.

Teaching the basics of how to cross the street without APS

- Before learning to navigate outdoors, students learn to navigate an indoor environment. In outdoor training, they learn how to orient themselves, listen for and use the sounds of traffic. Crossing the street is considered the culmination of navigation training.
- Start with a simple intersection, two streets at 90 degree angles without traffic islands.
- Listen to the flow of the traffic
    - Identify phases of traffic flow
    - How heavy is the traffic?
    - Is there turning, or designated turning periods?
    - How long are the phases?
    - What types of surfaces will be encountered?
    - With which sound of traffic is it appropriate to cross?

- Explaining the structure of an intersection is different and sometimes easier for people who have lost their sight compared with people that are born blind.

Crossing the street

- Three steps: Where, How and When?
- Where:
    - Align on the edge of the curb
    - Counterclockwise direction allows the pedestrian to be closer to the sound of parallel traffic.
- How:
    - Listen to the flow of traffic
- When:
    - Cross only with parallel traffic – if there is no traffic, don't cross.
    - Only start crossing when the cars start to move

General technology discussion

- Navigation technology
    - Everyone like to be able to use APS
    - Large numbers of people have at least a simple cell phone, especially those that travel independently.
- Problem intersections
    - People need to know who to inform about malfunctioning devices
    - Knocking sound is easier to hear than beeping sound present in Denmark
    - If signals are too soft people tend to hit the signal to make it adjust its volume louder

Contacts and resources

- List serve that goes to many orientation and mobility specialists
- Websites with resources on mobility and orientation
- Daniel Kish – interested in navigation, particularly echolocation daniel.kish@worldaccessfortheblind.org

2. *COPENHAGEN TRAFFIC ENGINEERS*

Type of Interview: Key Informant Group Interview
Where: City of Copenhagen Center for Traffic. Islands Brygge 37, 2300 København S.
When: April 7th, 2010 (Wednesday) at 11.00am CET
With whom: Neils Peter Bjerremose, Anders Kreutzfeldt, Lars Bo Frederiksen, Traffic signal engineers for the City of Copenhagen
How: In person

Lead Interviewer: Jeff Gorges
Note taking: Brian Shaw, Danica Rili
Summary: Brian Shaw

Note: APS stands for Accessible Pedestrian Signals, DBS stands for Dansk Blindesamfund

1. Key Ideas
    a. The simpler an intersection is, the better!
        i. Users need to understand how it works and what the signals mean
        ii. If the signals are efficient and make sense to the users, people will learn to respect the law and obey the signals
    b. APS are installed for safety, not necessarily convenience.
        i. The city's interest is in providing a safe route for the blind at the minimum cost
    c. The more money is spent on APS maintenance, the less will be available for installing new systems
2. How traffic signals work in Copenhagen
    a. The red + yellow phase
        i. Lasts 2 seconds
        ii. Indicates that the light is about to turn green
    b. No right on red anywhere
        i. Bikes often disobey this rule
    c. Bicycle considerations
        i. Bikes going straight present a challenge for turning cars
        ii. Bicyclists tend to protect each other when in larger groups, much like a herd
        iii. Types of bicycle paths

            1. Bike track: Bikes at a different elevation than the cars
            2. Bike lane: Bikes are separated from cars by a painted line
            3. Tracks are important for keeping cars out of the bike lane
        iv. Special signals for bikes
            1. These are only present when bikes need to behave differently from the cars. Otherwise bikes are required to follow motor vehicle signals
            2. Examples: Places where bikes should start moving before the cars when the light turns green, or where bikes need to stop early to allow cars to turn right
    d. All traffic signals must continue to operate at all times of day, as per the road rules. This means traffic lights cannot simply be shut off in favor of a flashing yellow.
        i. Detectors can be used to adjust the light timings based on traffic
        ii. Different timing programs are frequently used for different times of day.
            1. Morning rush hour
            2. Midday
            3. Evening rush hour
            4. Night
        iii. The duration of a green light can vary from 100 to 45 seconds, and is generally shortest at night
        iv. Traffic patterns are very consistent from day to day
3. Traffic and pedestrian detectors
    a. Stand-alone intersections require detectors. Intersections that are close together, for example along the Green Wave routes, can use different settings for each time of day
        i. Most Copenhagen intersections are time controlled
        ii. Detection based intersections are more common in the countryside
    b. Different kinds of detectors
        i. Video
        ii. Radar
        iii. Induction loops buried in the road
            1. Not preferred, because they often break when repaving the street and when concrete slabs move in frost heave. They also make it

                more difficult to redesign an intersection, since video and radar detectors can be relocated much more easily

4. Pedestrian signals and navigation
    a. Red man means it is not safe to begin crossing the street. Green man means that it is the designated time to cross
        i. It is challenging to ensure that pedestrians understand what these symbols mean.
        ii. When there are 2 red men, the meaning is unchanged. Tend to be used if there are multiple lanes with traffic islands. This is intended to catch pedestrians' attention and reduce the safety risk associated with dead light bulbs.
            1. Occasionally women in skirts are used instead of men. This is another attention-catching technique
        iii. In Denmark, the red man is used for "safe red" in addition to when the crosswalk is unsafe
            1. Each cycle: Green man -> red man (safe red) -> red man
            2. "Safe red" means it is not safe to enter the crosswalk, but pedestrians already in the crosswalk can continue to the other side
            3. Sweden and Norway use a flashing green instead of the solid red
    b. Traffic islands (also known as pedestrian refuges)
        i. Required to be at least 2 meters long
        ii. Engineers' goal: A pedestrian moving at normal speed can cross the entire intersection, including all islands, in one cycle.
            1. Slow moving pedestrians will use the islands
            2. It does not make sense to show a red when it is safe to cross to the next island. People are more likely to obey rules if the pedestrian phases correlate to when it is safe to cross.
        iii. The route from one side of the intersection to another is designed, whenever possible, to be a straight line. It is less confusing if contiguous signals are behind the relevant signal.
    c. Pedestrian speed is estimated at 1.5 m/s for the actual crossing. However, for the "safe red", the speed is estimated at 1.35 m/s. Actual pedestrian speeds vary widely.

        - i. Slow moving pedestrians are advised to wait for the next cycle, so they will be present as soon as the green man appears. This will give them both the green phase and the safe red to safely cross the street even when moving at half the normal speed
    - d. Pedestrian detection
        - i. Most Copenhagen intersections have dedicated pedestrian cycles, so detection isn't needed
        - ii. Pushbutton
            1. Often used when there is no dedicated pedestrian cycle
            2. Fairly rare in Copenhagen
            3. Pedestrians often forget to push the button because they are not as used to seeing them
        - iii. Radar or video
            1. Used for efficiency, not safety
                - a. Example: Radar is used at the exit to Tivoli Gardens to extend the green phase when large numbers of pedestrians are present
                - b. Occasionally used as a backup for the pushbutton; when a pedestrian is detected the traffic controller reacts as though a button was pushed

5. APS installation
    - a. DBS is consulted prior to installation
    - b. Prioritizing APS installation
        - i. DBS submits a priority list each year for new installations. Some of the installations are completed each year, as funding allows
    - c. The minimum number of APS is used
        - i. Rules only allow APS installation when there is a "special need"
        - ii. Not all of the sides of an intersection receive APS. A complete intersection will be covered by using APS on all but one of the sides, as the blind people who need that crosswalk can simply go around it. Other times not all of the corners need to be included in an accessible route so fewer crosswalks can be equipped with APS
        - iii. Key locations such as bus stops are often prioritized
    - d. Determining where there is a "special need"
        - i. People who are blind or visually impaired are referred to DBS

    e. Equipping a new intersection with these systems costs 20 to 100 thousand Danish kroner ($3,500 to $18,000 US)
        i. Prices appear to be on a downward trend as electronics get cheaper
        ii. The largest cost comes from laying cables underneath the street for APS on intermediate poles (such as on traffic islands)
    f. When traffic islands are involved, APS are generally installed so there is a straight line from one side of the intersection to the other
    g. The Danish standards only accept a beeping noise. Sweden uses a knocking sound
        i. Niels Peter personally finds that the knocking sound used at one test site in Copenhagen is less annoying than the generally accepted beeping
6. Complaints regarding APS
    a. They happen more often during the summer
        i. More pedestrians on the streets
        ii. People sleeping with their windows open
    b. Roughly equal number of complaints that the sound is too loud and that it is too soft
    c. The road rules generally balance the needs of both the blind and the community
        i. If APS were installed universally, there would be more neighbor complaints
    d. The engineers have observed that APS sounds sometimes travel upwards very well
    e. Auto-adjustment features sometimes perform poorly during the night
        i. Some systems have issues with wind blowing into the microphone
        ii. Others hear each other and think it's background noise
    f. Residents have occasionally sabotaged the APS devices, cutting the speaker wire inside the device. This was noted as an issue at the Ålmholm train station, but has since been remedied by repairing the devices and disabling the automatic adjustment feature
7. Remedying the complaints
    a. Written complaints submitted to the City are kept on file. Phone calls do not have formal records kept
    b. Engineers can have the APS disabled from 11pm (23:00) to 7am (7:00).
        i. DBS is consulted before this change occurs
        ii. This tends to be very effective at reducing neighbor conflicts

        iii. Timed shutoff modules cost approximately 5000 Danish kroner ($900 US) for an entire intersection
    c. Adjustments
        i. Older systems have screws and potentiometers to adjust their volume.
            1. This makes maintenance costly and difficult
        ii. Newer systems are computer adjusted
            1. RTB devices are able to store profiles, but their adjustment remotes do not work with any non-RTB devices
        iii. Technicians do not currently have sound-measuring equipment
            1. The city is currently looking into this
        iv. An important consideration while making adjustments: How does it sound with the cover on?
        v. One problem intersection in Ballerup was caused by the APS signal being reflected inside the corner of a building, increasing the volume. A delay was introduced between when the signal was broadcast and when ambient noise was measured. The problem was solved, but not easily!
    d. When undertaking new projects, outside experts will be hired to perform safety and accessibility inspections
        i. Accessibility inspections check for the needs of the blind: for example, ensuring a curb cut is 2-3 cm high at the edge so wheelchairs may cross but the blind can still detect the curb
8. APS maintenance
    a. When one APS is switched off at an intersection, all the APS servicing that device's crosswalk are disabled. This prevents pedestrians from being stranded partway across an intersection
        i. This occurs during maintenance
        ii. This occurs if a device fails its own self-test
        iii. To ensure reliability, all of the devices will be replaced together if one fails
    b. APS devices last approximately 10-15 years
        i. Aluminum corrosion destroys the boxes
        ii. The oldest variety in use are shaped like round cylinders, and are in the process of being replaced
    c. The more money is spent on APS maintenance, the less will be available for installing new systems

9. Contractors and suppliers currently used by the City of Copenhagen
    a. Main supplier of traffic control devices: Swarco Scandinavia
        i. Swarco bought their previous supplier
    b. Maintenance
        i. One main contractor for street lighting and traffic light repair
            1. They hire a subcontractor to maintain APS and surveillance equipment
10. New developments in APS and related technologies
    a. User-centered systems
        i. Especially in the past, people have been resistant to any device that could differentiate and identify them as “disabled people”. This resistance to user-centered systems seems to be weakening especially as common devices such as cell phones can be used.
        ii. The best way to test a user-centered APS alternative would be near a person’s home. It is far more practical to give devices to one person than everyone who might be using a particular train station
    b. Open standards for interfacing traffic devices from different manufacturers
        i. Currently many proprietary standards are in use
        ii. Non-proprietary standards for the interfaces between traffic signaling devices may be developed in the future
11. Legal and political considerations
    a. If a resident needs to have APS installed for them, they contact DBS, the city, or the mayor. Since DBS is responsible for these requests, the city and the mayor will refer requests to them. Afterward DBS prioritizes which intersections need APS installed and works to find a solution for the individual.
    b. Who is responsible for changes to the APS technologies used?
        i. The Road Rules are published by the Vejdirektoratet, a national organization
        ii. We spoke to the traffic signals team at the City of Copenhagen. At the municipal level they are responsible for applying the rules and existing technologies to intersections in Copenhagen, and hire contractors to install and adjust traffic control systems
        iii. New technologies and changes to the rules must happen at a national level

        iv. The City of Copenhagen has authority to specify one manufacturer's system over another, but choosing a competitor's product may cost extra. This is because the city normally works with Swarco, and non-Swarco devices have compatibility issues
    c. What drives change?
        i. Safety drives change and APS installation
            1. Since blind people are not involved in many accidents, installing APS is considered a service. Accidents are generally avoided because the blind tend to follow different, safer routes
        ii. Urban planners will contact the signals team when redesigning an area. The signals team will then consult DBS if any APS devices are involved in the project
            1. Conflicts occasionally occur with project managers since APS funding reduces the money that is available for the rest of the project
    d. Political Priorities
        i. Bikes, busses, and schoolchildren have been a priority and are receiving funding
        ii. The blind community is not a particularly big pressure group in mainstream politics

12. Things that traffic engineers expect the blind to do
    a. Know where APS are and which routes are accessible
    b. Report problem intersections
    c. Collaborate with the engineering team with regards to new installations and changes to existing systems
13. Historical and statistical notes
    a. Approximately 20% of the intersections in Copenhagen have APS
    b. 360 signaled intersections in Copenhagen
    c. Normally there are 5 traffic signal engineers working for the city
    d. 1928: First traffic signal installed in Copenhagen
    e. Highways were proposed in Copenhagen in the 1970's. They were not approved, so highways terminating outside the city contribute traffic to city streets
14. Items our student group has received
    a. Information on which APS is used in Copenhagen, and where
        i. A list of some intersections that use pedestrian detection equipment

        ii. Some intersections where complaints are often received
        iii. Additional information on how the systems work (product manuals)
    b. Contact information for a person who was involved in the recent Frederiksberg project
        i. Note: The Frederiksberg project updated the traffic lights and installed APS that use a knocking sound
    c. Information on a proposal for a user-based microchip system
        i. Contact information for the company proposing the system
    d. Contact information for a service manager at Swarco
        i. This person may be able to help us understand APS maintenance

15. Items for our student group to follow up on
    a. Contact the receptionist at the Road Directorate and see if any material regarding APS is available in English
        i. Ask for someone who works with Signals
        ii. Currently no abstracts of the Road Rules exist in English
    b. Send final IQP report to Niels Peter Bjerremose
16. Intersections for investigation
    a. Complaints
        i. Jagtvej / Østerbrogade
        ii. Pedestrian Crossing Roskildevej at Ålholm Station
    b. Examples of Devices
        i. Toftegårds Allé / Valby Langgade - type: DSI
        ii. Toftegårds Allé / Lyshøjgårdsvej - type: Swarco Scandinavia
        iii. Valby Langgade / Ved Ovnhallen - type: RTB
        iv. Ålholmvej / Grøndals Parkvej - type: Prisma

3. *FREDERIKSBERG TRAFFIC ENGINEER*

Summary: Interview with Morten Nikolajsen, Traffic Engineer for Frederiksberg

Type of Interview: Key Informant
Where: Morten's office, Frederiksberg Rådhus (town hall)
When: April 28, 2010 (Wednesday) at 13:00 CET (1:00 pm)
How: In person

Terminology

- DBS: Dansk Blindesamfund
- APS: Accessible Pedestrian Signals, the acoustic devices used to help the blind cross the street. However, APS is a general term that also applies to vibrating systems that do not make a sound.

Miscellaneous

- Morten Nikolajsen would like a copy of our final report.
- In general, Frederiksberg has strong relations with DBS and other accessibility organizations and will always consult them before making changes.

The Traffic signal project

1) Morten was the project manager.
2) Project was initiated as an effort to replace traffic lights with LED lights. This saves power consumption, money and carbon emissions.
3) DBS and the Handicaprråddet were contacted regarding accessibility considerations.
4) 49 of 63 intersections received LED traffic lights. 17 of 21 APS intersections were upgraded.
    a. The other intersections already had LED traffic lights.
    b. All the signal equipment at each intersection was replaced, so the APS was effectively installed in a new location with respect to installation costs.
5) All funds were provided by the City Council of Frederiksberg through a project funding request.
    a. The maintenance budget does not provide funding for new APS installations.
6) Inger Brandt was instrumental in this project.

Configuration of APS devices

1) Volume has 2 sound levels: Setting, and 3dB higher than that.
    a. Setting is a programmed sound level that is set for each device.
    b. Setting is established by a walkthrough of one intersection in Frederiksberg with a person who is visually impaired. During the most recent configuration, this person was Inger Brandt.
    c. All systems were initially configured to use the same volume settings
    d. The two volume system was decided on several years ago with the intent of keeping noise levels from going too high when traffic is loud.
    e. Newer systems may support a wider range of sound levels than this, but the feature is not used.
2) Button press will provide an additional 2-3 second of time to cross in most places.
3) There are still many complaints about the volume of APS systems

The knocking sound

1) DBS requested the knocking sound.
    a. When Frederiksberg used Swarco's knocking sound, it was inconsistent with previously installed devices. The prior devices were preferred, so DBS requested that Swarco's device switch to the other sound.
2) The knocking sound is preferred by neighbors as well as the blind community, though it has not resolved noise complaints.
3) The Vejdirektoratet has yet to comment on the knocking sound.
4) Copenhagen is waiting to see the results of Frederiksberg's switch to the knocking sound before making any changes.
5) Lyngby (a suburb to the north of Copenhagen) has taken an interest in using the knocking sounds.

Ideas Under Investigation

1) Various user-oriented activation schemes
    a. The issue is ensuring that the signals are accessible for people who do not reside in Frederiksberg.
2) Pedestrian Detection
    a. A test site for pedestrian detection was not successful, due to technical problems with the radar detector. This may have been an issue with the quality of the radar device chosen.
    b. Induction loops are widely used to detect bicycle and motor vehicle traffic.

3) Timer Controlled APS
    a. Frederiksberg will soon establish 2 test sites where the APS volume is lowered at night, but can be increased using an auxiliary button.

Political and Funding Processes: How Change Happens

1) Change is initiated. This could be Frederiksberg acting on a suggestion that DBS has made, or Frederiksberg looking to make a change to an intersection and consulting DBS for accessibility recommendations.
2) Funding request is submitted to the Frederiksberg City Council.
3) Typically the funding request is returned to the engineers 2-3 times with questions about the proposal.

Traffic Islands and Medians

1) The Frederiksberg Accessibility Plan included new traffic islands at 4 intersections to provide pedestrian refuges.
2) We mentioned how Christian Bundgaard was able to use the paving stone design of the traffic island at Fasanvej Station to correct his orientation. While DBS requested that the medians use cobblestones to distinguish them from the street, the actual design was chosen for aesthetic reasons.

4. *MANUFACTURER: PRISMA*

Type of Interview: Key Informant

Where: Dansk Blindesamfund

When: April 14, 2010 (Wednesday) at 8:30am CET

With whom: Mr. Marcus Lidhed, CEO of Prisma Teknik

How: Via phone

Note: APS stands for Accessible Pedestrian Signals, the acoustic beacons used at intersections to help the blind cross the street. DAPS is a specific Prisma APS product.

1) About our student project
    a. The reason our group has contacted Prisma is because we are trying to understand existing APS solutions that can be used to solve the problems we are addressing.
2) About Prisma
    a. Prisma has 23 years of experience working with APS
    b. Prisma entered the APS market around 1990, competing with a large company that dominated the market. Prisma has succeeded because they contacted the blind community to determine the community's needs, and researched sounds that are more pleasant to the human ear and easily audible in traffic
    c. Currently Prisma does business in 16 countries on many continents, including North America
    d. Mr. Lidhed's role at Prisma
        i. Mr. Lidhed is relatively new to the company
        ii. He has been travelling through Europe speaking to customers
3) Sounds produced by Prisma's APS
    a. The DAPS has 16 sounds that can be used, plus the ability to use up to 3 recorded messages
    b. Most countries already have standards defining which sound is required for APS. Due to this, the sounds that are available from Prisma were chosen to comply with the requirements of Prisma's customers
    c. Research was conducted into what sounds are most pleasing to a human ear yet able to be heard easily in heavy traffic
4) User and neighbor complaints
    a. Mr. Lidhed is not aware of particular noise complaint issues outside of Denmark

            - i. Danes were voicing this concern at the conference in Amsterdam
    - b. Other countries' solutions
        - i. Sweden - uses a knocking sound that has not been complained about
        - ii. Austria – continuous locator tone. There are two buttons, one on the front to activate the "walk" cycle for sighted pedestrians, and one on the bottom to activate audible "walk" cycle for blind pedestrians. For audible cycle, two loud directional speakers will broadcast a walk tone.

5) Prisma device installation
    - a. Some APS devices (from various manufacturers) work but are poorly installed, and therefore ineffective.
    - b. Prisma devices are installed by municipalities, resellers or subcontractors.
    - c. Whenever possible, Prisma trains APS installers. However, they have no way of verifying that the devices were installed correctly by the customers

6) Pedestrian detection systems
    - a. These may be a good alternative to turning off APS at certain hours of the day
    - b. Separate pedestrian detection devices can be and have been used with Prisma's APS products
        - i. The detection device has to be trusted to work correctly, since it is absolutely critical that the APS device accurately indicate the status of the intersection
    - c. Prisma has recently released an RFID-equipped APS product
        - i. This product was introduced at the recent traffic conference in Amsterdam
        - ii. It was developed to help Stockholm schoolteachers get large groups of children across the street. The teachers' short range RFID tags tell the device to request longer pedestrian walk cycles so the children can cross
            1. If RFID tags were used for blind pedestrians, the code used in the RFID tag would need to be standardized. While this is a nonissue for Stockholm schoolteachers, blind pedestrians should be able to activate the system in any country

7) Emerging trends in APS
    - a. More countries around the world are taking an interest in how the blind navigate traffic. This has created emerging markets for Prisma.
    - b. Pedestrian detection systems are becoming more common at APS installations
    - c. More people are considering directional sound devices

    d. There is an increasing need for international standardization of APS systems. Currently each country has a unique system that is very different from other countries' standards. Blind people are travelling more and need to be able to use APS in other countries with a minimum learning curve
        i. Germany, France, and the UK all use unique standards

8) Action Items
    a. Mr. Lidhed will send the group pamphlets on Prisma's new RFID-equipped APS
    b. The group will send Mr. Lidhed a copy of our final report

5. *MANUFACTURER: SWARCO*

Type of Interview: Key Informant Interview
Where: Swarco Office
When: April 19th, 2010 at 14.00am CET
With whom: Tonny Pedersen, Swarco Service Manager
How: In person

Lead Interviewer: Brian Shaw
Note taking: Jeffrey Gorges, Danica Rili
Summary: Jeffrey Gorges

Note: APS – Accessible Pedestrian Signal

1. About Swarco
    a. Austrian based company that does business around the world.
    b. Division of the Swarovski Group
    c. Manufactures traffic signals, control systems, LED signs, reflective paint, acoustic pedestrian signals and pedestrian push buttons
    d. In Denmark:
        i. 40 employees
        ii. Install signals, check signal timing, survey and document intersections, perform service and maintenance
        iii. Sister company in Odense makes APS and intersection controllers

2. Process for APS installation
    a. Municipalities request devices based on Road Authority regulations
    b. Swarco installs devices

3. Products
    a. Previous products
        i. Sound levels and other parameters adjusted with screwdriver
        ii. Known issues with wind causing the automatic sound adjustment feature to malfunction
    b. Current product

    i. Has been installed for the last two years
    ii. Uses wireless programming, allowing parameters to be set with a laptop
    iii. Microphone is on the back where wind is less of an issue
    iv. Can be set up where the bottom button push increases the volume of the signal
        a. This button can also be used for other specialized purposes, such as extending the walk cycle near a school
    v. Can be remotely monitored as the traffic signals in Copenhagen are
    vi. Can be programmed with any sound or recording
        a. Ex: Frederiksberg requested knocking sound similar to a competitor's (TTS) device
    vii. 10 year lifespan
    viii. Circuit boards can be easily replaced without uninstalling the APS device
    ix. Approximately 7.000 DK per device
    x. Black devices do not have button for altering signal adjustment, blue devices do
        a. As per Road Directorate's Danish standard
    xi. In most cases, Swarco devices use hex screws that can be turned with commercially available screwdrivers. Vandalism problems are not a major issue, though one place in Copenhagen uses a proprietary screw that is not readily available.

c. Future product
    i. Partnership with RTB
    ii. Similar to current device
    iii. Can use RFID or Bluetooth activation
    iv. Testing to commence this coming summer and winter with production expected next year

d. Other installations
    i. Swarco can install other companies' devices, but this generally will cost more or will have a lower profit margin because they have to purchase the devices from the other company. Example: Prisma
    ii. There are no compatibility issues between Prisma devices and intersection controllers

4. Maintenance
    a. Swarco performs yearly inspections on all traffic devices
    b. Reporting malfunctions
        i. Pedestrian or neighbor calls municipality
        ii. Municipality contacts Swarco
        iii. Swarco sends technician
    c. Fault detection
        i. Newer devices have capacity for centralized fault monitoring
        ii. Most faults shut off the system with failsafe
        iii. Fault detection only requires one free wire between the device and the intersection controller
            a. København already has centralized fault detection for traffic signals throughout the city
            b. Smaller municipalities without a centralized system can have faults reported by Swarco via e-mail

    d. All parameters, including volume settings, can be saved on a laptop or server. This allows devices to be easily reprogrammed and for new devices to use the same settings as the device they are replacing.

5. Problems
    a. Blind – don't like signal volume
        i. Volume set by technician, often done with a walkthrough with blind pedestrian
        ii. Volume for average person may not be loud enough for people with hearing loss
    b. Neighbors – annoyed by sound
        i. Sometimes the volume is louder at the fifth floor than it is a ground level
        ii. Volume can be turned to minimum or turned off during quiet hours
        iii. Only turned off with careful consideration of who is using the signal and if they will be using during the quiet hours
        iv. Municipality or Road Authority determines which signals to turn down or shut off
        v. Complaints still exist in Frederiksberg despite the improvements to the system

    c. Standardization – each country has their own ideas of the correct system
        i. Standardizing devices, activation systems, sounds and tactile arrows would greatly benefit manufacturing as well as mobility for blind pedestrians.
    d. Installation – cost
        i. The largest cost for installing systems is ensuring that the poles are correctly oriented and ensuring that there are enough wires running between signals. Tearing up sidewalks in København is expensive.

6. Action items
    a. Pedersen will send us specifications or a fact sheet for the new device designed with RTB.
    b. Pedersen may be able to send us a list of intersections that use the push button to increase volume.
    c. The team will send Pedersen a copy of our report when we are finished upon request.

7. *MANUFACTURER: RTB*

Summary: Interview with Christian Schulte, representative from RTB

Type of Interview: Key Informant
Where:
When: April 8, 2010 to May 4, 2010
How: By e-mail correspondence

Questions that were posed are shown with Mr. Schulte's responses in blue.

Current Device

Volume:

- Your brochure mentions that the device comes with a remote control that has a built in microphone to measure the volume during set-up. Does this microphone somehow filter the sound to distinguish the sound of the signal from the ambient sound?

➔ That's correct. The microphone of the remote control knows the frequencies of our Audible Signal Transmitter therefore it can distinguish the sound of the audible signal transmitter from the ambient sound.

- With all the various attributes that can be adjusted after installation (max and min volume, rate of volume reduction, ambient noise difference) is there any training for people installing the system that might be used to ensure these adjustments are made correctly? Is there a detailed manual for installing these devices?

➔ The installation of our products (Button and Audible Signal Transmitter) is done by the traffic light industry. With these products RTB is just the supplier. Therefore RTB offers trainings for the installation staff.

➔ Beside the notes for a correct wiring our detailed manual also provides settings for a correct adjustment (e.g. volume against length of the crossing or volume reduction against ambient building density)

Maintenance:

- Is there any way to remotely detect malfunctioning systems? Does this include malfunctioning volume adjustment?

➔ The Audible Signal Transmitter is equipped with an malfunctioning output. But it is up to the installing company to use this output and to connect it to the traffic controller. When the traffic controller is monitored somehow, it is possible to remotely detect malfunctioning. The audible signal transmitter monitors itself, in case of a loudspeaker volume above 90dB, the audible signal transmitter mutes its audible signals. But the signals restart with the next cycle. It is according to the DIN 32981:2002 and the German RiLSA (Guideline for traffic lights)!

- Is there a life expectancy for the devices?

➔ RTB gives an warranty of 5 years. Some of the devices are installed for 15 years right now.

Signal:

- Your website lists seven different tones that can be used. Can these be changed after installation?

➔ As you may know, mostly every country has its own specification concerning the tones. Therefore we have to install the correct tone for each country. It is possible to change the signal for the walk signal in some countries (e.g. Germany). That means that it is possible to change the walk signal to avoid a confusion because of two poles with audible signal transmitters close to each other.

- If an intersection uses both the locator signal (we say: guide signal) and the crossing signal (we say: walk signal) , can the tones be decided separately (i.e. can you have beeping for a locator tone and ticking for a crossing signal)?

➔ As I have mentioned before. We have to follow the standards and guidelines. I do not know one single country where it is allowed to exchange the guide and walk signal!

- Can the speed of the tone be adjusted? For example, if it starts at 1 Hz for the locator tone and 3 Hz for the crossing tone, can it be changed to 0.5 Hz for the locator and 5 Hz for the crossing tone?

➔ We can change it in the software. But you cannot change it on-site. As I mentioned before, it is possible to change the walk signal in Germany. It is allowed to change the signal from 4Hz to 2Hz. Therefore we have to signals available and you can choose one of them on-site!

Vibro-tactile:

- Briefly mentioned in the brochure is a vibrating pushbutton device. Do you have any vibrating or tactile devices for intersections that do not have push button activation?

➔ It is possible to activate the tactile signal of the button by the traffic controller. In this case you have to define a separate signal group for the tactile signal.

- Do you have any type of directional arrows to assist with navigation?

➔ Yes, these arrows (according DIN 32981:2002 and the German RiLSA (Guideline for traffic lights)) are placed at the underside of our button.

Other technology – A number of other companies produce audible pedestrian signals. What makes your units unique?

➔ New ideas like the data bus net.1 (compare our brochures), our unique service and customers focus (please ask our customers) and our own development department (seven development engineers)

Research – We are mainly interested in gaining a better understanding of how you developed some of the features of your system. What type of research do you as a company conduct and are there any sorts of independent published works that you reference when developing your products?

Location:

- We understand that an overhead speaker for the crossing signal may be advantageous for hearing the signal from the middle of the intersection. Since you use this type of system, do you have any research or know of any publications that support this idea? How does this compare to locating the speaker at the pedestrian level, as is done for the locator tone in the push button?

➔ Let's assume, we are standing at a traffic light pole with a lot of other people waiting for the walk signal. At this traffic light pole with the Guide Signal and Walk Signal in the button. All the waiting people absorb the signal. A visually impaired person can hardly hear the guide tone. During the pedestrian green phase, the people start walking. Now it is impossible to hear the walk signal from the opposite side because the people from both sides absorbing the signal. That's one big reason to install the Audible signal transmitter over head!

Tone:

- On your website, you mention that the signals used are unique. Are you referring to how well the signal can be distinguished from background noise? How was this determined?

➔ The DIN and RiLSA working group determined the signals for Germany. They did some tests. The signals of our devices are tested by an independent acoustical institute.

- What was the development process for choosing the current tones that are used? Did you base these selections on your own research and/or published literature?

➔ As I said before, the tones were defined by the DIN RiLSA working group. Therefore I cannot answer this question!

Future Research and Development – The majority of companies that currently produce accessible pedestrian signals tend to have variations on the same basic concepts – using one tone to indicate the location of the intersection and a different tone to indicate when to cross the street. What do you see as the future of accessible pedestrian signals?

Pedestrian Detection:

- In our research we have come across such technologies as piezoelectric force detectors and microwave motion detectors that can be used to detect pedestrians approaching or still in crosswalks. What is your opinion of these technologies and their cost and benefits?

➔ I guess there will be a better monitoring of the entire crosswalk by using radar or something else.

User oriented devices – the Ultra Body Guard:

- Your company also produces the "Ultra Body Guard." Would it be possible to use such a device to trigger the pedestrian signal or to trigger the locator tone to start?

This is no problem. Some countries visually impaired are using a remote control to activate the Audible signal transmitter. But in Germany the association of blinds does not want such a remote control!

E. GROUP INTERVIEW

Type of Interview: Group Interview
Where: Dansk Blindesamfund conference room
When: April 16, 2010 (Friday) at 9:30am CET
How: In person, interview format conference

Attendees

Project Team
Brian Shaw
Danica Rili
Jeffrey Gorges

Translation
John Heilbrunn, lead interviewer

Total subjects: 9
Total attendees: 13

Terminology

APS: Accessible Pedestrian Signals, acoustic beacons used at intersections to help people cross streets.
DWS: Detectible Warning Surface, a tactile device placed on the ground to aid navigation.

Overview

In this group interview, we asked representative members of the blind community how they feel about various assistive technologies found at intersections. The ensuing discussion highlighted a number of complaints, concerns, and issues while reinforcing that many basic features of APS and DWS are very useful. Additionally, John explained many of the basic details of our project to key community leaders.

Demographics

Our interview group was chosen to include a wide range of volunteers so we may determine the range of opinions present in the blind community. Demographic information was collected to identify potential biases in our results. Geographic diversity is shown in the list of attendees.

The interview group also contained a variety of levels of visual impairment, ranging from total blindness to limited vision.

Geographic Distribution

Our attendees come from 3 districts in the Greater Copenhagen area. Figure 38 shows the balance of people from each district, indicating that Copenhagen, Frederiksberg, and the Northern Suburbs were represented equally.

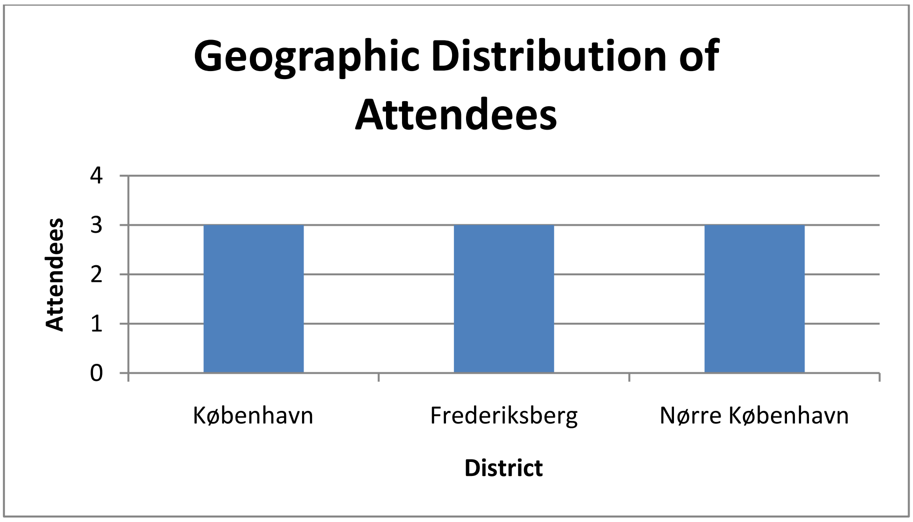

Figure 38: Geographic distribution of Group Interview attendees

København: 3

Frederiksberg: 3

Nørre København: 3

Age Distribution

Figure 39 shows the age distribution of our attendees. It indicates the bias of our responses towards younger people with blindness or visual impairments. While the community of blind and partially sighted people includes many more elderly people, our subjects may be more representative of those who are more mobile and actively travel around the greater Copenhagen area.

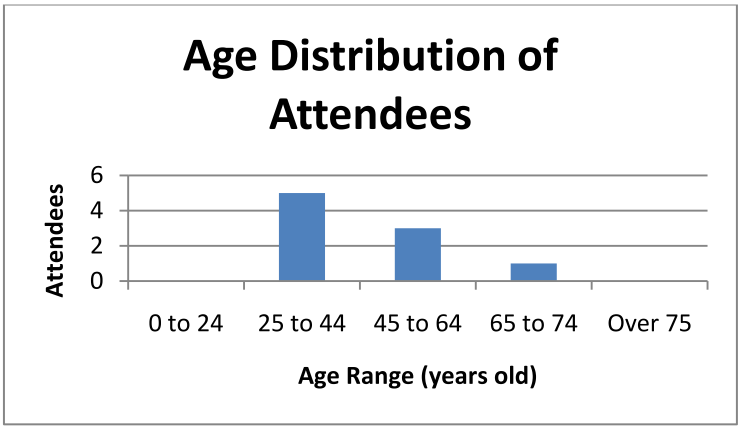

Figure 39: Age distribution of Group Interview attendees

0 under 24 years old

5 between 25 and 45 years old

3 between 45 and 65 years old

1 between 65 and 75 years old

0 over 75 years old

Gender Distribution

7 of 9 attendees are male. 2 of 9 attendees are female.

Navigation Considerations

Different people navigate different ways, as every blind or visually impaired person has unique personal preferences and different limitations to their vision.

Navigation Techniques Used

No attendees had significant hearing loss.

Everyone uses a standard white cane.

3 of 9 attendees use a guide dog.

3 of 9 use GPS navigation technologies. However, they use these devices to different extents.

All attendees use sighted guides to some degree, but it depends on what they are doing. For example, if a friend is going to the same destination, then they can act as a guide.

Most attendees are consultants for the Dansk Blindesamfund. As part of their jobs, they get out 3-4 times a week into familiar areas. This frequently occurs without any assistance from a sighted guide.

Most attendees travel ever y day via bus and train. However, our attendees are generally more courageous and mobile than the blind community as a whole.

Crossing the Intersection

First the pedestrian will check beacons, arrows, and other accessible features present. Then they decide whether or not to ask for sighted help.

The hardest situation to cross is a slanted crossing where streets intersect at a non-right angle.

Determining when to cross

The difficulty associated with determining when to cross depends on the sound level.

When facing into the wind, wind blows in a pedestrian's ears covering other important sounds, presenting a potential hazard.

At unregulated intersections: Sometimes there is a "do-or-die" situation where the person gives up on waiting for an indication regarding when to cross, ventures out into the crosswalk, and hopes for the best.

In each municipality there is at least once instance where the phases include a separate right turn phase. This makes it hard to determine which phase is the correct phase to cross with.

Bikes will turn right regardless of the phase, often at very high speed, despite traffic laws.

Crossing Safely

Sometimes people next to the blind person help. If however, a person has decided to ask a sighted person for directions they may have to wait a long time for someone to ask. This is frequently an issue in the evening.

One person prefers to wait for large vehicles like trucks to leave in case they aren't looking down to see blind people. Also these vehicles tend to make a lot of noise.

Some intersections: Traffic going into and out of town has priority, so there is not enough time to cross the entire intersection. In one case, there is only 15 seconds to reach the median.

Night Travel

Inger, who is older, would not go out at night. She recommends people avoid rush hours and getting in the way of people on their way to work. John thinks this varies from district to district, and mentioned that many of Inger's constituents in Frederiksberg are elderly.

Another attendee finds night to be easier to navigate in than the day, since sun glare in the day makes it hard to see the pedestrian lights. He is partially sighted, so he is able to rely on color contrast for orientation and navigation. The difference between white and black is easiest for him to distinguish.

Sighted Assistants

Danish law: 15 hours of guide time per month is available for leisure purposes. Municipalities try to get around this. This service can continue to be used after the age of 65 if the person applies for it.

Sighted assistants can come from the following sources:

- Guided assistance as per legislation
- Friends
- Frederiksberg: Can call 3 days in advance and ask for an assistant

All assistants provided by the government are free of charge, but you have to pay the person's transportation expenses.

Problems on the Horizon

Electric cars will be a big problem as they become more common in Denmark, as they make less noise than regular cars. This depends on if they make it mandatory to put a noise maker on electric cars.

Frederiksberg has small electric cars to collect dustbins. They now have audible signal devices to warn people they are coming.

There is an increasing phenomenon called "shared spaces" with bikes and pedestrians at the same level. This is often a challenging/dangerous situation for the blind as it is easy to wander into the path of a bicycle.

DWS and Tactile Pathways

Detectable Warning Surfaces are bumps used to indicate where a pedestrian should stop, for example at a bus stop or the edge of a train platform. Tactile pathways are metal plates, rubber plates or cobblestones used to indicate which way the sidewalk is going so pedestrians do not veer from their destinations.

One guide dog user has found the tactile guides and DWS to be useful orientation tools at places where she wants to change direction. They supplement the capabilities of the guide dog, which is able to guide pedestrians between places such as street corners.

One subject finds the dotted designs of DWS, such as the kind used in train stations, is harder to use and detect than solid bars used as tactile pathways.

Regulations prohibit installing lights on DWS and tactile pathways.

DWS

8 of 9 attendees find the DWS on the sidewalk to be useful. The only attendee who does not find them helpful has reduced feeling in his feet.

Warning surfaces are particularly helpful when approaching stairs. This helps prevent falls, but DWS is installed very inconsistently so there is no reliable indication for when stairs are present.

Tactile Paths

Problem with DWS: It is only at the outer row next to the sidewalk. You may not necessarily find them. They work the best in conjunction with the leading tactile guidelines.

Apart from the specially constructed tactile lines (which Inger uses and finds excellent; these are put in Frederiksberg in various places) the Copenhagen sidewalks use bricks and concrete slabs. The bricks between the slabs form tactile paths which people find very useful.

Tactile paths and such are more useful for areas people are not familiar with.

At the Copenhagen town square, there is a special tactile line for helping blind pedestrians cross the wide open space. People find it very helpful.

Copenhagen Central Station: there are 3-4 parallel lines on one track, this is easier to follow. People standing on these are an annoyance, but will get bumped into by the blind person.

Problems and Issues

Problem: Markings are not used consistently

Hot dog stands sometimes park themselves on the tactile line.

Some places have historical restrictions (ex. Heritage sites), so different kinds of tactile stones are required. Figuring out what to look for can be a problem. Guide dogs can identify different colors. Partially sighted people can often also distinguish drastic color changes. Distinct colors are helpful, but since yellow is used at bus stops that could be a problem. Black-white contrast could be desirable.

Acoustic APS

Everyone uses the APS to cross the street when they are audible. However, many find that the volume is frequently too low.

The locator tone is very useful for finding the APS devices.

Some places, like in Norway, APS is turned off at red but beeps at green. This is not useful because the user has no guiding tone to find the appropriate place to start. This is even more of a problem when a button is required to turn on the audible signal. If the button does not have a locator tone, there is little chance that the button will be found and pressed.

In Frederiksberg there is one with slow hammering. It needs to be activated with a button to have a slow/fast cycle. This is helpful.

Places where the signal is lowered at night: Some places turned off, others turned down. Turning down the volume for example between midnight and 7am is OK but turned off is unacceptable.

Spoken message could be helpful for sighted people and elderly as well.

Hans says that for him, the best systems are the ones with spoken recordings that count down and tell pedestrians where they are, for example talking signs.

For sighted people sometimes there is a button to make the light change. This can be a problem for people who don’t understand how the system works.

Frederiksberg: Pilot (locator) tone is pretty good but elsewhere it is often hard to hear. It varies from place to place, but with heavy traffic, locator tones can be hard to hear.

Directional sound could be interesting.

Different types of sounds

Which is most audible over traffic? Inger likes the Swarco ones in Frederiksberg. Others also like the knocking sound. Some have heard beeping combined with a knocking sound which seems to work well. Combined sound makes it easier to hear where the sound is coming from.

Valby: Having a loudspeaker further up in the pole means the volume does not need to be as high for the intersection to be accessible.

2 months ago, in Frederiksberg, 21 crossings were outfitted with Swarco. So far they are easy to use, no complaints or dissatisfaction. Tactile arrows are located on the top of the APS.

High pitched sounds are helpful because they don't travel as far.

Hammer sound can be easier to hear than a beep, Hans disagrees. The biggest factor is the volume and ability to tell one sound from another

Frederiksberg chose hammer sound which works well, but when traffic is heavy, noisy trucks drive the sound volume down. It returns to normal when traffic is less. Swarco is going to address this soon.

Diode light and vibrating features are quite helpful

Problem with vibration: Some technicians think they can turn off the sound.

Frederiksberg has found the vibration does not have a sufficiently clear distinction between the walk phase and the stop phase. This is especially an issue for the deaf-blind.

A universal standard for the sound heard throughout Denmark and the world would be very helpful.

Tactile Arrows

Correctly mounted tactile arrows are very helpful for orientation, especially if the crossing is at an angle. However they need to be mounted so people cannot turn them around.

Unless the APS beacon at the other side of the crosswalk is audible, the tactile arrow is the only way to know where to go. Pedestrians simply have to begin crossing and hope that another APS is audible from the crosswalk.

Hans thinks it might be helpful to have bike path indication on the tactile arrows. For example, when a pedestrian crosses the street and they reach a curb, they may think that they are now safely on the sidewalk when in fact they may have just found the curb to the bike track. While additional information about the intersection could be nice, our subjects noted that the information provided needs to be brief and concise to prevent confusion.

Tactile arrows are not as helpful if the crossing changes direction partway across the intersection.

Tactile Maps

Virtually no tactile maps have been encountered by our subjects in Denmark.

Places where tactile maps have been found: the King's Square; Kongens Nytorv Metro station.

Maintenance

Always, very often there is a problem with broken or too quiet APS.

How long does it take to fix things? It is reported pretty quickly when found, things are fixed anywhere from a few days to 2 weeks (sometimes never)

Some municipalities outsource the repairs to an electrician or other firm.

Some are experiencing a battle between neighbors asking electrician to turn it down and blind calling municipality to have it turned up.

Frederiksberg has a hotline.

Related and User-Centered Technologies

People would be willing to use user-centered devices for activating the beacons. However, any such device needs to be a feature of a single gadget people carry around, such as a cell phone. "Gadget hell" (needing to carry a multitude of devices for different specialized purposes) should be avoided.

People need to know whether or not the phone should be in activation mode.

Good solutions include a piece of software that can be installed on a phone, or a device that can be put on a cane or guide dog.

Problem Intersections

We discussed both general problems that pertain to a variety of intersections and specific intersections that cause problems.

General Issues

Some subjects have encountered issues crossing intersections that do not have traffic lights, which are unfortunately ineligible for APS installation

While the Road Directorate has common rules for all Danish municipalities, subjects have encountered different systems and methods of installing APS in different places.

Intersections Identified

Flintholm station

Frederiksvej and Grondal Parksvej, near the border of Copenhagen and Frederiksberg. The issue is that two municipalities have jurisdiction of different parts of the same intersection. The Copenhagen side is a problem for the blind community.

Bellahøj

At Holmens Canal (near the Parliament at Christiansborg)

Ideas for Improvements

Suggestions and ideas for new or improved systems our subjects gave us.

One possible idea: providing tactile indications of where the person is.

For deaf-blind approaching a crosswalk, a cell phone could provide tactile feedback.

APS activation could potentially be added to GPS units.

Traffic Islands

It is nice if there is an elevation change or louder sound, etc to say you are safe.

It would be more helpful if the traffic islands had information on them

User-Adaptive APS

Have a minimum standard but with the possibility for individual users to make requests, such as "I am hard of hearing, please make it extra loud." Or "please only use certain frequencies because I can't hear high frequencies". This would allow for optimizing the volume, frequency, and time based on individual users. The specific settings would have to be determined by proper authorities.

Walkthroughs

A walkthrough in Gentofte and Hellerup has already been conducted.

A walkthrough in Flintholm is to be conducted immediately after the meeting.

The week of April 19th is the last week for conducting field research.

Inger would be happy to show us a specific crossing and inspect a Frederiksberg crossing. This will be conducted Thursday at 11:00, and cover approximately 6 crossings.

F. NEIGHBOR RESPONSES TO NEWSPAPER AND RADIO ADVERTISEMENT

The following is a list of the e-mail responses from the newspaper and radio advertisements that were made. Technical difficulties caused the phone messages to be erased before full transcripts could be made.

1.

Hej Dansk Blindesamfund.

Jeg har hørt i Radioavisen at man vil have et nyt system for blinde ved fodgængerfeltet fordi lyden åbentbart genere hørene???.
Jeg har lige været i Chiang Mai i Thailand hvor der i et fodgængerfelt var et system som måske kan bruges hjemme for blinde og så sandeligt også for døve. Ved fodgængerfeltet er der på lyssignalet monteret en boks som vi har,men den siger intet,og på en tavle overfor fodgængerfeltet er et lyssignal som viser rødt for døve og seene. Når en blind trykker på kontakten begynder et signal at lyde langsomt,og tavlen lyser gult. Efter et forudsat tidspunkt stoppes trafikken, og lyden bliver anderledes,og samtidig viser tavlen for andre hvor lang du har til at komme over på den anden side.Når tiden er ved at udløbe bliver lyden hastigere, og holder op når overgang er forbudt. Jeg har selv set det virke perfekt for blinde folk på stedet,og så er systemet jo også til stor gavn for alle andre,og lydløst når ingen aktivere det.

Ja det var bare en af de ting jeg har set her i Thailand vedrørende trafik regulering,og måske kan ideen bruges af Dansk Blindesamfund og Dansk Døveforbund.

2.

jeg er stærkt generet af lyden

3.

Hej John
… har talt samme engang for lang tid siden da jeg arbejde for firmaet Ortofon som har en del med lyd at gøre.
Jeg har sendt denne mail til jeres organisation og fremsender en kopi til dig blot til orientering.

Jeg kan forstå at i har problemer med de omtalte lydsignaler.
Eller rettere sagt folk som bor i nærheden af dem.
Jeg kan løse problemet hvis i er interesseret.
Tillad mig at præesentere mig kort hermed.

Jeg har arbejdet med lyd i snart 30 år og er sepecialist indenfor området. Jeg driver firmaet www.etec.dk som konstruerer kundedesignede løsninger desangående.

Løsningen på jeres opgave er relativt simpel og kræver blot en mindre modification på udgangsforstærkeren lige inden højttaleren. Det handler generelt om at ændre lydniveauet på højttaleren så det matcher lydniveauet i omgivelserne.

Det vil være nødvendigt med et samarbejde med det firma som producerer de omtalte lydboxe med jeg går ud fra at i ved hvem det er og kan etablere kontakten hertil.

4.

Vedrørende jeres undersøgelse af hvordan man kan sikre at lydsignaler for blinde ikke bliver generende for den øvrige befolkning:

Jeg har en produkt-idé, der vil kunne løse problemet. Jeg forestiller mig, at Dansk Blindesamfund går ind som sponsor for ide-beskyttelse, udvikling og salg af produktet, og at jeg også selv får en økonomisk gevinst af ideen.

Jeg tror selv på at det både vil kunne hjælpe de blinde,blive en stor fordel for den øvrige befolkning og også give et netto overskud til Dansk Blindesamfund via salg af produktet på verdensplan.

Henvend jer venligst, hvis dette skulle have interesse.

5.

Vi har for nyligt set i pressen at der kan være et problem med den lyd/støj som udsendes fra lyskryds når en blind skal passere gaden i et lyskryds.

I Scanmiljø har vi en idé til hvordan problemet måske kan løses, men inden vi går videre med konceptet og begynder at ofre penge på det, ville vi gerne høre omfanget af problemet, og om der er en teknisk løsning på vej?

6.

Hej John Heilbrunn

Jeg skriver til dig foranlediget af din udmelding i pressen om fodgængersignalerne.

Jeg arbejder i DELTA hvor vi har beskæftiget os med lyd, støj, lydmålinger, alarm og varslingssignaler samt lydopfattelse i rigtig mange år.

Problemet med fodgængersignalerne kan formentlig løses, måske med de eksisterende, men helt sikkert med andre løsninger, men her kommer økonomien jo nok ind. Jeg kender for lidt til de konkrete problemstillinger (fra klagerne), så jeg skal ikke komme med nogen hurtige patentløsninger, men vi er åbne for en snak om emnet.

Den egentlige grund til at jeg kontakter dig, er at vi er ved at ansøge om et projekt vedrørende ekstern lyd til elektriske biler ved lave hastigheder. Vi ved, at de vækker bekymring, bla. hos blinde og vi vil undersøge problemstillingen og søge at finde lyde der giver optimal sikkerhed med minimal gene og støjforurening i omgivelserne.

Som en del af arbejdet vil vi udføre nogle tests med lyttere i felten og vi mener det vil være relevant, at der blandt disse er blinde personer. Jeg vil derfor høre om der er nogen blandt foreningens medlemmer .som vil være interesserede i at deltage i et sådant forsøg, såfremt projektet kommer til udførelse.

7.

Hej John. Tak for svar.

Jeg kender godt problematikken med vinden.
Det er altid en faktor som er svær at takle i forbindelse med mikrofoner og udendørs optagelser.

En anden ting som vi normalt også skal tage i betragtning er ventilations støj som altid findes i koncertsale og den slags.

I dette tilfælde kræves der nok en speciel form for filtrering samt en art kunstig intelligent til at afgøre hvilken slags støj der måles på.

Filosofien kunne ligge i at vindstøj er nogenlunde ensartet hvorimod trafikstøj er anderledes i lydspektret og varierende i styrke. Derudover kan man inkludere lysforhold og temperatur samt tiden på døgnet.

En anden ting som måske kunne bruges var en knap til at aktiveret en forøgelse af lydstyrken for en kortere periode når der var aktivt brug for det.

Og så er der jo den ultimative løsning hvor blinde personer simpelthen har en sender i lommen som aktiverer signalerne.
Lidt ligesom en refleksbrik man hænger på tøjet.
Det kaldes en "Tac" og er temmelig billig i produktion.
Du kender dem fra tyverisikring af tøj i forretninger.

Du er velkommen til at vende tilbage til mig på et senere tidspunkt hvis du ønsker min assistance.

8.

Hej,

Jeg føler mig ofte generet af lyden ved fodgængerovergange og vil gerne være med til at give min mening til kende i udviklingen af lydsignaler i fremtiden.

9.

I fortsættelse af jeres indlæg, har vi tænkt på, om ikke problemet kan
løses, ved at man udstyrer den blinde/svagtseende med en Bipper, som først aktiveres, når hun/han er få meter fra en lyskurv.

De kendte lydsignaler med korte- og lange signaler bevares men demonteres på lyskurven og erstattes af en sender til Bipperen, som den blinde/svagtseende bærer på sig.

Løsningen vil forhåbentlig medføre at såvel beboere- andre trafikanter,samt ikke mindst de blinde/svagt-seende vil blive tilfredse. Endelig håber vi at de blinde/svagtseende
fortsat kan færdes trykt og sikkert på gaden.

10.

Jeg skriver ikke til jer for at beklage mig over lydende fra blindesignaler, men for at komme med et forslag til ændring af signaler.

Min søn studerer på Harvard og ved mine besøg hos ham i Cambridge har jeg konstateret at denne by, i hvert fald for en del signalers vedkommende, bruger fuglelyde.

De fungerer tilsyneladende særdeles godt og det er ikke mit indtryk at disse lyde generer nogen - snarere tværtimod.

Så mit forslag er at afprøve dette i Danmark.

11.

Til jer tre studerende.

Undskyld jeg svarer så sent på jeres anonce.

Jeg bor åå Gl. Kongevej 179, 2th altså lige ved det store kryds ved Frederiksberg Rådhus. Jeg har i årevis været plaget af de højt bippende lydsignaler som jo bippede døgnet rundt. Jeg har som følge heraf skrevet, og talt med kommunen lige siden 1992, og altid blevet afvist. Lige indtil 2009 hvor jeg igen klagede min nød. Denne gang fik jeg et venligt svar fra viceborgmesteren som skrev at man i forbindelse mod opsætningen af lny og og mere energibesparende lyssignaler, ville opsætte nogle mere "lydvenlige " lydesisignaler. Det skete bare i det kryds hvor jeg bor, Hvorefter jeg påpegede at miljølovgivningen siger at et lydsignal masimalt må kunne høres i 3.5 meters afsstand. Det gjorde de signaler jeg bor ved idet de kunne høres gennem vinduerne i 2 sals højde. Dette viceborgmesteren til at sørge for at lyden blev dæmpet. Nu er der imidlertid sket det at man har skifttet bipsignalerne ud med nogle mindre generende kliksignaler. De kilkker ganske vist ganske højt, men så vidt jeg har kunne konstatere skal man ikke så langt væk fra signalet før lyden fortoner sig.

Jeg har iøvrigt for mange år siden påpeget overfor kommunen, at lignende signaler findes i mange europæiske storbyer.

Held og lykke med jeres undersøgelse.

12.

Hej

I stiller 3 spørgsmål vedr. gener fra lydfyr. Jeg kan svare bekræftende på alle 3.

Vi bor nærmest præcist på hjørnet af Tagensvej og Tuborgvej, og fordi det er et af Københavns mest trafikkerede kryds er lyden fra lydfyret meget kraftig (tror jeg).

Jeg blev opmærksom på at der gøres noget ved problemstillingen ved at høre om det i radioen i dag. Jeg har i de 10 år vi har boet på adressen bidt tænderne sammen og ligesom accepteret tingenes tilstand af hensyn til de synshandicappede. Men det er virkelig en belastning at man ikke kan åbne sine vinduer i de meget få timer, der ikke er kraftig traffik i krydset. Jeg håber meget at dette initiativ kan føre til noget. Jeg har iøvrigt i de ti år ikke en eneste gang set en (synligt) synshandicappet passere krydset.

13.

Hej Dansk Blinde Samfund

Jeg skriver til jer efter at have hørt indslaget om "støj" fra lyssignaler.
Hvis I skal lave en teknisk løsning, der kun aktiveres af den blinde, kan I så ikke tænke en løsning til el og hybrid biler ind i løsningen?

Jeg kører ofte i elbiler og det er meget ubehageligt at man ikke bliver hørt.

Jeg har foreslået at det skal være en "dims" den blinde kan holde i hånden og aktivere, når man ønsker at krydse vejen. Alle el og hybrid biler bør pr lov have udstyr der kan kommunikerer med denne "dims". Den skal så også kunne aktiverer lyskryds

Bare et lille forslag.

14.

Hej I tre studerende.

Min familie og jeg bor ved lyskrydset Nordre Fasanvej / Peter Bangs vej.

Onsdag før Påsken i 2006, blev der sat 9 lyd givere op i krydset, alle 9 på fuld styrke. Efter som det var helligdage var det ikke til at få fat på kommunen. Det endte med at vagten fra Frederiksberg kom og fik skruet ned til et acceptabelt niveau.

I årene derefter har jeg være i dialog med kommunen mange gange.

Det hylede og hylede, dag og nat. Vi kunne høre det i lejligheden, for lukkede vinduer. Vi kunne høre det i vores gårdhave.

Lyden blev via murene kastet op til os, jeg bor på 3. sal. Nede på gaden druknede de i trafikstøjen.

Om natten sov jeg med ørepropper. Kommunen regnede tilsyneladende med, at alle blinde og svagtseende rendte rundt i vores kryds hele natten. Det var til at blive sindssyg af. Jeg kunne også høre hylen når de ikke var der, på arbejdet.

I marts 2007, fik jeg brev fra formanden for Teknik- og Miljøudvalget. Hun informerede om at lyd giverne ville blive reduceret til mindste lydstyrke i nattetimerne.

Kommunens signalleverandør kunne ikke forklare hvorfor lydniveauet tilsyneladende ændrede sig.

For det var det de gjorde. Hvis der f.eks. kom et tordenskrald, fik det en af lyd giverne til at gå på fuld styrke.

Efter strømsvigt, alle på fuldstyrke. I sommers under ”Tour de Frederiksberg”, var lyssignalet slukket. Da de blev tændt, hylede de igen højt. Den flinke betjent jeg talte med, kunne ikke skrue ned.

Nu i 2010 er lyd giverne blevet udskiftet til nogle der ikke generer. Dejligt!

Jeg vil gerne gøre det klart, at ikke er fordi jeg er ligeglad med at blinde og svagtseende kommer sikkert over vejen.

Det er muligt at finde en løsning, det kan vi jo se, hvor man kan høre signalet der hvor man skal og ikke i lejlighederne.

Det er ligegyldigt med støjdæmpende asfalt, hvis der er et lyssignal der hyler Hvem vil sidde på en udendørs café en aftentime hvis den er i nærheden af et kryds?

En aften hvor jeg skulle på skadestuen med min søn, måtte vi vente på bussen imens de 9 lyd givere hylede omkring os. Da vi stod af ved Frederiksberg hospital blev vi modtaget af andre lyd givere.

Der kommer mere og mere støj i det offentlige rum.

15.

Hej.

Jeg bor på Emdrup Torv, med altan og stue ud til torvet.

Når busserne ikke kører så hyppigt og det bliver sidst på eftermiddag/aften og man er hjemme fra job for at nyde fritiden, så hører jeg signalerne tydeligt som aftenen går. Nu kommer den lyse tid hvor jeg gerne vil have luft ind og så må der skrues lidt op for anden lyd så jeg ikke bliver irriteret over lydsignalerne.

16.

Hej hos Tfs- undersøgelse,

Så sent som forleden morgen cyklede jeg forbi en af disse standere (for blinde) som bippede himmelhøjt der i morgenstunden, og tænkte både at jeg var glad for ikke at bo i nærheden af sådan en larm, og enforundring over disse højst besynderlige foranstaltninger man i DK gør for at hjælpe nogle, men ender med at genere de fleste.

Så ja, skru gerne lidt ned for dem, er sikker på de blinde godt kan høre den i mindre decibel. De er meget sensitive i forvejen.

mange Hilsner (og med håb om forandring via jeres projekt)

17.

Dav, Jeg hedder ---------. I ville høre om lydfyr. Det drejer sig om et lyskryds Snogesvej og Vangede Bygade. Jeg bor Vangede Bygade 77. Du må meget gerne ringe til mig på ---------.

18.

Ballerup d. 19, April 2010

Trafikregulering med lyd:

Dansk Blindesamfund opfordrede forleden I en radioudsendelse lyttere til at henvende sig direkte til foreningen, hvis man havde kommentarer til ovenstående, idet man var åben over for tiltag, der kunne begræanse eventuelle problemer ved lysregulering med bip –lyde.

Lad mig starte med ay understrege, at jeg har fuld forståelse for, at man skal tage initiative, der kan sikre svagtseende medborgeres færden I traffiken!

Men trafikreguleringen ved fodgængerfeltet, hvor jeg bor, larmer med sit: "Dyt – dyt – dyt…dytdytdytdytdyt… dyt – dyt – dyt …! Så meget,at mit I forvejen forhøjede blodtryk, som lægen gøt alt for at sænke, blot stiger yderligere! Det nærmer sig psykisk terror!

I en periode var lyden så høj, at jeg end ikke kunne sidde I min stue for lukkede vinduer og læse I en bog.

Nu ser jeg med gru hen imod en sommer, hvor jeg ikke kan opholde mig på min altan på grunf af denne støj I alle døgnets 24 timer!

Min lejlihed vender mod vest – også mit soverum, hvilket medfører, at rummenes temperature nærmer sig de 40 – 50 grader, og jeg kan end ikke have et vindue på klem, når jeg skal sove – ikke trafikreguleringen af den trafik (der ikke er).

Til borgermøder har jeg meddelt bade borgmesteren og ansatte I Teknsik Forvaltning, at der her er et problem, vi måske kunne gøre noget ved – og jeg har foreslået, at man I stedet udstyrede den svagtseende med en chip I f.eks. stokken eller armbåndsuret.

Jeg har også tidligere tænkt på, at jeg I virkeligheden skulle henvende mig til Dansk Blindesamfund for at finde forståelse for, at det, der I dette tilfæde er til hjælp for én gruppe borgere, kan give alvorlige

Problemer for en anden.

Idet jeg håber, at man kan nå frem til en tilfredsstillende løsning for alle parter!

G. WALKTHROUGH DESCRIPTIONS

1. RASMUSSEN

What: Intersection Walkthrough
With whom: Hans Rasmussen
When: April 13, 2010
Where: Ryvangs Alle and Hellerupvej, Hellerupvej and Rugårds Alle, Kildegårdsvej and Niels Andersens Vej

Hans is a very experienced independent traveler. The three intersections that are shown were between his house in Gentofte and the Hellerup train station. Of the three intersections, one did not have functioning APS devices. The following is a description of how Hans used the functioning devices at the other two intersections.

Hans approached the intersection using the white cane to navigate. When he heard an APS signal he walked toward the device. As he walked toward the origin of the sound, he would find the pole the device was mounted on with his cane. He would then use his hand to locate the device on the pole. After finding the box, he positioned himself on the correct side of the pole, generally orienting his direction of travel parallel to front of the box. To get a better idea of the direction and whether or not he would find an island, he felt the tactile arrow. In this instance, the whole box vibrated. At the correct time, he stepped off the curb, heading in the direction of the island APS. Since he could hear the island APS, he continued walking past without stopping or using the tactile arrow. Since he could not immediately hear the signal on the opposite side, he veered slightly to the right (away from the intersection) until he reached the curb. He was then able to follow the curb back until he could hear the APS.

At every crossing with an audible signal, Hans found the opposite sidewalk before he was able to direct himself toward the signal pole on that side of the street. The arrows on the tops of the boxes could be rotated by hand. At least half of them did not start pointing in the correct direction.

Hans was interested in performing a comprehensive survey of all the APS in the area and their status. These different statuses include the fully functional system, the system that has the vibrator moved to buzz against the pole for the sound with the beeping turned down, turning the beeping down during certain hours of the night, turning the beeping off at certain hours of the night and turning the signal off completely.

Problems that Hans identified:

- The Danish word for the system implies that it is a system for making noise, not necessarily acting as a "lighthouse" or beacon that guides people.
- When people complain about the system, the signal is turned down to the point where a person can no longer hear the signal at the distances required by Danish standards.
- A signal may have to be turned down at night to keep people from complaining, but it should never be turned off completely because it could pose a safety risk.
- If there is not enough curb and no color difference on the edge of the sidewalk, a guide dog may not stop at the edge of the intersection.
- When the volume of the beacons is too low, it is impossible for him to hear the signal coming from his destination.

Hans also brought up a couple different points regarding possible solutions.

- Recorded messages and countdown timers: These provide more information than just when to cross including location and how much time is remaining to cross the street.
- Phone triggering system: Most people who independently navigate also have cell phones. Denmark provides software for phones to make them more accessible, though the users have to chose and buy the phone. DTU is interested in developing technologies like this.
- Sweden: Uses a knocker that resonates through the entire pole.
- A Canadian company had considered installing APS in Denmark that had a quieter locator tone and a button that would trigger the louder signal.

Notes from intersection of Ryvangs Alle and Hellerupvej

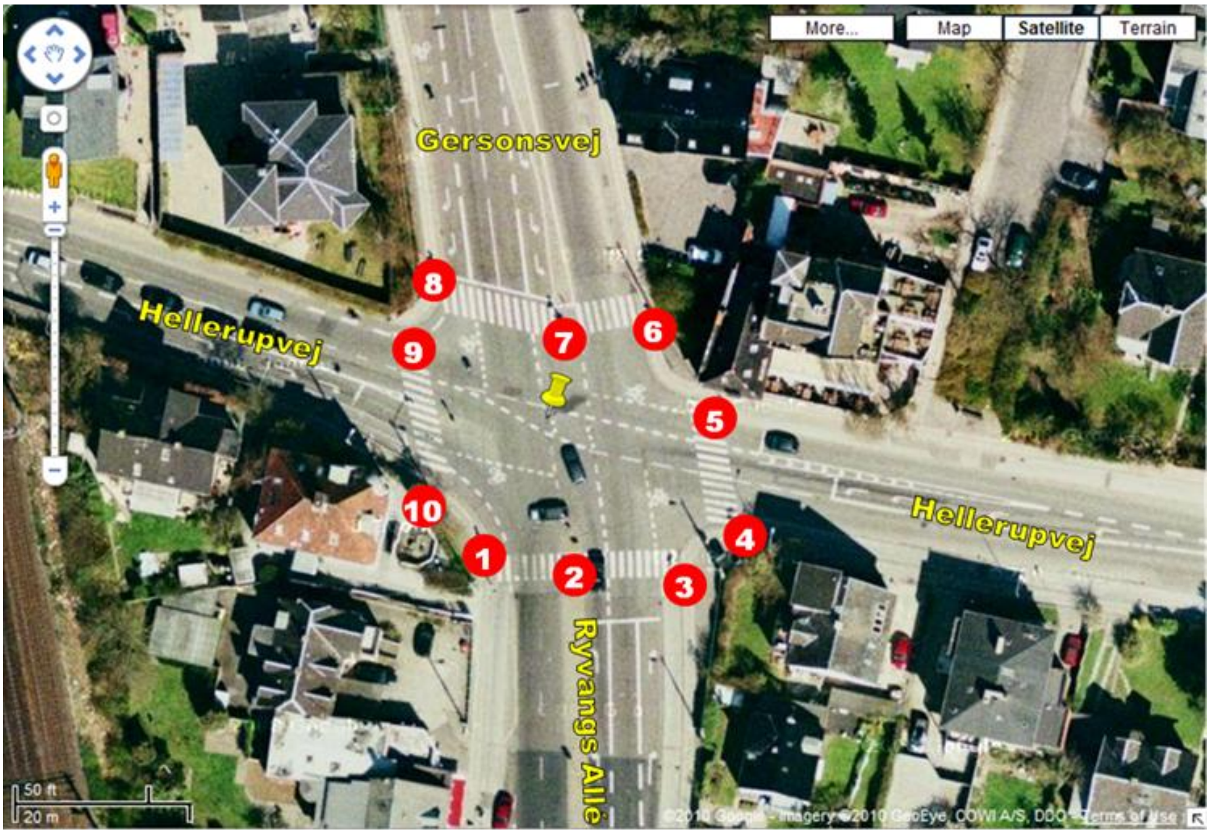

Figure 40: Top down view of the intersection of Ryvangs Alle and Hellerupvej (Google Maps, 2010)

- Vibrating APS at a moderately low volume.
- At Unit 5, the sound is shut off but the vibration makes the pole emit sound.
- At Units 6, 7, and 8, the APS is not on the pedestrian signal pole. It has its own pole, located to the outside of the intersection.
- Unit 8 had a tactile arrow that was not positioned correctly.
- Significant amounts of turning traffic, including buses, make this intersection challenging and more dangerous to cross.
- Although the western crosswalk (shown on the left) is APS-equipped, Hans chose to take the other three crosswalks instead. He described that crosswalk as the most dangerous one at the intersection. However, his route kept him close to parallel traffic: a technique we discussed with an Orientation and Mobility Specialist named Lisbeth Hallestad.

Notes from the intersection of Hellerupvej and Rugårds Alle

- APS present but not functional.

- Tactile bumps present at crosswalk, but do not cover the entire ramp from sidewalk to street. This was identified by Hans as a problem.
- Intersection is not crossable without significant parallel traffic or a sighted guide.

Near the intersection of Hellerupvej and Rugårds Alle

- Bike lane is at the same elevation as the pedestrian sidewalk
    - They are separated by 3 paving stones. Hans felt this is insufficient for a blind person to detect.
    - It is dangerous to be a pedestrian who has accidentally wandered into the bike lane.
    - As Hans understands it, this is the result of a regulation regarding the heights of various lanes. When the elevation difference cannot be more than about 1-1/2 cm, the two lanes must be at the same height.

Notes from the intersection of Kildegårdsvej and Niels Andersens Vej

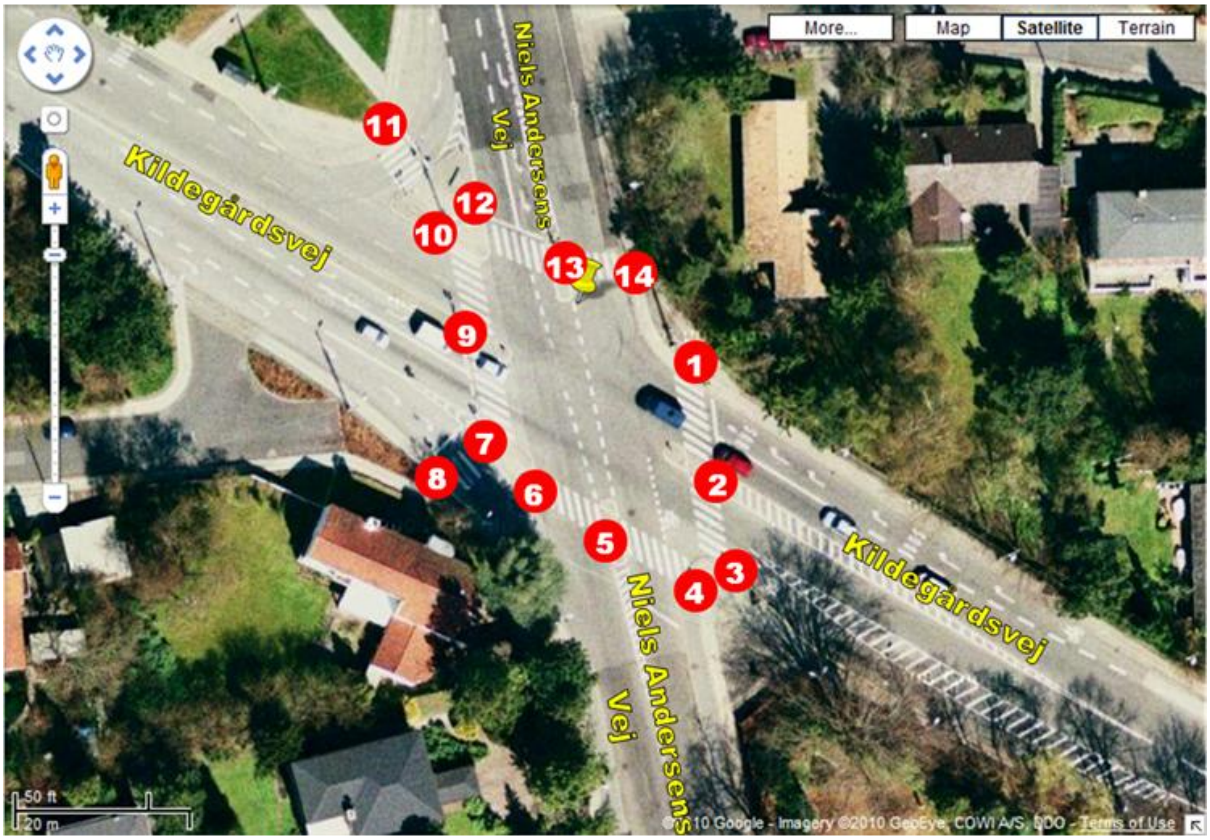

Figure 41: Top down view of the intersection of Kildegårdsvej and Niels Andersens Vej (Google Maps, 2010)

- The tactile arrows at this intersection could be turned by hand.
- APS Unit 1 is set to vibrate but not make any sound.
- It was impossible for Hans to find Unit #5 while standing near Unit #4. The sound was so low our group couldn't hear it clearly as well.

Summary of navigational issues that were encountered

- Significant amounts of turning traffic near Hellerup Station make the intersection of Ryvangs Alle and Hellerupvej difficult to cross safely, even with the assistance of APS.
- It is not sufficient to have tactile bumps present at crosswalks. They must cover the entire length of each curb ramp, and be a much different color than the surrounding sidewalk.
- When bicycle lanes are the same elevation as the crosswalk, it is very easy for a blind person to wander into the bicycle lane where it is not safe to walk. The regulations specifying that 3 paving stones separate the lanes are not sufficient.
- Without a substantial volume of parallel traffic or APS assistance, Hans could not cross even a relatively simple intersection. He was forced to rely on his wife, a sighted guide.
- Pedestrians need to be able to hear the APS at their destination as well as the APS they are currently near. This is a safety issue when crossing intersections, but also caused Hans to become stranded on an unusually shaped traffic island.

2. *MADSEN*

What: Intersection Walkthrough
With whom: Ulrik Dahl Madsen
When: April 16, 2010
Where: Rebildvej and Randbølvej, Bellahøjvej and Sallingvej

Ulrik is partially sighted and uses the APS primarily to detect the appropriate time to cross. He could determine where the crossing was, which direction to orient and how to navigate to the other side of the crossing without the aid of the APS. Since he could not see the signal lights, he relied on listening to the "walk" and "don't walk" signals to know when it was appropriate to cross.

Notes from the intersection of Rebildvej and Randbølvej:

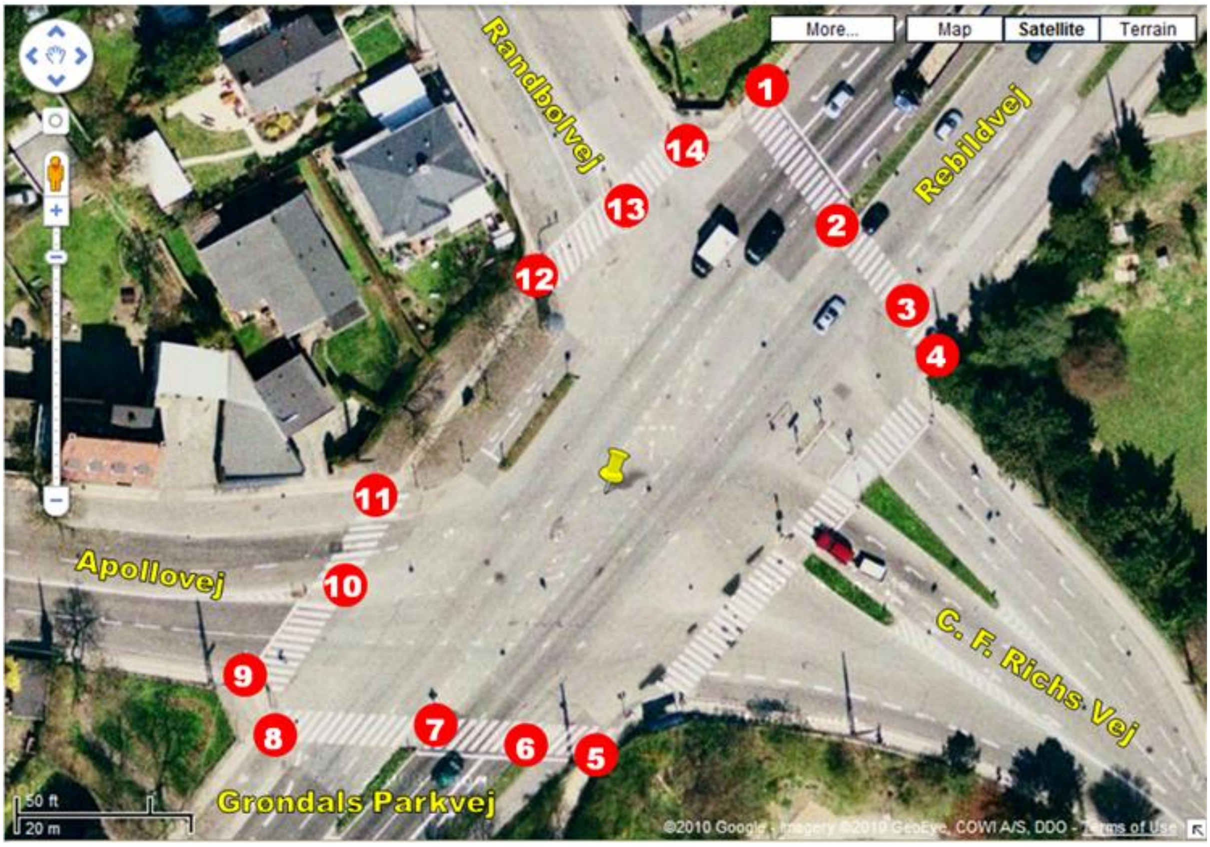

Figure 42: Top down view of intersection Rebildvej and Randbølvej (Google Maps, 2010)

1. Tactile arrows should have as many bumps as there are islands. The maximum number of extra bumps on an arrow, excluding the end indicators, is one. For example, when crossing Rebildvej, device #1 had a tactile arrow with one end bump in the direction of travel and another bump close to the first to indicate that there is an island. Device #2 had one bump on either end to indicate that one can travel both directions and one bump near to the end pointing to device #3. Device #3 was the same as device #2, just pointed on the opposite direction with the island indicator on the end toward device #2. Device #4 was the same as device #1, only it was pointed in the opposite direction, toward the street. To indicate the total number of islands, devices #1 and #4 would have to have an extra bump next to the existing island indicator. While it may be that one bump is supposed to indicate that islands exist, rather than the total number of islands, there is some confusion among the blind community which expects the island indicator to indicate how many islands will be encountered.
2. Ulrik also mentioned how an intersection that does not have symmetric APS installation can allows the user to determine which corner they are standing on. For example, in the intersection observed, there are no APS for crossing C.F. Richs Vej. This means that if a

pedestrian is standing on a corner with an APS to the left and no APS to the right, they are standing on the south corner of the intersection near device #5.

3. Device #13 looked as if it had been hit by a car and was no longer functioning.
4. The reaction to ambient noise for the devices was tested by rapping on a few of the different devices. The volume would increase drastically while being rapped on, and the volume would quickly fall back to its normal state after rapping ceased.

Notes from the intersection of Bellahøjvej and Sallingvej

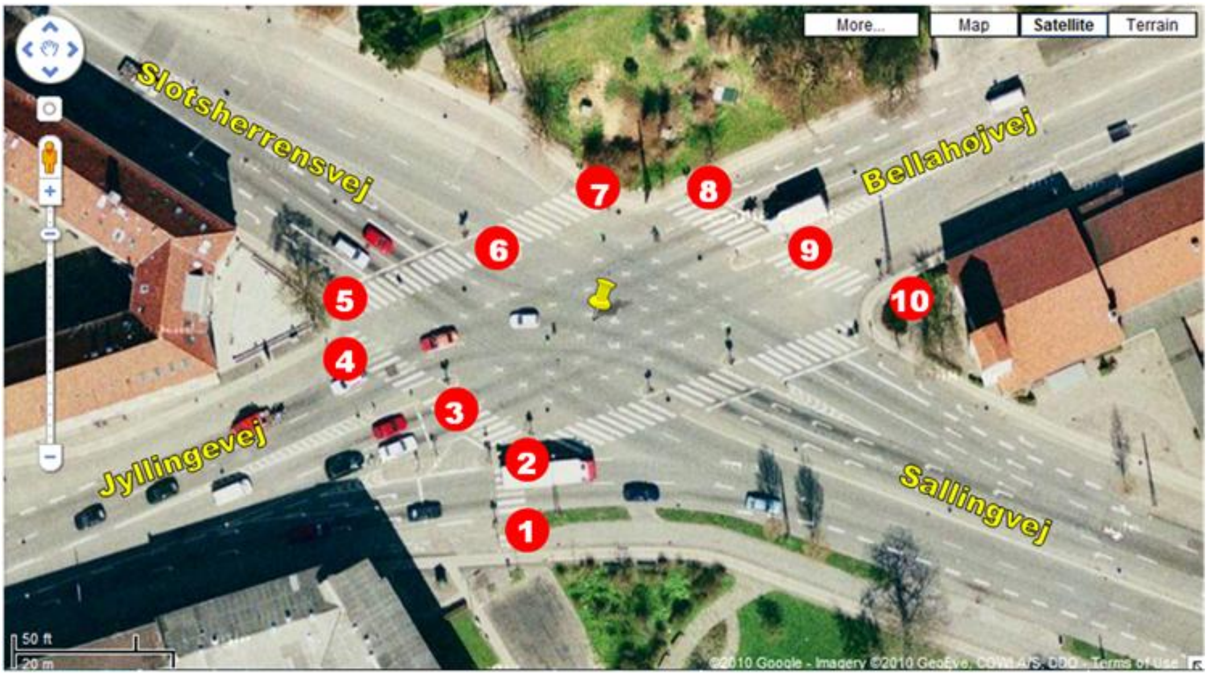

Figure 43: Top down view of the intersection of Bellahøjvej and Sallingvej (Google Maps, 2010)

1. Between the sidewalk and the traffic island with device #1, there is an unsignaled bike lane. There is a sign for the cyclists that there is a pedestrian crossing, but Ulrik said that the cyclists often ignore this sign when a pedestrian is present. This particular instance with the bike lane can pose a problem because the pedestrian must cross an uncontrolled intersection before they even reach the first acoustic device.
2. Again, this intersection does not have signals for every side. The crossing of Sallingvej does not have any acoustic signals.
3. Device #2 did have an angled tactile arrow. It was bent in the middle to show that after reaching the island, the pedestrian must change direction.

4. Ulrik mentioned that more complex sounds are easier to hear, especially with regard to determining the direction of the origin.

3. *HEILBRUNN*

What: Intersection Walkthrough

With whom: John Heilbrunn

When: April 16, 2010

Where: Frederikssundsvej and Hillerodmotorvejen

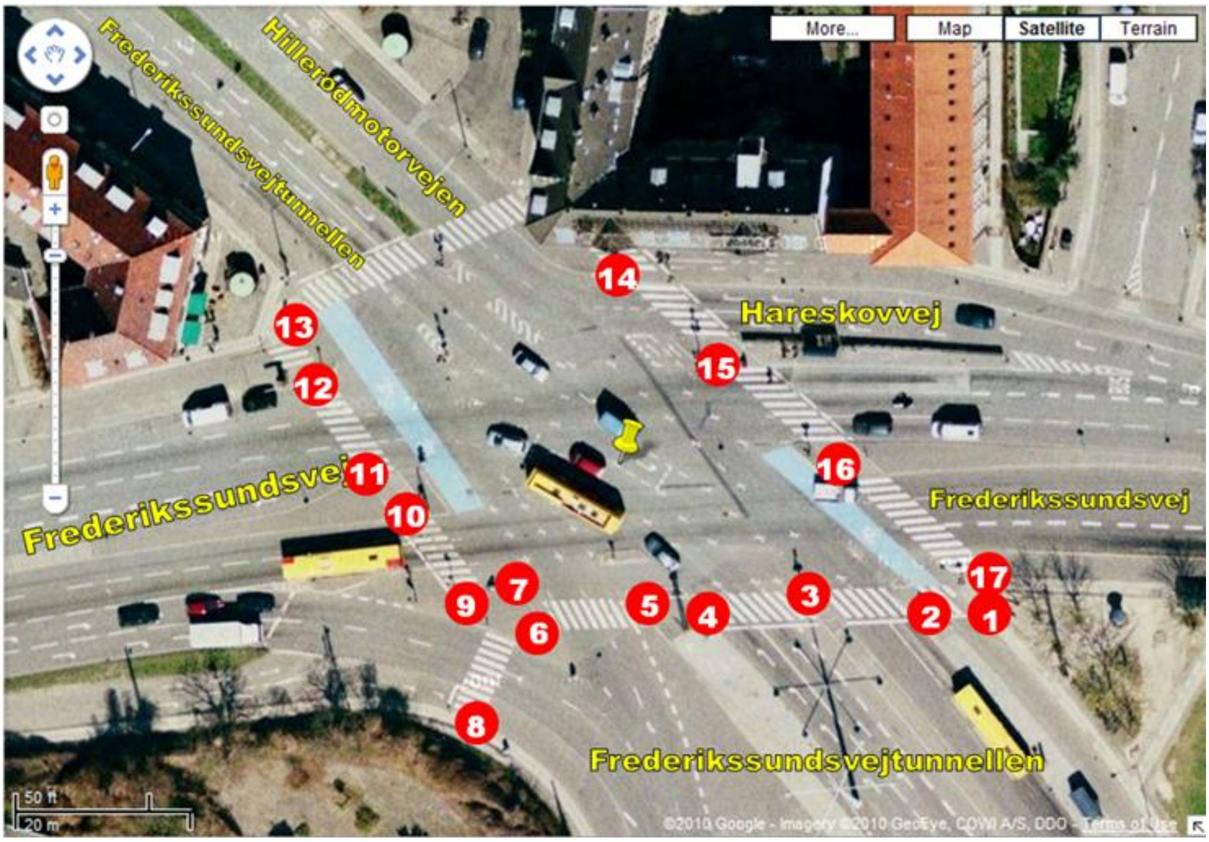

Figure 44: Top down view of the intersection of Frederikssundsvej and Hillerodmotorvejen (Google Maps, 2010)

John is a very experienced independent navigator. His method of crossing the street generally followed these steps. First he listened for the tone as he was approaching the corner. If he found the curb before hearing the signal, he would slide along the curb, moving laterally and maintaining his heading. He would listen for the signal as he moved to the side based on which direction he thought the signal was located. When he either heard the signal or found the pole with his cane, he would feel for the signal with his free hand. After finding the box, he would move to the appropriate side of the pole. When he was on the correct side of the pole, he felt the tactile arrow to gain the correct heading. It was important to find the directional arrow because simply lining up perpendicular to the curb did not work for the severely skewed intersection.

John then positioned himself at the edge of the sidewalk facing the direction the arrow indicated with his feet spread apart. When he heard the correct signal, he began crossing.

The first crossing that was made was from device #1 to device #8. The total distance is approximately 65 meters (213 ft.) By the time John reached the island with devices #4 and #5, he was slightly off course. He found the curb of the island and followed it back to the cut in the island and the APS devices. By the time John reoriented at device #5, he had to wait for the next crossing signal. The crossing from #5 to #7 went well, but John did not completely make the sharp turn from #7 to #6 and across to #8. Instead, he reached the curb of the sidewalk a few meters northwest of device #8. Often, John walked through islands quickly with the intent of crossing within the given time rather than stopping at the APS device to reorient every time. While this strategy worked well for the straight crossings, it may have been necessary to stop at device #6 to determine that the crosswalk did in fact veer to the left.

The other crossings that were made at the intersection followed much the same process including stopping at the large island with devices #10 and #11 to wait for the next signal. Since John knew about the sharp turn to be found at the island with devices #6, 7 and #9, he stopped to reorient with the tactile arrow at device #9 during the crossing from #8 to #13.

Notes from the intersection of Frederikssundsvej and Hillerodmotorvejen:

1. Devices were manufactured by Prisma Teknik.
2. Devices #1 and #17 are quite close to each other and caused brief confusion when the #17 indicated walk while trying to cross with #1.
3. Sharper angles are harder to line up with because you must rely on the direction of the arrow rather than using the curb to point in the correct direction.
4. Most often, the beacon that John was walking toward could not be heard until he was at the sidewalk or at the island. This means that he was mainly relying on being able to walk a straight line in order to successfully reach the other side of the intersection.
5. The complexity of the intersection makes it difficult to familiarize oneself with. Most often a person would familiarize themselves with a particular route. For example, if a person needed to get from one bus stop to another, they would only have to become familiar with one or two of the four crossings.

4. *Bundgaard*

What: Intersection Walkthrough

With whom: Christian Bundgaard

When: April 22, 2010

Where: Nordre Fasanvej at Fasanvej Station

Figure 45: Top down view of the intersection of Nordre Fasanvej at Fasanvej Station (Google Maps, 2010)

Christian is a very experienced independent traveler. Though this particular intersection crossing was fairly simple, this was only the second time Christian had crossed it. One complexity to the intersection is that there is no traffic that is parallel to the direction of travel. This would have made the crossing difficult without an APS with the rule that one should only ever cross with the flow of parallel traffic. Also, if one were walking along the sidewalk, it would be very difficult to know where precisely the crossing was since there is no cross street at which to stop and turn.

When crossing this intersection, Christian first stopped and listened for the signal. This proved difficult from a couple meters until the traffic lightened. He found the pole with his cane and felt for the box with the arrow. He then oriented himself on the correct side of the pole facing the direction the arrow indicated. When the signal indicated, he crossed the intersection, not stopping at the island. When he reached the far side of the intersection, he turned to the right to find device #3 and to reorient. Again, since there was no cross street with which to orient in the north/south direction, it was necessary to find the pole to be able to determine his precise location to base his further navigation from.

Notes from the intersection of Nordre Fasanvej at Fasanvej Station

1. The intersection is located in Frederiksberg and therefore the device made a knocking sound as do all Frederiksberg devices. Christian said that he enjoys the sound more and it seems easier to hear over the traffic than does the beeping sound common to Copenhagen.
2. The APS boxes also have a button that extends the walking interval by five seconds when it is pressed.
3. Christian classified the intersection as moderately difficult because of the traffic noise and the heavy pedestrian traffic going to the metro stop. He said that it is sometimes difficult to know if people with baby carriages will move out of the way for him or if he will have to move to the side and potentially lose track of his orientation.
4. The cut-through of the traffic island was slightly raised from the main street surface. It was also composed of cobblestones and larger paving stones. Christian believed that the pattern of the median texture helped him to make sure that he was still heading in the correct direction. This is important because he did not stop to use the tactile arrow at the traffic island.

H. ANALYSES

1. COMPARISON OF VERBAL AND NONVERBAL TONES

The following is a discussion on the different criteria and how they will be scored. Scores will be from 0 to 5 although not every criterion will necessarily use all five points.

1. **Indicates street being crossed**: This is a binary choice. Either the audible message does or does not indicate which street is being crossed.

0	Does not indicate which street is being crossed.
5	Indicates which street is being crossed.

2. **Cannot be confused with other sounds**: It is important that the pedestrian does not mistake any noise in traffic for the signal to be used to indicate when to cross. Such confusion could prove dangerous.

0	Similar to a wide variety of common ambient traffic sounds.
3	Similar to a few common traffic sounds.
5	Not similar to any common traffic sounds.

3. **Greatest understanding for the most people**: When the user hears the message and identifies it as a crossing signal, what is the chance the user will misinterpret the signal?

0	Most people will not be able to understand the message provided.
2	Some locals and few visitors will be able to understand the message.
3	Many locals and some visitors will be able to understand the message.
4	Locals and many visitors will be able to understand the message.
5	Universally apparent message.

4. **Minimum volume to be understood**: In order to not annoy neighbors, it is important to use the lowest volume that is possible while still providing the necessary information to the blind pedestrians. The following scores are based on how many dB above the ambient noise a signal must be to still be understood.

1	20-25 dB
2	15-19 dB
3	10-14 dB
4	5-9 dB
5	0-4 dB

5. **Speed message is understood:** The faster a pedestrian knows that it is appropriate to cross, the sooner they can begin crossing. The sooner they begin crossing, the more likely they are to finish crossing within the dedicated crossing interval. The following scores are based on approximately how long it takes for pedestrians both familiar and unfamiliar with the intersection to know when to cross after the signal for crossing has begun.For example a person unfamiliar with the intersection may have to listen to an entire verbal message before beginning to cross.

0	Both pedestrians familiar and unfamiliar with the intersection take more than 2 sec.	
1	Familiar: 1-2 sec.	Unfamiliar: more than 2 sec.
2	Familiar: 1-2 sec.	Unfamiliar: 1-2 sec.
3	Familiar: less than 1 sec.	Unfamiliar: more than 2 sec
4	Familiar: less than 1 sec.	Unfamiliar: 1-2 sec.
5	Familiar: less than 1 sec.	Unfamiliar: less than 1 sec.

6. **Amount of information to be comprehended:** Crossing an intersection requires focus. Even if an intersection has APS, a pedestrian must still determine if it is safe to cross, what other pedestrians are doing and maintain appropriate orientation. The following scores are based on how much information is needed to know when to cross.

0	Message completely distracts average pedestrian from navigation
3	Message requires some thought and concentration for correct interpretation
5	Understanding the message can become instinctive

7. **Requirements for installation:** How easily a system is set up will often determine how likely it is to be implemented and how likely it is to be done correctly. Therefore, the

simpler a system is to set up, the better. The following scores are based on how easily the message can be installed and used by current APS systems.

0	Message requires specialized equipment and different messages for different intersections that must be independently created.
1	Message uses different messages for different intersections that must be independently created.
3	Message uses different messages for intersections but messages have already been created.
5	Message uses the same pre-existing message for all intersections.

Table 10: Comparison of verbal and non-verbal messages

Criteria	**Weight**	**Verbal**		**Non-Verbal**	
		Raw	**Weighted**	**Raw**	**Weighted**
What street is being crossed	5	5	25	0	0
Cannot be confused with other sounds	25	5	125	3	75
Greatest understanding for the most people	25	3	75	5	125
Minimum volume to be understood	10	2	20	4	40
Speed message is understood	12	3	26	5	60
Amount of information to comprehend	13	3	29	5	65
Requirements for installation	10	1	10	5	50
Total Score	100	**Final**	315	**Final**	415

Weighting was based on the importance of each category in relation to the others. For example, categories that had to do with safety concerns or those that would directly affect the ability of a person to safely cross the street are given a higher weighting than things that are simply helpful such as knowing what street is being crossed.

The second and third criteria were the most important. Knowing when the appropriate time to cross requires a message that cannot be confused for other sounds including nearby signals. Likewise, the message must be able to understood by the greatest number of people possible. If someone cannot understand the signal it poses a safety issue.

The other safety concerns are evident in how quickly the message is understood and how much the message taxes the pedestrian's cognitive resources. If it takes too long for the pedestrian to understand when to cross, there may not be an appropriate amount of time left to cross the intersection. This is especially true for people who might normally need the entire time to make it across the intersection during the crossing period. If there is too much delay, the pedestrian may still be in the intersection when the traffic signals change. Distracting the pedestrian from their orientation is slightly more important because the pedestrian must be listening for such safety hazards as turning traffic and must also maintain correct orientation, a process that requires concentration. Therefore, if a signal takes too much thought to understand or is too distracting, it can pose a safety hazard. However, these safety hazards are weighted less than the first two because they don't necessarily affect all pedestrians the same as an unintelligible signal might. Walking quickly can make up for a delayed start for many and distraction by excessive information can be countered by stricter concentration.

The two other stakeholders besides the blind are represented with the minimum volume and the installation requirement criteria. These are weighted less than the others because they do not pose a safety risk. However, it is important to consider the needs of the other two stakeholders. It is important that the neighbors do not become particularly annoyed with the type of message. It is equally important that the system be easy to install. If it is too complex or takes too long, the cost of implementation may be prohibitive.

What street is being crossed is seen as a helpful item, but is not a necessity for any of the stakeholders. For this reason, the first criterion was given a lower weight than any of the others.

What street is being crossed: The verbal message was given a 5 because it has the capability of providing information on which street the walk signal is on for. The non-verbal message was given a 0 because a non-verbal signal cannot accurately give information on which street is being crossed. While different tones have been used to differentiate between north/south crossings and east/west crossing, this type of distinction becomes ambiguous with angled intersections and if the pedestrian does not remember which signal applies to which direction.

Cannot be confused with other sounds: The verbal message was given a 5 because it cannot easily be confused with the ambient traffic sounds. One could argue that there could be confusion between verbal messages and other pedestrians talking. However, if the message is intelligible, there should not be confusion between conversations and the crossing message that is being delivered. Also, if the verbal message includes the name of the street that is being crossed, it will help eliminate confusion between signals that may be near to each other.

The non-verbal message was given a 3 because it is often very distinctive from most ambient sounds. However, a knocking or a beeping can be produced by things other than an APS. Also, signals that do not have distinctive sounds for directions may be confused for neighboring signals.

Greatest understanding for the most people: The verbal message was given a 3 because many locals would be able to understand it, but not many visitors would be able to understand it. This is assuming the verbal message would be recorded in Danish. Locals would be able to understand it but visitors may have a more difficult time. While the majority of visitors to Denmark come from Scandinavian countries, a language barrier might still exist that might prevent clear understanding. If the message were recorded in English, a large portion of the older population might not be able to understand the message.

The non-verbal message was given a 5 because it can be used as an unambiguous message to the widest population.

Minimum volume to be understood: The verbal message scored 2 because it must be 15 dB above the ambient sound level to be intelligible. The non-verbal message scored 4becasue it only has to be at least 5 dB above the ambient sound (Harkey, et al., 2007).

Speed message is understood: The verbal message scored 3 because people familiar with an intersection would be able to recognize the crossing signal in less than a second and people unfamiliar would have to listen to most of the message which would take more than two seconds based on the prescribed verbal message outlined in various regulations (Harkey, et al., 2007).

The non-verbal message scored 5 because it would take less than one second to recognize for people both familiar and unfamiliar with the intersection.

Amount of information to be comprehended: The verbal message scored 3 because the message does require some concentration to recognize and understand. The non-verbal message scored 5 because it can become second nature to react to a non-verbal sound without having to interpret the message.

Requirements for installation: The verbal message scored 1 because each individual message would have to be recorded separately if it included information such as which street was being crossed. This type of individual recording would take extra time and effort on the part of the installers.

The non-verbal message scored 5 because it can use the same message for any intersection since it is not specialized.

2. *ANALYSIS OF DIFFERENT USER ACTIVATION SCHEMES*

One strategy that can be used to mitigate noise complaints and improve accessibility is user activation. This can either be done by detecting the pedestrian or by having the pedestrian trigger the system.

Criteria:

Learning Curve

1. Ease of use for first time user
2. Ease of use for visiting user
3. Ease of use for frequent user
4. Similarity to other existing systems

Devices Required

5. Reliability for user-centered device
6. Additional Per-Intersection Costs
7. Additional Per-User Costs

The following is a discussion on the different criteria and how they will be scored. Scores will be from 1 to 5 although not every criterion will necessarily use all five points.

1. **Ease of Use for First Time User**: It is important that a first-time user who is totally unfamiliar with the system, such as a visitor to the area, can easily activate the system. If they cannot do so easily, they may not obtain the benefits associated with activating the APS such as longer walk times and increased signal volumes. Additionally, unintended users should understand how to avoid triggering the device unintentionally. It can be assumed that if a user-centered device is included in the design, this person has obtained one.

1	Knowing how to activate the device requires separate instruction
2	Knowing how to activate the device requires simple explanation
3	Knowing how to activate the device is self evident with significant user exploration
4	Knowing how to activate the device is self evident with little user exploration
5	Does not require understanding of how to activate the system

2. **Useable by visitors or non-visually impaired pedestrians**: Not all potential users will have the correct user-centered device, even if one is required by a standard, for example, international travelers and those who have recently become blind. Also, APS may benefit other users.

1 A pedestrian without a specific device cannot activate the system
5 System can be activated by anyone

3. **Ease of Use for Frequent User**: It is important that a resident who relies on the device every day can activate it easily and reliably. It can be assumed that if a user-centered device is included in the design, this person has it and the device is functioning.

1 The user cannot consistently activate the system
2 Activation requires the person to examine the APS device
3 Activation requires thought
4 Activation is intuitive
5 Activation does not require consciously interact with the device

4. **Similarity with Existing Systems**: This is a harmonization issue—users see more of a benefit when the systems in use are similar from municipality to municipality as visitors can know what to expect.

1 Completely new system that must be learned by a user
3 Similar to existing systems but with noticeable differences; or the system is completely new but does not require the user to understand how it works
5 Identical to a system currently being used in Frederiksberg or Copenhagen

5. **Reliability of User-Centered Devices**: If the user-centered device runs out of battery or is accidentally left behind, it is useless. This criterion discusses how likely the user device is to become inoperable. It is assumed that the user will always bring their cane and/or guide dog with them, occasionally forget their cell phone, and more frequently forget a dedicated device.

6 Device is easily forgotten and runs out of battery
7 Device is easily forgotten but does not run out of battery

8 Device is occasionally forgotten and runs out of battery
9 Device is occasionally forgotten and does not run out of battery or is always carried but runs out of battery
10 Device is not forgotten and does not have a battery

6. **Additional Intersection Costs:** This criterion reflects the cost that is added to a design by incorporating user detection. It reflects the additional costs incurred when installing the system at an intersection.

1 Additional equipment must be installed at the intersection
3 Additional features must be installed in the APS
5 No additional devices or features are required

7. **Additional Per-User Costs:** This criterion reflects the cost that is added to a design by incorporating user detection. It reflects the additional costs incurred when purchasing user-based systems, delivering them to their intended recipients, and ensuring they are configured properly.

1 Expensive devices must be provided to users, or a custom configuration is required
3 Inexpensive devices or software must be provided to users. The additional cost due to deployment is much more significant than the production cost of the device. Default configuration is helpful to most users
5 No user-oriented device needs to be deployed

Table 11: Types of user activation, existing and developing technologies

Existing Technologies	Development Technologies
Pedestrian Detection	RFID Detection
Auxiliary Button Press	Bluetooth Detection
Extended Button Press	

Table 12: Comparison of user activation

Criteria	Weight	Ped Detection	Extended Button	Auxiliary Button	RFID	Bluetooth
Ease of Use: First Time	15	5	2	3	2	1
Ease of Use: No Device	15	5	5	5	1	1
Ease of Use: Frequent User	15	5	4	4	4	3
Similarity to Existing Systems	10	3	3	5	1	1
Reliability	20	5	5	5	4	3
Per-Intersection Cost	15	1	3	3	3	3
Per-User Cost	10	5	5	5	3	1
Total Score	100	420	390	425	270	200

The most important criteria are those that have to do with what most affects the most people. In this case, most people for a given intersection would be the frequent users. Therefore how easy the device is to use on a day to day basis is the most important criteria. Many of the other criteria were considered almost equal in importance. To begin with, how easily a new system is learned is important, especially when it is first implemented. However, once everyone understands the system it can become a simple matter of just explaining during mobility training.

One of the less important criteria is how much the device costs for the user. This is because the Danish healthcare system covers many of the costs for systems that aid people with visual impairments in their day to day living.

3. ANALYSIS OF SYSTEMS

Criteria:

Blind

1. Ease of use for first time user
2. Ease of use for visiting user
3. Ease of use for frequent user
4. Similarity to other existing systems
5. Cannot be confused with other directional indicators
6. Can be followed across the entire intersection
7. Can be used by the deaf blind
8. Reliability for user-centered device
9. Personalization capacity
10. Cost for user

Neighbors

11. Necessary volume of signal
12. When the signal make noise

Government

13. Cost per intersection
14. Cost per user

The following is a discussion on the different criteria and how they will be scored. Scores will be from 1 to 5 although not every criterion will necessarily use all five points.

1. **Ease of use for first time user**: It is important that a first-time user, who is totally unfamiliar with the system, can easily activate the system. If they cannot do so easily, they may not obtain the benefits associated with activating the APS such as longer walk times and increased signal volumes. It can be assumed that if a user-centered device is included in the design, this person has obtained one.

1	Knowing how to use the system requires separate instruction
2	Knowing how to use the system requires simple explanation
3	Knowing how to use the system is self evident with significant user exploration
4	Knowing how to use the system is self evident with little user exploration
5	Does not require any further information than is otherwise understood by an independent pedestrian

2. **Ease of use for visiting user**: Not all potential users will have the correct user-centered device, even if one is required by a standard. For example, international travelers may come from a place that does not use the same system and therefore would not have the correct device. Also, other people may be able to benefit from the APS and so would need to be able to be activated by anyone.

1	A pedestrian without a specific device cannot activate the system
5	System can be activated by anyone

3. **Ease of use for frequent user**: It is important that a resident who relies on the device every day can activate it easily and reliably. It can be assumed that if a user-centered device is included in the design, this person has it and the device is functioning.

    1 The user cannot consistently activate the system

    2 Activation requires the person to examine the APS device

    3 Activation requires thought

    4 Activation is intuitive

    5 Activation does not require user consciously interact with the device or does not require activation

4. **Similarity with existing systems**: This is a harmonization issue—users see more of a benefit when the systems in use are similar from municipality to municipality as visitors can know what to expect.

    1 Completely new system that must be learned by a user

    3 Similar to existing systems but with noticeable differences; or the system is completely new but does not require the user to understand how it works

    5 Identical to a system currently being used in Frederiksberg or Copenhagen

5. **Cannot be confused with other directional indicators:** Orientation is very important for pedestrians crossing the street. It is important that a pedestrian does not get confused by other indicators. This is judged by how easily a user can distinguish which direction to go while they are standing at the crosswalk ready to begin crossing.

    1 Pedestrian has no ready way to tell which indicator to follow

    3 Pedestrian can tell which indicator to follow with some investigation

    5 Pedestrian can tell which indicator to follow immediately

6. **Can be followed across the entire intersection:** It is important that the pedestrian can make their way across the intersection and know where they are headed at all times. If a pedestrian becomes disoriented on their way across the intersection, they may not reach the appropriate location. The different scores for this criterion are based on where in the intersection the pedestrian is receiving feedback on which direction to go.

1	Nothing to help pedestrian navigate between one curb and the other.
2	Aided with navigation near to either sidewalk or islands.
3	Aided with navigation by the middle of the intersection.
4	Marginally aided with navigation for the first half of the crossing, clearly aided for the second half.
5	Clearly aided with navigation for the entirety of the crossing.

7. **Can be used by hard of hearing or deaf:** It is important not to alienate a portion of the blind population due to hearing loss. In order to score the full points in this category a blind-deaf person must be able to navigate the entire intersection. The middle score is for systems that can point them in the right direction and tell them when to cross or systems that only help pedestrians who are hard of hearing.

1	Does not provide navigational information to pedestrians with auditory impairments
3	Provides minimal navigational information to pedestrians with auditory impairments
5	Provides sufficient navigational information to people with auditory impairments

8. **Reliability of user-centered devices**: If the user-centered device runs out of battery or is accidentally left behind, it is useless. This criterion discusses how likely the user device is to become inoperable. It is assumed that the user will always bring their cane and/or guide dog with them, occasionally forget their cell phone, and more frequently forget a dedicated device.

1 Device is easily forgotten and runs out of battery

2 Device is easily forgotten but does not run out of battery

3 Device is occasionally forgotten and runs out of battery

4 Device is occasionally forgotten and does not run out of battery or is always carried but runs out of battery

5 Device is not forgotten and does not have a battery

9. **Personalization capacity:** One feature of user oriented devices is that the user can specify something that they might need specially for crossing. For example a pedestrian who is hard of hearing might request a tone that is either louder or a different frequency. Someone who needs a longer time to cross the street might request an extra two or three seconds for the walk portion. This criterion is graded based on how many options the user would potentially have.

1 No options, only the same setting for everyone.

3 One option for personalization

5 Many options for personalization

10. **Cost for user:** This criterion reflects the cost that is added to a design by incorporating user detection. It reflects the additional costs incurred when purchasing user-based systems, delivering them to their intended recipients, and ensuring they are configured properly.

1 Expensive devices must be purchased by the user

3 Inexpensive devices or software must be purchased by the user

5 No cost to the user

11. **Volume of signal:** Neighbors need to be considered when a system is used. It is important to try and minimize negative effects on any of the stakeholders. This criterion is measured by where the sound can be heard, since most complaints by neighbors are noise related.

1 Signal needs to be heard from at least halfway across intersection.

3 Signal only needs to be heard from near APS.

5 System does not make a sound.

12. **When signal makes noise:** This criterion describes when the device is actively making noise.

1 Signal is constantly loud

2 Signal is constantly loud during the day but turned down at night

3 Signal is loud only when a pedestrian is present

4 Signal is loud only when a pedestrian needs the assistive technology

5 System does not make a sound

13. **Cost per intersection:** In order for a system to be widely adopted, it is important that the government can provide the necessary funding. This includes the cost of the system components, the cost of installation and the cost of maintenance. Since there is no ready way to make the comparison directly, this criterion is judged on the number and complexity of the components at an intersection. For example, many electrical components are more expensive and require more expensive maintenance than material components.

1 Many electrical components and material components

2 Many electrical components

3 Few electrical components and material components

4 Few electrical components

5	Material components only

14. **Cost per user:** This criterion is interested in the cost to the government of distributing devices or programs to users. While programs for phones can be downloaded easily off the internet, writing the program incurs a cost.

1	Expensive devices provided to all necessary individuals
3	Inexpensive devices or phone program provided to all necessary individuals
5	No devices or programs are necessary for the user

Weights for criteria

The weights for the criteria that were used in the decision matrix are explained as follows. Each criterion was given a percentage of a total score of 100 to be used as the weight.

The overarching weights of the table are based on how much invested interest each of the stakeholders has. People with visual impairments hold the greatest stake in the system because they are the customer, the people that use the device in day to day life. It is also these pedestrians who have the greatest interest in how reliable the system is and how safe it is to use. An unreliable or unsafe system could cause direct harm to the user. The blind were therefore given a total weight more than the other two stakeholders combined with 65%.

The government was given the next most priority. Since they are the ones responsible for purchasing, installing and maintaining systems, they receive more priority than the neighbors. Splitting the remaining percentage, the government was given a 20% stake.

The neighbors only have an interest in keeping the overall noise minimized. Therefore the neighbors are given only 15% of the stake.

The 65% that makes up the blind’s stake had to be divided between all the different criteria that directly applied to the blind. There were 10 criteria that applied to the blind. The most important criteria are the ones that have to do with safety. For example, criterion number 6 is if the signal can be followed across the entire intersection without the opportunity to lose orientation. As is mentioned in the results section of the report, it is important that the pedestrian can find their way across. The other criterion that was of equal importance was the risk of failure of user-centered devices. If a pedestrian has a device that runs out of battery or is lost halfway through the day, they may be stranded. This is an important safety concern, because they might not be able to cross streets safely without a functioning device.

Another safety and navigational concern is whether or not the device can be confused with other signals. This was weighted slightly less than the other two safety concerns because it would more likely become an issue of how long it takes the pedestrian to cross. All systems considered use a tactile arrow which could be the primary means of determining the correct direction. However, if a person were to become confused, it could pose a safety threat.

The next two heaviest categories were how easy the system would be for a frequent user. Since the frequent user would be the primary customer, ease of use is most important for them. This is weighted less than safety issues because while a system that is safe but inconvenient is acceptable, one that is safe and convenient is better. One that is also easy to learn is even better.

The next most important weight was whether or not the system could be used by pedestrians who are deaf or hard of hearing. It is important not to alienate a portion of the blind population. A large portion of the blind community is made up of older people who often have age related hearing loss. The reason that this criterion is not ranked higher is because more independent travelers come from the younger range of the population of people with visual impairments.

Ease of use for the first time user is ranked next. This criterion outlines how easily a new system can be learned. This will be important when a new system is implemented, but will become less important as the majority of pedestrians become frequent users of the system.

Four criteria were weighted the same with the least weight for the blind stakeholders. The ease of use for visitors covers whether or not a person needs a specialized device to activate the system. This was seen as a less important criterion because a lack of devices for people can be worked around.

Similarity to other existing systems was also ranked fairly low. This was because it is not necessary for the success of a system for it to be similar to other systems. This is only considering the continuity of a system rather than how hard it is to learn since this is already covered in a previous weight.

The capacity to personalize the various aspects of the system is a nice feature though not vital to its functionality. This criterion was therefore given a lower weight than other criterion. Some people would benefit from being able to personalize the system, but the majority of users would not ordinarily need any special consideration.

The last criterion for pedestrians with visual impairments is the cost for the user. This is in reference to user centered systems. For the most part, costs would be covered by the government and the only expensive technology that is suggested for the user would be a cell phone with Bluetooth capabilities which many people already use. Because of this, the cost to the individual user is one of the lowest ranked criteria.

Two different criteria apply to the neighbors. These are when the signal has to play and the necessary volume of the signal. Since the majority of specific complaints are with regards to not being able to sleep at night, the heavier weight goes to when the sound is being played. The rest of the portion goes to the volume of the signal. This is less important because if the signal is only played minimally, it can be louder without disturbing the neighbors.

The two criteria that apply to the government are what the cost of the system is per intersection and what the cost is per user. The intersection cost is the most important because that is where the majority of any expense is going to fall and also where the decision is going to be made whether or not a system is installed. If a system is too expensive, it is not going to be used. The cost per user is also important. Even if only a few intersections are installed with an RFID device, RFID tags will still need to be provided to a large number of pedestrians. Therefore, the cost per user criterion takes a close second place.

Systems to be evaluated

The following is a list of each system that was chosen to be analyzed and the accompanying description. These describe optimal systems that address the needs of the user for crossing the street. Each one has a way for the pedestrian to locate the intersection, orient, know when to cross and navigate to the far side safely. Also, each system assumes to have a vibration that indicates when to cross. This is assuming a vibration that is both strong enough and a correct frequency to be felt. Each system also assumes that there is an APS device with a tactile arrow installed on it. All sounds adjust to ambient noise.

The following table is a list of the devices. The features to select from include a tactile path and a locator tone. The tactile path refers to a system where the pedestrian can follow a tactile path to a DWS from which the APS could be found. The pedestrian could then follow a tactile path across the intersection. Islands would be denoted by further DWS from which the island APS could be located. A system that does not have this tactile path would instead just have DWS at the curb and would require the volume of an acoustic crossing signal to be heard at least halfway across the intersection. The locator tone feature refers to whether or not the system would have a tone that the pedestrian could use to find the APS device.

Constant cycle – This system does not have any type of activation scheme. The indicator, whether just vibro-tactile or both tactile and acoustic, simply switches back and forth between a “don’t walk” indicator and a “walk” indicator. The constant cycle with a locator tone and no tactile path is most analogous to the current system.

Pedestrian detection – This system activates a locator tone as the pedestrian approaches the intersection. At the appropriate time, a crossing signal is given.

Button press – This system requires the pedestrian to use an extended button press or an auxiliary button press to activate the walk signal.

RFID – This system requires the user to have an RFID chip within a few centimeters of the APS device in order to activate the walk signal.

Bluetooth – This system requires the user to have a Bluetooth enabled phone or other device turned on, running a specific program. The phone would trigger either the locator signal and then the walk signal or just the walk signal.

Bluetooth user device output – This system works the same as the Bluetooth, but instead of the APS device signaling the crossing period, the pedestrian’s phone or Bluetooth device signals the crossing period.

Table 13: APS systems compared

	Constant Cycle			Pedestrian Detection		Button Press			RFID			Bluetooth		Bluetooth user decive output
Feature	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Tactile Path	X	X		X		X	X		X	X		X	X	X
Locator Tone		X	X	X	X		X	X		X	X	X		

Scoring

Scores that were given are shown in Table 14.

Table 14: Comparison of APS systems

Criteria	Weight	System Analyzed													
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1. Ease of use for first time user	5	4	5	5	5	5	2	2	2	2	2	2	1	1	1
2. Ease of use for visiting user	4	5	5	5	5	5	5	5	5	1	1	1	1	1	1
3. Ease of use for frequent user	8	5	5	5	5	5	4	4	4	4	4	4	5	5	5
4. Similarity to other existing systems	4	1	3	5	3	3	1	3	3	1	1	1	1	1	1
5. Cannot be confused with other directional indicators	9	5	5	3	5	3	5	5	3	5	5	3	5	3	3
6. Can be followed across the entire intersection	10	5	5	3	5	3	5	5	3	5	5	3	5	3	5
7. Can be used by deaf-blind	7	5	5	3	5	3	5	5	3	5	5	3	5	3	5
8. Reliability of user-centered device	10	5	5	5	5	5	5	5	5	4	4	4	3	3	3
9. Personalization capacity	4	1	1	1	1	1	3	3	3	5	5	5	5	5	5
10. Cost for user	4	5	5	5	5	5	5	5	5	3	3	3	1	1	1
11. Volume of signal	6	5	3	1	3	1	3	3	1	3	3	1	3	1	5
12. When the signal makes noise	9	5	1	1	3	3	3	3	3	4	4	4	4	4	5
13. Cost per intersection	12	3	3	4	1	2	3	3	4	3	3	4	3	4	3
14. Cost per user	8	5	5	5	5	5	5	5	5	3	3	3	1	1	1
weight for blind	65														
weight for neighbors	15														
weight for government	20														
Total	100	**439**	**404**	**360**	**398**	**346**	**399**	**407**	**355**	**366**	**366**	**314**	**335**	**283**	**338**

Outcomes

Of the 14 systems that were compared, the system that seems to cost less, require less maintenance and annoy neighbors the least while still meeting the needs of the pedestrians is a purely tactile solution. This system would use a tactile path to locate a DWS from which the APS device could be easily found by hand or with a white cane. The device would have a “don’t walk” and a “walk” vibration signal that would continuously cycle as appropriate. The device would also have a tactile arrow. When the vibration indicated, the pedestrian would follow a tactile path to DWS at subsequent islands or the far side of the intersection. The reason this system fared well in the analysis is because it scored well for every criteria except for the similarity to the existing system and the personalization capacity.

The replacement of locator tones and opposing crossing tones with tactile paths and DWS needs to be more thoroughly investigated. DWS and tactile paths have been used around the world, most notably in Japan for the last 40 years. This length of implementation has created a body of knowledge on the best practices for installation and use. Research needs to be conducted specifically for Denmark including what the best shapes and materials are for paths and DWS. Another consideration is the type of material that is used. If a tactile path crosses a road, it must be made of a material that can withstand heavy wear, not interrupt the flow of traffic and still be able to be detected underfoot or by cane. Another point that was brought up was the effectiveness of underfoot detectable surfaces for people who may not have feeling in their feet such as people with diabetes. It is important then that the tactile paths and DWS must be easily detectable with a white cane. Lastly, it is important to consider the effects of snow and ice on how well the surfaces can be detected as well as how snow removal might affect them. Much of this research can be done by conducting a closer literature review of successful implementations such as those in Japan. Because of the further research that must be done, this solution is considered a long-term solution.

If the tactile paths are found to be problematic, difficult to implement or do not somehow meet the necessary needs, a different set of systems can also be considered. Of the systems that do not use the tactile paths to aid with navigating the crossing, the top three scores were within 14 points. Such a close score is not conclusive. A robustness test indicated that the relative ranking of the scores depends on the weighting of stakeholders.

When the pedestrians are favored in the weighting scheme, the high scoring system describes the ideal implementation of the current system in Copenhagen. This is an interesting observation to make. This means that of the currently available technologies, the current implementation is the best for pedestrians. However, if the neighbors need more consideration, then this is not the ideal system for using existing technology. Instead, a button triggered system or pedestrian triggered system would be better to use.

One interesting observation to make about the outcomes of this comparison is that the user centered devices did not score well. The systems tended to score high in such categories as ease of use for the pedestrian and personalization capacity. However, these advantages were countered by the problems associated with user centered devices such as the potential to forget the device or having it run out of battery and the problem with not being able to accommodate people who do not have a specific device or program. In terms of the neighbors, these systems did have some advantage over other systems, but not significant enough to make much of a difference in the comparison.

Conclusions

Increasing the use of tactile surfaces would prove advantageous to all three stakeholders. However, this will require more investigation into the how to implement tactile surfaces most effectively. If investigations should prove that increased use of tactile surfaces is not a viable solution, than the next best thing would be to either improve the current system or to implement a system that is activated by a button push, depending on whether the needs of the pedestrians or those of the neighbors should be considered more. Systems that require user devices were found to be the least useful for all stakeholders.