Thesis Report

Independent Navigation at Schiphol Airport for the Blind

Integrated Product Design
Master Thesis
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Abstract

This thesis investigates the development of Pathfinder, a wearable navigation system designed to support Visually Impaired Passengers (VIPs) in navigating airports more independently. Large-scale transport hubs like Schiphol can be particularly challenging for VIPs due to their unfamiliar layouts, limited sensory cues, and reliance on visual information. Pathfinder explores whether smartphone-based Visual Simultaneous Localization and Mapping (VSLaM), combined with intuitive feedback mechanisms, can offer a more autonomous alternative to traditional airport assistance.

The project followed a human-centred mixed method design approach, starting with contextual research and user analysis. Insights were gathered through desk research, interviews with experts and the user group, basic solution tests, and simulated context studies, where the researcher blindfolded himself and studied how blind navigation works. These methods helped identify key user needs, such as the importance of spatial orientation, environmental feedback, and a sense of control throughout the travel experience. Findings informed the development of a low-fidelity prototype and a refined system concept supported by flowcharts, user flows, and interface sketches.

The prototype was evaluated in a simulated airport setting at TU Delft, to test how effectively it guided users along designated paths, responded to directional changes, and conveyed spatial and relevant information. Although testing did not involve blind users directly, the results indicated that the system enhanced route awareness and reduced reliance on human assistance. Participants responded positively to the audio-haptic feedback and the structured, intuitive nature of the guidance provided.

Limitations remain, particularly in real-time environmental adaptation and the prototype's dependency on static maps for references. The lack of testing with actual VIPs also limits the depth of validation. Nevertheless, the project outlines a clear path forward, recommending steps such as API integration, improved feedback personalization, and deeper co-design with blind users for future iterations.

Ultimately, Pathfinder demonstrates how VSLaM technology can be reimagined to meet the accessibility needs of visually impaired travellers. With further refinement and collaboration, systems like this could contribute to more inclusive, independent, and empowering travel experiences in airports and beyond.

Acknowledgements

For this thesis I would like to thank the various people involved to make it all possible for this thesis.

I would like to first of thank my chair and mentor Sicco Santema, and Wolf Song, for guiding me throughout this project, and also teaching me how to become more independent as a researcher and designer.

I would also like to thank the 16 VIPs, such as the Blindfluencer Inge de Munnik whom I interviewed, by sharing their unique ways on navigating with limited or no vision through airports and the world in general, as well as helping me better understand the how one experiences the world when they become visually impaired.

In addition to that I would like to thank the various Experts from Visio and CBM as well as assistance staff from Garuda Indonesia, KLM and Schiphol on giving me further insight on how assistance is provided, and how navigation is though to the visually impaired.

Lastly I would like to thank my family and friends for making this journey all the more enjoyable and supporting me wherever possible.

List of Abbreviations

VIP	Visual Impaired Person
VI	Visual Impairment
SLaM	Simultaneous Localization and Mapping
VSLaM	Visual Simultaneous Localization and Mapping
API	Application Programming Interface
NS	Nederlandse Spoorwegen (*National Dutch Railway Company*)
LiDAR	Light Detections And Ranging
IR	Infra Red
ToF	Time of Flight
RGB-D	Red Green and Blue Depth ***Camera***
IMMU	Inertial and Magnetic Measuring Unit
YoLo	You only Live once ***Algorithm***

Interactivity

This thesis might contain figures which are too small to read from a first glance. Hence the interactive zoom feature is included. By pressing on the icon, that is visualized on the right at images, a zoomable version would pop up in your webbrowser allowing you to study and look at the images up close and with better detail.

Report Content

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Last part to finish

Introduction

Wayfinding at airports is quite a challenge for a lot of people. Airports are large, busy, and complex environments (Legge et al., 2017). However with our sight eventually we could gather enough information on our surroundings to know where we are. Our sight gives us information on where obstacles are such as static ones like poles and dynamic ones like people, and how to avoid them. Lastly our sight gives us a lot of access to navigational aids located all around the airport like signs, information panels, and indicators of time (Indoor Wayfinding and Navigation, 2019). In the end our sight allows us to find our way to our intended destination at the airport like the check in gate and departure gate, and do so often independently with minimal help.

However how would it be like if we suddenly lost a significant or complete portion of our eye sight? How do we know where we even are in an large environment like an airport? How would it be like to travel at an airport like a blind individual?

Those are some of the questions that a VIP encounters when travelling through an airport. In short the task to travel individually through an airport is nearly impossible and often carries too much risk and stress to be done alone by a blind individual (Jeamwatthanachai et al., 2019). Hence for now VIPs are dependent on others like their personal assistance such as their family members and friends or airport assistance staff to help guide them through such environments (Schiphol | Assistance for Departures From Schiphol).

While assistance is highly appreciated by VI individuals and often works well with minimal cases of serious issues (Chen, 2024). It does result in the VI person to become overly dependent on another, to know about their surroundings and navigate through the environment of an airport. In doing so it decreases the VIPs ability to stay in control of their environment and ability to act independently in it.

Hence throughout this thesis assignment my aim is to create an indoor navigational aid prototype device for VIPs at airports. The prototype device should provide information on their surrounding environment and allow them to navigate more independently through it.

Intro to the Visually Impaired

Who are the Visually Impaired?

The World Health Organization defines VI as someone who has low vision, or a visual acuity between 6/18 and 3/60, with the best possible correction or a visual field of 20 degrees or less (World Health Organization: WHO, 2023). If one has VI, ones vision cannot be corrected through the means of ordinary glasses, contact lensnes, medication or surgery (World Health Organization, 2019).

Globally about 1.1 billion people suffer from VI (The International Agency for the Prevention of Blindness, 2022). From them 510 million suffer from near distant vision, and 596 million suffer from distant vision. Distant vision can be further split into four levels, with each level becoming much worse and affecting the persons ability to navigate and act independently in the environment (World Health Organization, 2019).

With travelling at airports requiring one to look at signs and way findings aids from a distant (Legge et al., 2017), distant VI becomes a focus group for this study.

Navigating as a User

With VI causing one's vision to become significnatly limited or obsolete, navigating any environment becomes a unique challenge in itself. Due to this memory becomes a key driver to help familiarize and navigate through a certain environment (Wise et al., 2012). Furthermore senses like hearing and touch become crucial gaining knowledge of an environment (Tariq, 2024).

Aside from that memory of an environment is often built through the use of a human guide. They help explain certain routes from beforehand and identify landmarks for turns or key areas. Gradually a VIP learns to navigate the route individually (Golledge, 1999). Navigational aids like the white cane and or guide dogs are also always used, in combination with mobile apps and other wearables that can help describe and familairize the environment (Başgöze et al., 2020). Environmental aids like blind paths and walls also help navigate where one has to go (Lubomirsky, 2024). The smaller, static and simpler the area, the easier it is to remember it and hence navigate through it.

Airport Travel

Unfortunately airports like Schiphol, are neither small, static or simple. Instead they are the exact opposite, being large, dynamic with the numerous people moving around, and complex in the sense that there are many turns to take to reach ones destination (Ashford & J, 2025). The area is also noisy which can create a sense of disorientation.

However one factor that makes the area extremely difficult to navigate through, is the fact that it is a large area that one cannot go through on a frequent basis. Given the fact that most VIPs travel 1 - 2 times a year by plane through Schiphol (Bhagchandani, 2020). Hence it becomes very challenging to familiarize and memorize for a VIP. Resulting in it being an area they are extremely dependent on someone else.

Intro to Schiphol Airport

Schiphol Airport

Schiphol Airport, located in Haarlemmermeer, 9km Southwest of Amsterdam, is the main international airport in the Netherlands. The airport is built on a single terminal concept, which is split into three main departure halls . These departure halls then seperate into main piers where aircraft can go to.

Figure 1
Aerial view of Schiphol showing its layout

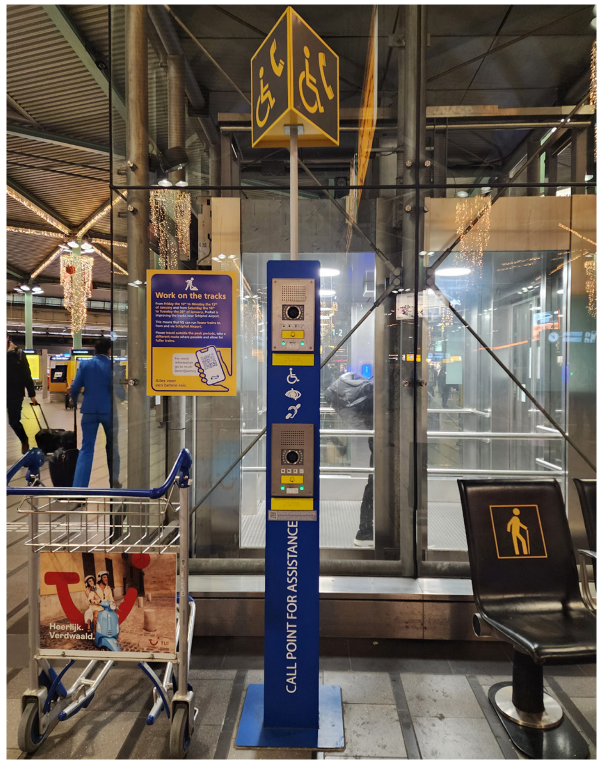


Figure 2
Assistance Pole at Schiphol

The airport has a total floor surface area of 1.3 million square metres, and handles more than 66.8 million passangers a year (Schiphol | Valuable Assets). Making it a very large and busy airport and environment to navigate through. It is a popular departure point for many including the blind as it connects them to up to 273 destinations (Schiphol | Valuable Assets). Furthermore the airport is accessible both by public transportation means like the train and bus as well as by car and taxi.

Assistance at Schiphol

Schiphol also has a dedicated assistance service for people with disabilities, such as VIPs . These services aid blind in navigating their way from the assistance pole or assistance desk all the way to the gate (Schiphol | Assistance for Departures From Schiphol). This service can be requested through the use of assistance poles or by going to the assistance desks near the check-in counters. It is often required though to book this service 48 hours in advance either through Schiphol or with the airline (Schiphol | Requesting Assistance). Requesting on site is also possible though with the risk of a long wait.

Assignment Aim & Approach

Assignment

The assignment is to design and prototype a device that can help the User passanger navigate (more) independently in large unfamiliar environments at airports where they do not travel through frequently.

Aim

Through this assignment I aim to help User have more control and independence in their navigation of the airside of the airport environment.

Approach

To carry out this assignment successfully, a combination of quantitative and qualitative through the means of desk research, field research and interviews with both the User and relevant stakeholders is required.

The project begins with literature review to famiarize and understand visually imapired passangers, context, and existing solutions. Due to the fact that I am not a User individual, interviews are done with VIP to better understand their perspective of the issues at hand. This is further aided by simulating as a VIP through mobility training at Visio is done to further understand the perspective of the User passanger. Field research is also conducted at the context area such as Schiphol to famiarize with the assistant services that exist and the challenges User passanger face there.

Finally these findings are used to form a User journey map that highlight all possible scenarios and then broken down into distinct scenarios where problem areas and solutions are highlighted.

This is eventually used to find a focus area for the project forming the design brief that acts as the foundation for the solution field of this project. From the design brief requirements are derived that are used to iterate several concepts directions which lead to a prototype solution. This prototype solution will be tested to gather feedback and refine the prototype.

The project ends with a refined prototype device and implementation plan which will be presented to TU Delft in the end.

Exploration
Part 1

1 User Analysis

Understanding the user group is key to the successful design of any product. This chapter will focus on the causes and levels of visual impairment, eventually leading to a specific user group. Furthermore it explores the life and behaviour of this user group, how they navigate and orientate and how they create mental maps of surrounding areas.

1.1 Causes

As wayfinding is an important aspect of finding ones way at an airport, viewing from a distance is more relevant than near sightednes. Hence focus would be on the passangers at airports that suffer from distant visual impairment. Distant visual impairment has five main causes which are as follows:

1.1.1 Cataracs

Affects 94 million people (Steinmetz et al., 2020)
A cataract is the clouding of the lens in the eye, making it difficult for a light or image to be focused on the retina, leading to a decrease in vision (Khorrami-Nejad et al., 2016).

1.1.2 Refractive Errors

Affects 88.4 million people (World Health Organization: WHO, 2023)
Refractive errors happen when the light entering the eye is not properly bent (refracted) to focus on the retina, leading to blurry or distorted vision (Inner West Eye Surgeons, 2023).

1.1.3 Age Related Macular Degeneration (AMD)

Affects 8 million people
AMD is a common eye condition that primarily affects central vision. It occurs when the macula (Brand, 2023), the small central part of the retina responsible for sharp, detailed vision, deteriorates over time.

1.1.4 Glaucoma

Affects 7.7 million people (Furtado et al., 2024),
Glaucoma is a group of eye diseases that damage the optic nerve, which is crucial for transmitting visual information from the eye to the brain. It is a leading cause of irreversible blindness worldwide. Glaucoma often progresses slowly and is sometimes called the "silent thief of sight" because it can cause vision loss without noticeable symptoms in its early stages.

1.1.5 Diabetic Retinopathy

Affects 3.9 million people (National Eye Institute, 2024)
Diabetic retinopathy is a serious eye condition caused by damage to the blood vessels in the retina as a result of long-term diabetes. (National Eye Institute, 2024) It is a leading cause of visual impairment and blindness in working-age adults globally.

1.1.6 Influences at the Airport

The five main causes have significant influence on how an airport environment is percieved and how what challenges arise from it.

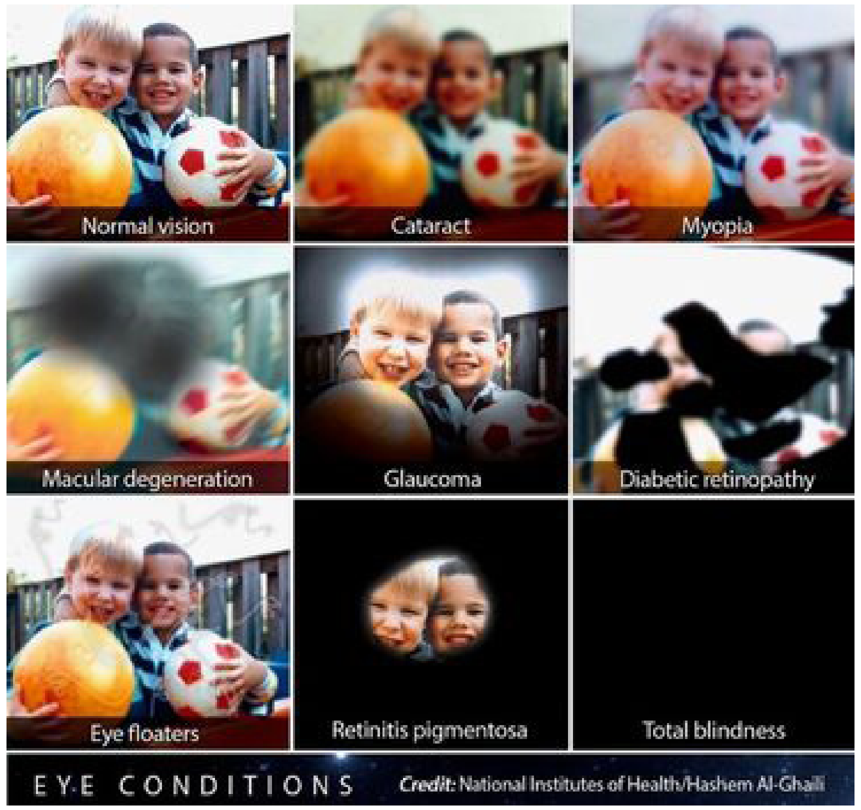


Figure 3
Causes & Affects on Vision

Blurry vision
Difficulty reading flight information boards, departure gates, or baggage claim signs.

Depth Perception
Struggles with identifying gate numbers or directional signs in the terminal.

Crowded Environments
Challenges with judging steps, escalators, or uneven flooring, increasing the risk of trips or falls.
Difficulty distinguishing people and objects in busy terminals, leading to disorientation.

Strain during Long Distances
Struggles to identify distant signs or people, such as airline staff or assistance desks.

Navigational Challenges
Trouble judging distances or detecting small obstacles on escalators, stairs, or moving walkways.

Reading Signs and Information
Difficulty spotting directional signs, flight information screens, or gate numbers, especially if they are placed outside the central field of vision.

Peripheral Vision Loss
Trouble estimating distances, such as on escalators, stairs, or moving walkways.

Spatial Awareness
Trouble estimating distances, such as on escalators, stairs, or moving walkways.

Blurry or Distorted Vision
Difficulty reading flight information screens, gate numbers, or directional signage.

Blind Spots or Floaters
Dark or blurry patches in the visual field can make it harder to detect obstacles, people, or important details like terminal maps.

Reduced Peripheral Vision
Peripheral vision loss due to retinal damage may hinder the ability to navigate crowded spaces or avoid obstacles.

1.1.7 Take Aways from Causes

From the causes, it can be deduced that the significant limitations of sight, makes it extremely difficult or impossible to make use of existing wayfinding methods provided at airports like Schiphol. Information points and screens are inaccessible to VIPs , making it difficult to get feedback on their current locations and where to go. This hence makes it difficult to hence determine if they have reached the right check-in desk or boarding gate, without the help of those around them.

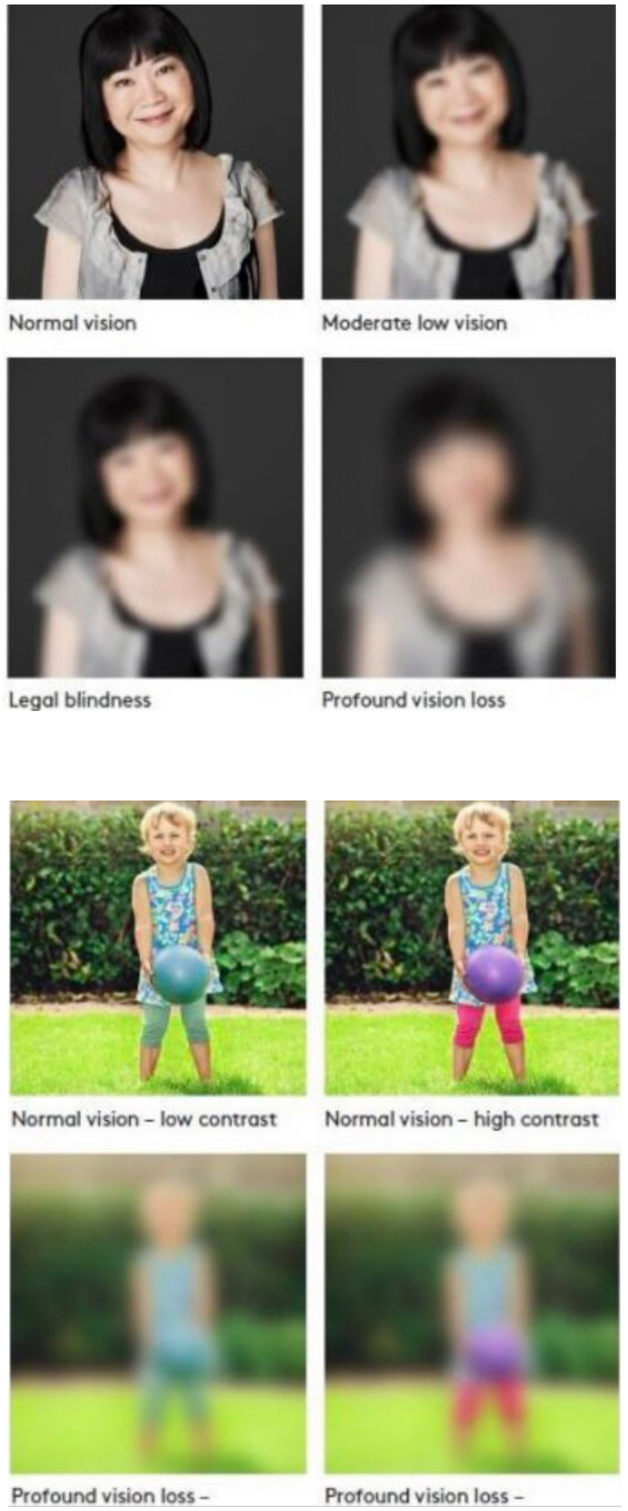


Figure 4
Visual Impairment Levels Impact on Sight

Lastly due to the reliance on hearing, crowded environments can also pose as a huge problem, causing confusion and disorientation for VIPs.

1.2 Levels of Visual Impairment

While causes influence how one percieves the world as a VIP, the level of their impairment ultimately deduce its severity (Jones et al., 2018). The more severe the impairment is, the more influence it has on ones ability to function in their life, such as navigating through an environment (Kamelska & Mazurek, 2015)). The more severe the impairment, the less one can do, and the more dependent one becomes on others. Figure XX Visualize the sight of different levels. Legal Blindness and Profound vision loss are Level 3 and 4 (Vijayalakshmi & Kv, 2020).

Based on the International Classification for Disease ICD-11, visual impairment can be divided into several levels/categories. For distant vision, which is the type of vision focussed on for this assignment there are 4 levels (McDonnall & Sui, 2019). Levels are based on visual acquity, which determines how well one can see objects and details from a certain distance (Visual Impairments - Health Policy Institute, 2019). Someone with a visual acuity of 6/18 can see at 6 meters what someone with normal sight can see at 18 meters. The classifications are based on Best Correct Visual Acuity (BCVA) and the Visual Field of one's sight (World Health Organization: WHO, 2023).

1.2.1 Level 0D (Normal Vision)

Visual Acuity 6/6 - 6/12
Regular vision, hence does not really count as a level.

1.2.2 Level 1 (Mild Visual Impairment)

Affects 258 million people (R. R. A. Bourne et al., 2017)

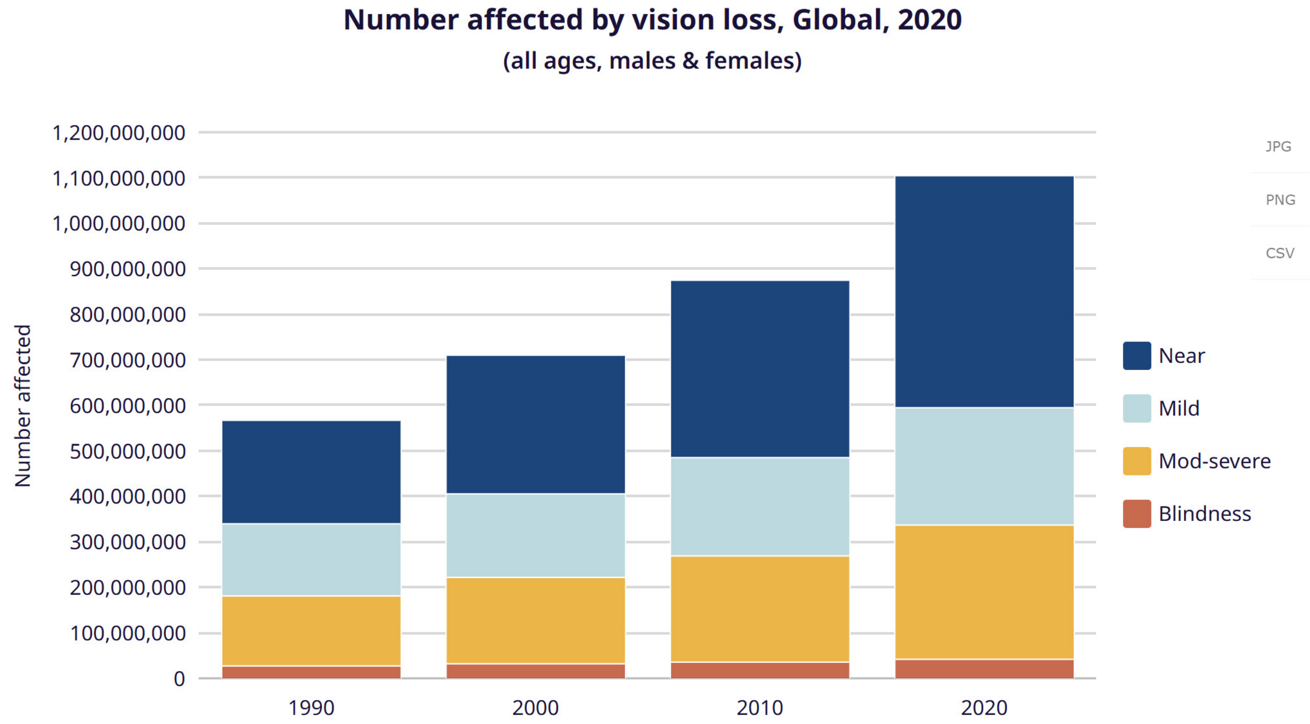


Figure 5
Visual Impairment Levels and their Proportions (The International Agency for the Prevention of Blindness, 2022)

Visual Acuity 6/12 - 6/18
Near normal vision
Suffer from difficulty with clarity at far distances, though can still see objects around them.

1.2.3 Level 2 (Moderate Visual Impairment)

Visual Acuity 6/60 - 6/120
Struggles seeing clearly at a distant and also around. Can still distinct areas with sight but with difficulty.

1.2.4 Level 3 (Severe Visual Impairment)

Visual Acuity 6/18 - 6/60
Affects 295 million people (Combination of Level 3 and 4 (Besser, 2023)
Major vision loss, where seeing objects and performing tasks becomes extremely challenging. Difficulty recognizing obstacles or navigating terminal layouts independently.

1.2.5 Level 4 (Blindness)

Visual Acuity Worse than 6/120
Affects 43 million people (The International Agency for the Prevention of Blindness, 2022)
Either still has limited perception of light and shapes, known as profound blindness, or complete lack of vision known as total blindness. Requires a guide or assistive device to move through the airport, including passing security and finding gates (Zwillinger, 2024).

1.1.7 Conclusion of Levels

From these levels it can be deduced that Level 3 and 4, also known as Severe and Blindness suffer the most when navigating through an airport. While they make up only a smaller proportion from the visually impaired community as seen in Figure 5, their significant significant loss of vision results in them both to suffer from the lack of independence and control of their environment.

As the aim of this assignment is to help visual impaired passangers navigate more independently on airports, Level 3 and 4 are chosen due to their significant loss and hence demand for it. Furthermore by focussing on the worse cases, hopefully parts of the result can be used to aid in the less severe cases such as passangers with mild and moderate visual impairment.

From here on focus would also be on the passangers with Visual Impairment Level 3 and 4.

1.3 Life & Behaviour

With the limitation or loss of one's sight due to VI, there will be significant impact on one's daily life. While the level of impact varies based on the level of visual impairment, the type of impact is experienced in a similar way throughout all levels of VI, whether one is moderately visually impaired or totally blind (Vuletić et al.).

1.3.1 Daily Life

Cooking, cleaning, and shopping require adaptions, often this is achieved through the usage of tactile markers and organized storage. VIPs like tidy places, as this makes it easier for them to locate and find their way around (Khorrami-Nejad et al., 2014). Due to limited or lack of vision, other senses like smell, hearing and touch are used to do daily tasks. 'Reading' is predominantly taken over by hearing what is written down or using Braille through touch (Möller et al., 2009). Seeing and navigating around such as knowing ones surroundings is done using a combination of hearing and touch (Guerreiro, Sato, et al., 2019).

1.3.2 Social Interaction and Leisure

Regardless of age, visual impairments may hinder involvement in social activities as well as relationships with family and friends. A much larger proportion of people with visual impairments — 16 percent — are limited in social activities, compared to people without — 3 percent (Kamelska & Mazurek, 2015).

This is often caused as VIP try to avoid going to unknown locations, and navigating there, preferring the comfort and familiarity of home (Jones et al., 2018) While it is more comforting to stay at home, it will eventually result in social isolation. Furthermore they would feel left out of events happening outside of their home (Brunes et al., 2019).

1.3.3 Emotional and Psychological Well Being

Almost one-quarter of adults who have difficulty seeing, compared to only one-tenth of those who do not, report feeling hopeless all or some of the time in the past month (Jones et al., 2018).

Among adults with visual impairment, the prevalence of moderate loneliness is 28.7% (18.2% in general population) and prevalence of severe loneliness is 19.7% (2.7% in general population) (Brunes et al., 2019). The risk of depression and anxiety are also increased in the VIP; 32.2% report depressive symptoms (12.01% in general population), and 15.61% report anxiety symptoms (10.69% in general population) (Visual Impairments - Health Policy Institute, 2019).

1.3.4 Physical Well Being

On a physical level, VIPs face several challenges. For example when navigating, often certain areas are avoided to prevent inconveniences when travelling (Kamelska & Mazurek, 2015). Often these are areas that are difficult and exhausting to navigate like open areas (Jeamwatthanachai et al., 2019). Some of the main physical challenges VIP face are:

Physical exhaustion – It can be physically exhausting to navigate and try to avoid obstacles, as well as going up stairs, and familiarizing new areas (Moeilijke Oriëntatieplaatsen Voor Blinden En Slechtzienden).

Danger – Navigating through an unknown area can result in the risk to trip, collide with obstacles and fall. This can result in physical injury and discomforts (Living With Blindness and Visual Impairment | Help & Support).

Sensorial Overload – To compensate the limited and lack of vision, touch and hearing are often used. However due to this compensation of both senses and other senses can risk being overloaded resulting increased physical effort and exhaustion (Hoe Kunnen Blinden En Slechtzienden Zich in Een Gebouw Oriënteren?)

The feeling of uncertainty and the risk of getting lost can lead to anxiety and stress in blind and partially sighted people. Being able to navigate independently can be crucial for their daily activities and social interactions (Jones et al., 2018).

1.3.5 Behavioural Take Aways

What can be concluded from the life and behaviour of visual impairment is that being independent is no easy task, requiring high levels of certainty, a low amount of energy and confidence to avoid the many risks that await them in the surrounding environment. When there are too many risks in an environment, such as obstacles and uncertainty on where to go, it can cause increased levels of stress and ultimately frustration. Due to the higher levels of risks more energy is also required to avoid and overcome these risks.

Eventually when too much energy is required to conduct a task resulting in too much frustration, independence is abandoned in the favor of dependency of another. While this is not a problem in itself, it often results in the loss of the VIP's sense of control and independence in that particular environment.

Due to this Energy, Frustration, and Dependency are important to take into account when aiming to make tasks more independent. This leads to three acting as parameters for activities in the Journey Map in Chapter 4.

1.4 Orientation & Navigation

Both orientation and navigation are essential for VIP when moving around and knowing where they are. With the limitation or lack of sight, several methods have been developed and or are used to help VIP find their way around. These methods are further complimented and enhanced with the solutions described in Chapter 2.

1.4.1 Orientation

Focusses on methods to that help a VIP determine their location.

1.4.1.1 Tactile Exploration (Perkins School for the Blind, 2023)

Hands and Feet

Use hands to feel walls, furniture, and objects.
Feet help detect floor texture changes or steps.
Blind and partially sighted people can use their sense of touch to orient themselves in busy environments.

Landmarks

Identify key tactile markers, such as the texture of a table, the shape of a doorway, or the feel of a rug.

1.4.1.2 Temperature (Möller et al., 2009)

They can feel the temperature, allowing them to determine if they are inside or outside, or what environment they are in.

1.4.1.3 Smell (Tariq, 2024)

Blind and VIP can use their sense of smell to orient themselves in busy environments.
The smell of food, flowers, perfume, coffee, grass, rain, and other scents can help them determine where they are.
Some people use their sense of smell to recognize specific locations, such as a bakery or a park.

1.4.1.4 Auditory Cues (Lubomirsky, 2024)

Sound Mapping:

Listen for echoes, air movement, or specific sounds (e.g., a ticking clock, hum of an appliance) to identify the size and layout of the room.

Voices

People's voices can provide information about the location and activities of those around them.

Music

Music can help identify a specific location, such as a store or restaurant.

Natural sounds

The sounds of wind, water, birds, and other natural elements can help identify the environment.

Footsteps

Sounds of footsteps on different surfaces can indicate proximity to furniture or walls.

1.4.1.5 Trailing (Pissaloux & Velazquez, 2017)

Run fingers along walls or furniture edges to maintain orientation and locate features like doors or switches. This is often used in airplanes to locate where the seat is and also find their way back to it.

1.4.1.6 Memory and Repetition (Perkins School for the Blind, 2024)

Room Familiarization

Repeatedly navigate the room to reinforce its layout in memory.

Consistent Organization

Keep furniture and objects in predictable, fixed positions to make orientation easier.

1.4.2 Navigation

Focusses on methods to that help a VIP determine where they are going. When navigating several important things have to be taken into account such as:

1.4.2.1 Space (Bhagchandani, 2020)

Sense if the area around them is clear and spacious enough for them to move around.
It is important that obstacles are detected, to prevent colliding with them.

1.4.2.2 Hidden Obstacles (Perkins School for the Blind, 2024)

Hidden obstacles, such as a radiator or a chair under a table, can pose a fall hazard.
Make sure these obstacles are clearly visible, for example by marking them with a contrasting colour.

1.4.2.3 Tactile Cues (Qiao et al., 2023)

Tactile cues are often used to detect what are they are walking to. This is often achieved by sensing a change in the floor, such as a threshold or a staircase, can pose a fall hazard.

Make sure these changes are clearly visible, for example by marking them with a contrasting colour, or clear difference in texture.
For example a VIP can sense if they have reached a gate, as those areas are carpetted while the walk towards it is usually textured by tiles.

1.4.2.4 Elevation (Yau et al., 2004)

Sensing a difference in height is often used to know if the VIP is experiencing vertical movement, like going up stairs or up the lift.

1.4.2.5. Movement (Pissaloux & Velazquez, 2017)

VIP can easily sense movement around them, such as travellators or if they are inside a vehicle. They can also use movement in wind to determine what direction they are moving in.

1.4.2.7 Light and Contrast (Bhagchandani, 2020)

Lighting and contrast: Provide sufficient and even lighting to make obstacles clearly visible. Also create contrast between floors, walls and furniture to make the walking route more visible.

1.4.2.8 Spatial Organization (Golledge, 1999)

Keep walkways clear of obstacles such as furniture, cables, bags or shoes. Also, organise the space logically so that essential areas such as the kitchen,

1.5 Mental Mapping

By combining methods used to for orientation and navigation, eventually VIP can make a mental map of the area they are in. By successfully creating mental maps VIP can navigate through the areas individually and often without the need of additional assistance (Golledge, 1999). This is often achieved through repetitively moving through an area, spending a lot of time in an area to, and keeping the area organized so that it stays familiar to them.

Though mental mapping is very useful, it does require some time and effort to create it. Furthermore it is often only achieved successfully in small and familiar areas like at home, or the supermarket the regularly go to (Hoe Kunnen Blinden En Slechtzienden Zich in Een Gebouw Oriënteren?).

At airports it is very difficult to create mental maps, due to their large sizes and unfamilair and chaotic environments (Bai et al., 2019). However it is still possible to create a mental map to a certain extend to for example get familiar with certain key points in certain areas.

1.6 Simulating a VIP

To better understand the problem from the Users perspective, I also tried to simulate being a VIP at an airport and carry out an orientation training at Visio Netherlands. While the simulation is not as accurate as that of a real VIP, due to my significantly lower experience in navigating as one, the simulation did provide useful insights on how VIPs percieve their surrounding environment and time as well as their use of energy through navigating.

Figure 6: Regular Route from Train Station to Check in Desks

Figure 7: Blind Route from Train Station to Check in Desks

1.6.1 Environmental Perception

With the lack of sight sound and touch were predominantely used to scan the surroundings.
It often took a while to identify what was being touched or heard, leading to a feeling of uncertainty. Furthermore it takes time to determine the direction of dynamic objects such as rotating doors, escalators, and elevators. Not knowing where to clearly go, finding ones way finding ones way is a process of trial and error. Resulting in much more turns and a indirect path as seen in Figure 7. Asking people in the surrounding area is often the method used to obtain information about one's surrounding. Though this process takes time and effort, and also requires one to find a suitable person to explain this information to.

1.6.2 Distances and Time

Sound is often used to percieve how far something is. Though without sight it is still difficult to determine where exactly and at what distance that certain object is. Since one constantly has to move their white cane around and scan the environment, it takes a longer period of time to travel a certain distance when compared to sighted people (Guerreiro, Ahmetovic, et al., 2019). Feedback on time is also more difficult to obtain, as one cannot simply look at clocks.

1.6.3 Guidance

Due to not knowing what is around one's surroundings in unknown environments, human guides such as friends family and or personal assistant staff usually highlight important landmarks, the surroundings, and obstacles along the way (Chen, 2024). These guides will highlight the route until it has been covered multiple times to allow the VIP to create a mental map of the area.

1.6.4 Energy

Sight helps to very efficiently percieve what is in an environment, with minimal energy for a VIP. For VIPs constant sweeping and listening and percieving is used to percieve and understand what is around them (Başgöze et al., 2020). While this process works, it is extremely exhausting when done without guidance, and in large crowded environments where one also has to filter the noise to determine what is being heard (Jeamwatthanachai et al., 2019). Furthermore it also takes time to confirm if what is being heard and touched is actually the actual thing being percieved. Whereas with sight this confirmation is done in an instant.

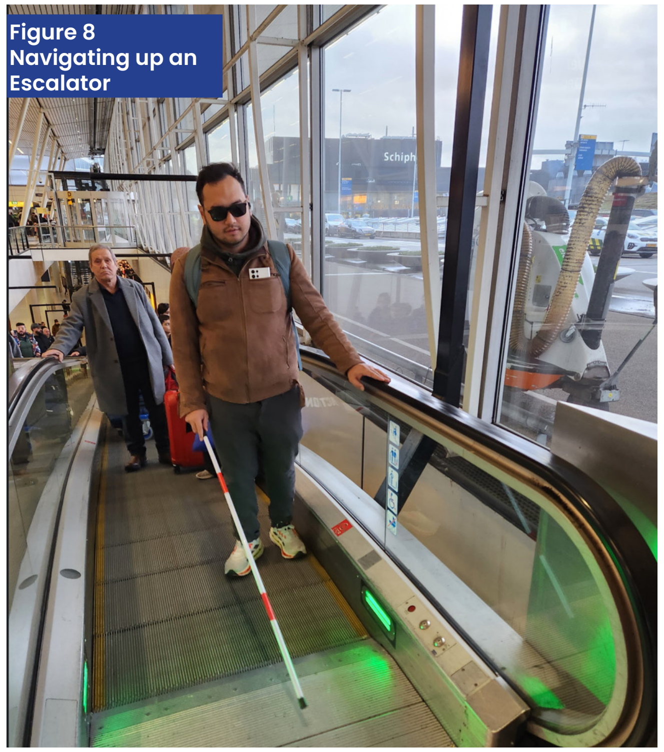


Figure 8 Navigating up an Escalator

Methodology

The methodology for this simulation required a White Cane, Strava Tracking App, and Shaded Goggles to Block vision. An assistant was there to take pictures and at times guide the way when totally lost.

1. Preparation of Experiment
2. Start Timer and Tracker
3. Start Navigating from the Platform to Schiphol Plaza
4. Navigate through Schiphol Plaza to the Departure Hall
5. Navigate through Departure Hall to the Check In Desk
6. Go Back to Start Point
7. Do Steps 2 - 5 but then as a regular sighted person
8. Compare results and draw conclusions

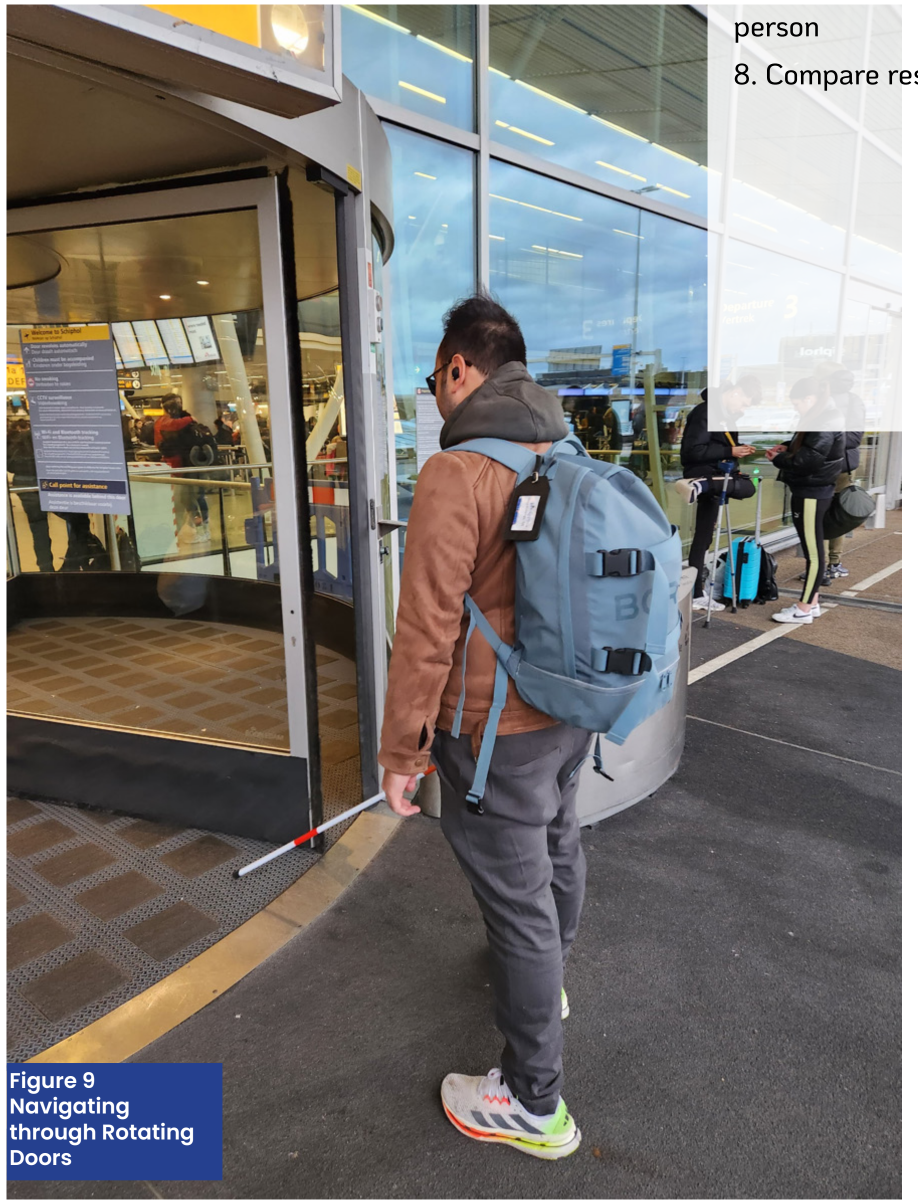


Figure 9 Navigating through Rotating Doors

Figure 10: Navigating up a Staircase

1.7 Design Implications

From this chapter it can be understood that the intended VIPs are those with Level 3 - 4 VI. These VIPs have limited or no sight at all, and hence make use of their other senses such as hearing and touch. While this process works in familiarizing ones surroundings and creating a mental map, it is often an energy intensive task when required to navigate large and unfamiliar areas like airports. Due to the many obstacles and complexity of an airport a lot of energy is required to understand and process all the information around them, as well as to confirm that what is heard and felt is actually what is percieved.

Due to the complexity and high level of energy required, it often leads to disorientation, stress and ultimately frustration, which results in VIPs to abandon the initaitive to do activities independently. The dependency on others often comes in the form of family and friends or assistance staff at the airport. These help guide and describe the surroundings creating certainty. While welcomed and appreciated, dependency comes at a cost of no longer being in control of ones environment and ones ability to act in it independently. In the end a VIP would love to navigate through an airport no more than a regular person would.

From this Chapter Several Key Drivers are Identified
> Perception of an Environment at Low Cognitive Loads
> Navigating through an Environment with Certainty
> To act Independently and be in Control in an Environment

2 Context Analysis

Since the Airport, Schiphol specifically is the context of this study. An analysis on the context was conducted to better understand its impact on the User and to identify problems and opportunities areas for possible solutions. The context analysis explores the environment and layout of Schiphol airport, current assistance services that exist, as well as solution implementations at other airports and context areas.

2.1 Airport Environment

Airports like Schiphol, having a floor area of 1.3 million square metres and handling up to 66.8 million passangers a year (Schiphol | Valuable Assets), are generally large and crowded places, where multiple different things happen at once. This environment presents certain challenges for VIPs.

2.1.1 Time and Distance

Time is an important factor at airports, and one has to reach the gate within a given time if they do not want to miss their flight (Kozlova, 2023). Furthermore depending on where the flight departs at Schiphol, User have to cover a significant distance before they reach the gate. As VIPs have difficulty seeing or cannot see at all estimating the distance and time left is challenging limiting their control of their environment (Jeamwatthanachai et al., 2019). This significantly reduces ones certainty and confidence in navigating the environment independently.

2.1.2 Obstacles

Aside from time and distance, Schiphol contains numerous different types of obstacles. They can be categorized as dynamic obstacles, which move and are difficult to detect, and static obstacles which do not move and are easier to detect.

Dynamic

Rotating and Sliding Doors, People, Carts

Static

Walls, Barriers, Posts, Pillars

2.1.2 Transporters

Transporters refer to things that one might need to use to move vertically or horizontally.

Vertical

Elevators, Escalators, and Staircases

Horizontal

Travellators

Currently obstacles and objects in an environment are detected through

Figure 11
Car Drop off Zone at Schiphol

Figure 12
Train Drop off Area at Schiphol

Figure 13
Check In Hall at Schiphol

Figure 14
Check In Desks at Schiphol

Figure 15
Terminal Airside
at Sydney Airport

Figure 16
Terminal Airside
at Hong Kong Airport

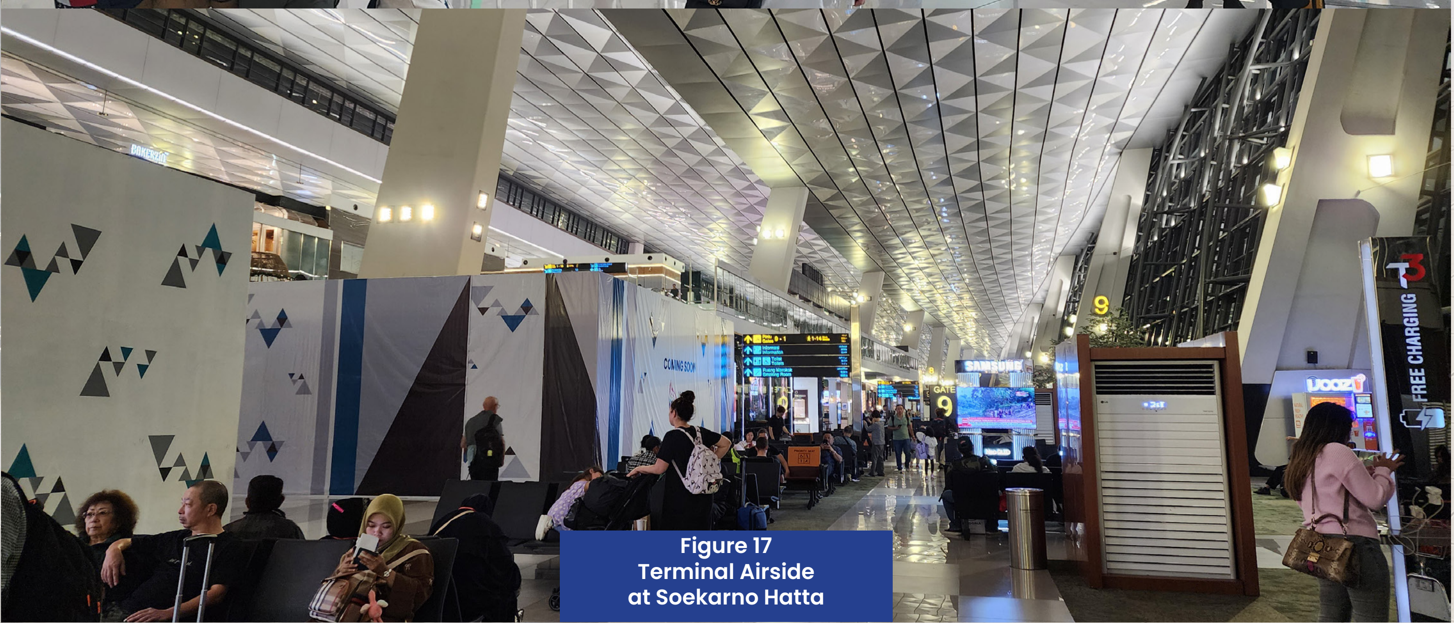


Figure 17
Terminal Airside
at Soekarno Hatta

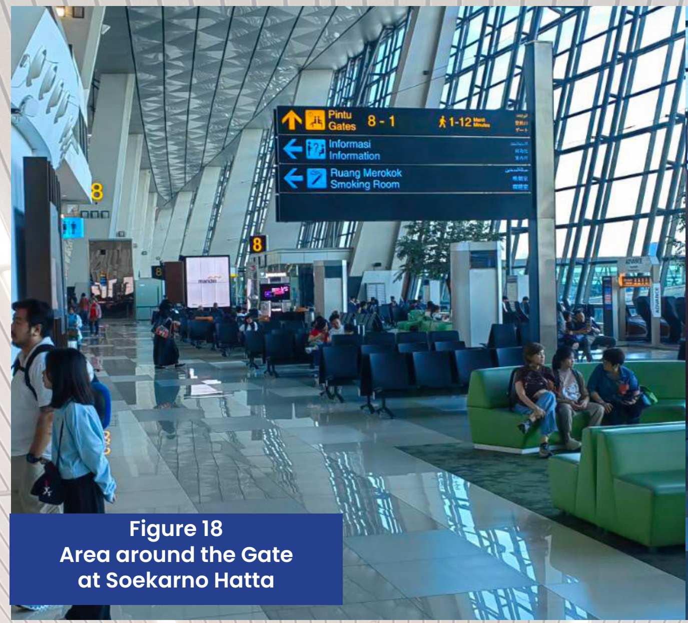


Figure 18
Area around the Gate
at Soekarno Hatta

Figure 19
Gate Area
at Soekarno Hatta

listening for them or feeling them with a white cane. (Indoor Wayfinding and Navigation, 2019). However to percieve this information and deduce what it means can take a lot of energy. For example to use an esclator or travallator the location first needs to be deduced and then the right direction (Real & Araujo, 2019). This process requires time, which is not necessarily plentiful when trying to catch a flight by yourself.

2.1.3 Silent Airport

Schiphol is also known to be a silent airport, hence information like gate changes and flight information is only presented via visual means through information screens. While information like this is also presented via the Schiphol app, it cannot be guaranteed with certainty that all visual impaired have the app. Making them miss out on vital travel information for their journey.

2.1.4 Key Take Aways

With a large airport like Schiphol, the environment contains a lot of details and pieces of valuable information. The problem is that it is either percieved in a way that information becomes overloaded through noises from crowds, or that information is lacking such as distance time and flight information. Both making it difficult to process and deduce the environment around them. This creates a lack and overload of information is rather frustrating and makes the large airport environment not just complex to navigate through but also one full of uncertainty.

2.2 Airport Layout

2.2.1 Layout Configuration

Schiphol Airport is built using a single terminal concept, which is split into three main departure halls. These departure halls are then seperated into main piers where aircraft are parked to the gates (Schiphol | Valuable Assets).

While this configuration is beneficial in the sense that terminals are identical to another creating familiarity to navigate through them, it also contains challenges. The main challenge is that pier terminals contain a multiple turns. Usually in smaller areas turns are identifiable by VIP by identifying the corner (Guerreiro, Sato, et al., 2019). However in large buildings like Schiphol, corners are not easy to identify. Furthermore sound is often used to identify and pinpoint a certain direction, however with a noisy environment like Schiphol knowing where to turn and in what direction can be disorienting (*View of Investigation of Blind Spatial Cognition and Understanding of Spaces to Navigate Without Vision)*.

2.2.2 Airport Sections Configuration

Like all large airports, Schiphol can be divided into several sections namely the the Entrance, Check In Area, Security, Immigration, Terminal Airside, and Gates (Ashford & J, 2025). These sections can also be further categorized into two distinct groups, Fixed and Dynamic. Fixed sections being those that do not change in location, and dynamic ones being those that change in location. For each section key destinations and points of interests are identified, as well as the goal for the User passanger. The entire Journey is highlighted in Chapter 4.

	Enterance	Check In	Security	Immigration	Terminal Airside	Boarding Gate
						
Description	*The entry point into the terminal building right before check in, where passengers arrive after being dropped off by car, bus, taxi or train.*	*Counters or kiosks where passengers confirm their flights, check luggage, and receive boarding passes. Check-in areas can change, hence the area is a dynamic environment.*	*Passport control area where are verified for departure clearance.*	*The main concourse or hall leading from security/immigration to boarding gates, with amenities like shops, lounges, and restaurants.*	*The entry point into the terminal building right before check in, where passengers arrive after being dropped off by car, bus, taxi or train.*	*The area where passengers wait to board the plane and access the aircraft through boarding bridges or stairs. Gates can change, hence the area is a dynamic environment.*
Goal	*Find enterance to airport*	*Find the right check in counter*	*Take off luggage and recollect after scanner*	*Show right documentation*	*Find the check in gate*	*Wait for boarding gate to open or explore surrounding area*
Points of Interest	*Assistance Desk, Ticketing Office, Accessible Toilets, Cafes & Restaurants, Minimarkets, Shops*	*Assistance Desk/ Meeting Point*	-	-	*Accessible Toilets, Cafes & Restaurants, Minimarkets, Shops, Exhibitions,*	*Accessible Toilets, Cafes & Restaurants, Minimarkets, Shops*

Figure 20
Schiphol Airport Sections

2.3 Assistance at Schiphol

2.3.1 Airport Assistance

At Schiphol assistance services are provided for VIPs. This can be requested at the desk, at the 27 assistance poles spread throughout the departure zone and drop off zones, as well as online via the website. It is often suggested to book it 48 hours from beforehand (*Schiphol | Assistance for Departures From Schiphol)*, so that the airport can prepare someone in advance to avoid long waiting times that can take up to 30 - 45 minutes (*Schiphol | Requesting Assistance*). This assistance comes in the form of guides, that will lead the VIP from the assistance pole or service desk all the way into the seat of the aircraft.

Using airport assistance generally gives VIP several privileges. One is that they can make use of airport buggies that bring the VIP to the gate in a fast and time efficient manner (Bhagchandani, 2020). Aside from that making use of airport assistance also grants access to use priority lanes, skipping lines and crowds.

Assistance staff by default bring the VIP directly to the gate, however they also assist the VIP if they want to go to café's restaurants or toilets along the way (The Blind Life, 2019). However time at these places is limited as assistance staff have busy schedules.

At the gate, often assistance staff place VIPs at a designated waiting area, and could either stay or leave with the VIP. When leaving they are obliged to check on the VIP every 30 minutes (*Schiphol | Requesting Assistance*).

When assistance stays, they also offers the VIP the opportunity to explore a bit around, and go to the toilet while waiting for their aircraft.

2.3.2 Other Forms of Assistance

Aside from airport assistance, VIP also make use of their own assistance, or request it from a stranger.

Personal Assistance

Having a family member or spouse as guide is often the best for of guide, due to the higher level of trust and personalized level of service. Personal guides often know what restaurants and cafes to stop by before going to the gate, and when the User passenger needs to go to the toilet (Kozlova, 2023). Furthermore they also know how to more easily guide them, and what to do if something might go wrong. Their assistance however is not always possible, as often family members could be busy with their own schedules, and it is also a financial burden as an additional ticket has to be booked (Campese et al., 2016). In general family members or friends are more often there for assistance on leisure trips, when compared to business trips.

Requesting Strangers

Requesting assistance from strangers is simply done through the method of asking randomly. The process of asking is in general fine and VIP easily entrust strangers to guide them. Sometimes certain VIPs find it uncomfortable, as they do not know in what state strangers around them are in (Blindman Jack, 2023). It can be quite exhausting after a while and asking multiple strangers for where to go to (Rello, 2017). When requesting help though VIPs do prefer it to be done in a subtle but noticeable manner.

2.3.3 Limitations of Assistance

High Dependency on Others

One of the main limitations of assistance is the dependency on another to carry out tasks in the environment of an airport. While help is appreciated,

Figure XX:
User Interface of Assistance Poles

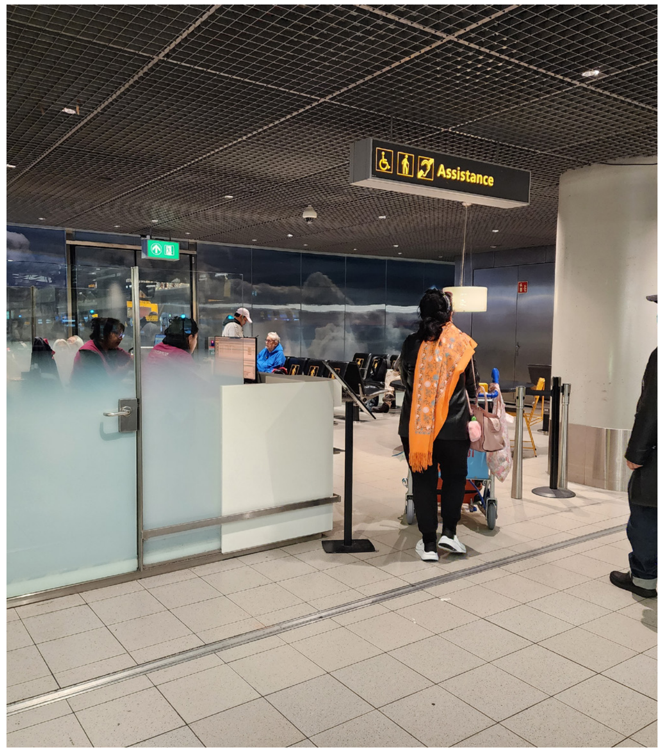


Figure 21:
Assistance Desk at Schiphol Departure 3

being dependent on someone else for knowing where one is and gaining information of the surroundings can get frustrating overtime (Dainty, 2019). The journey to the gate and experience at the airport is both influenced and dependent on the assisting party as well.

Communication Issues

Another issue is that it can be difficult to communicate what one needs or wants to know from the environment. Assistance might ignore certain details the VIP wants to know (Guerreiro, Ahmetovic, et al., 2019). When left alone, it can be difficult to get in contact with assistance staff, making VIP feel abandoned and anxious that they might not get picked up (Blindman Jack, 2023).

Figure 22:
Assistance Pole at Schiphol Departure 3

2.4 Initiatives at Other Airports

The issue of independent navigation and way finding for VIPs is not a new problem, and several airports around the world have taken the initiative to provide services or facilities to enhance a VIPs ability to travel independently through the airport.

2.4.1 Bluetooth Beacons

One of the initiatives implemented at Pittsburg Airport in the US, Sunshine Coast Airport in Australia (Aap, 2023) and Narita in Japan is the usage of NavCog (Iozzio, 2014). NavCog is an indoor navigation system which makes usage of numerous bluetooth beacons and a mobile phone to help localize and navigate a VIP through an environment such as the airport (Harrison, 2018). The system is relatively precise with errors of up to 1 meter (Abidi et al., 2024). With the system a VIP can find their way independently to the gate, and to other amenities like toilets, significantly boosting their independent capabilities. The main drawback of this system is that it requires preinstalled infrastructure in the form of bluetooth beacons in order for it to properly work (Kunhoth et al., 2019). These beacons also need to be maintained regularly in order to provide higher accuracy of localization.

2.4.2 Virtual Assistance

In Louisville, and Milwaukee Airport in the US, another iniative is used in the form of Aira Glasses (Kunzler, 2023). Using the wearable glasses and a mobile phone, VIPs can contact an Aira agent. By looking through the glasses with an installed camera, the agent acting like a virtual assistant leads the VIP through the environment (WHAS11, 2017). While this method still makes the VIP dependent on someone else, the assistance is more personal, and the agent will stay with the VIP throughout their journey until they reach their plane. In the end this method creates certainty that allows VIPs to explore an airport more independently (Mashiata et al., 2022).

2.4.3 Take Aways

From the iniatives used by other airports, it can be seen that by providing means of certainty empower independence. This is certainty is achieved in two distinct ways. NavCog creates certainty through relatively high precision localization giving feedback to the VIP on their position, and the surrounding environment. While Aira creates certainty through having the ability to request assistance, who can help in situations when things can go wrong. Both iniatives do have their limitations in terms of infrastructure requirements, though this will be explored more in Chapter 3.4.

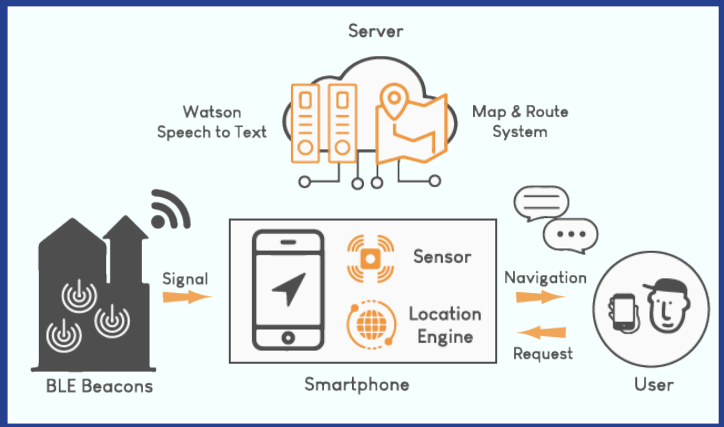


**Figure 23:
Working principle of
NavCog**

**Figure 24
Set up of navigating
using NavCog**

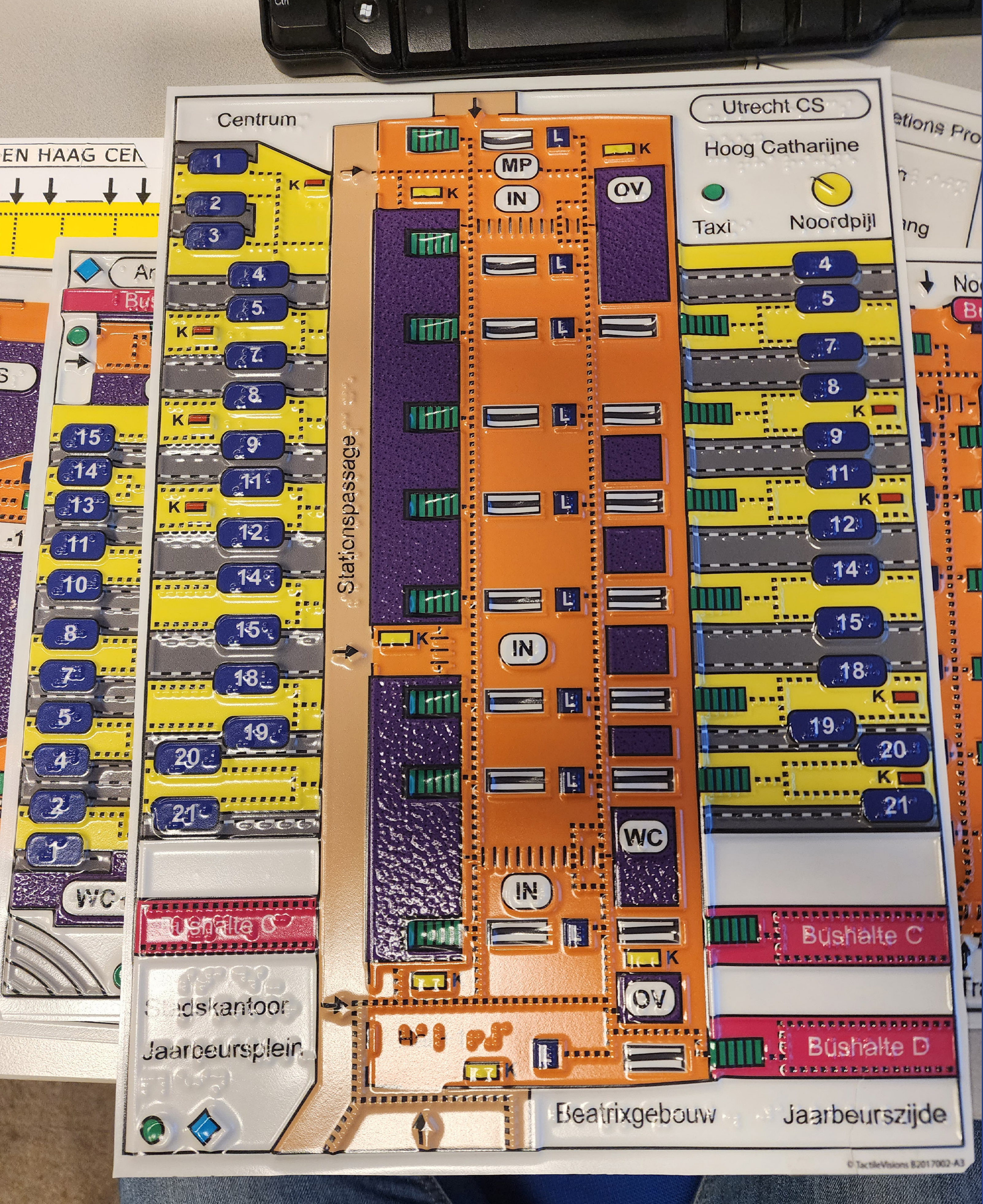


Figure 25:
Braille Map of
Utrecht Central Train
Station

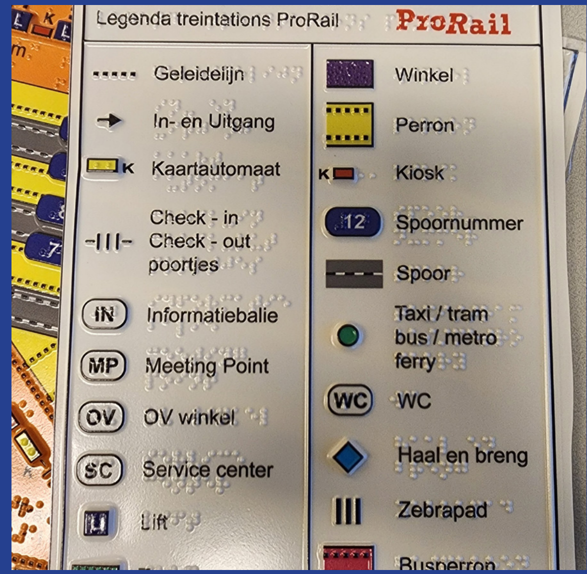


Figure 26:
Relevant Environmental
Information at a Train Station

2.5 Initiatives in other Contexts

Aside from at Airports, other areas like train stations in the Netherlands also have carried out their own initiatives to make travel for the User more accessible and indepent for them. This is achieved through providing tactile cues at stations such as blind paths and braille signage to indicate platform numbers, as well as through providing Braille Maps.

2.5.1 Braille Maps

Every major railway station in the Netherlands has a Braille version of itself which can be used by VIPs to find their way in the station (Guerreiro, Sato, et al., 2019). Different areas of the station have a distinct texture, color and braille is used to describe platform numbers and where facilities like service centers or shops are located.

2.5.2 Treinweizer App/Feature

Aside from Braille Maps, the NS also has an app and web feature called Treinweizer which described the route and travel information VIPs have to take when travelling by train. Through this app assistance can also be requested when necessary, which would help guide VIPs at stations.

2.5.3 Take Aways - Conveying Relevance

One of the key take aways of the initiatives carried out by the NS and ProRail is how information on Braille Maps are conveyed to the VIPs (Golledge, 1999). Stations being large buildings, though still significantly smaller than airports, contain a lot of detail. This can create information overload and clutter for VIPs. However by looking at stations and how they are organized, several key information can be derived that can also be used to breakdown and describe large areas at airports (Guerreiro, Sato, et al., 2019).

Pathways

A necessary piece of information is to describe the route and where appropriate turns should be made.

Areas

Information should be given when entering a new area or section of the airport.

Gate Location and Numbers

Information should be given about the gate location and the number, as well as feedback be provided when arriving there.

Amenity Locations

Information of surrounding amenities should be provided when necessary for the VIP.

Travellators and Escalator Locations

Information on where to go from one level and by what means should also be provided.

2.6 Design Implications

From this chapter it can be understood that Schiphol Airport provides numerous navigational challenges for VIPs. One of the main challenges is its dynamic and chaotic environment, which is difficult to percieve and process for VIP. Furthermore the airport is large making it difficult to memorize and produce mental maps that otherwise help VIPs. What makes it worse it that the airside of the airport is seldomly visited by VIP, making it even more challenging to memorize and familiarize with.

The high amount of detail can create information clutter, and disorient VIP. On the contrary due to it being a silent airport, their reliance on sound is obsolete and VIPs can also miss on valuable travel information.

Fortunately assistance services are provided by the airport, which provide priority access to avoid certain crowded areas. However the dependency on others, reduces the ability to retain control of ones environment. This is especially worsened when assistance leaves, and there are no ways to get into contact with them.

Laslty through iniatives at other airports and context, certainty can be created through certain technologies like NavCog and Aira Glasses. One providing certainty through providing information on location and another through means of communicating with assistance staff. Furthermore by breaking down a surrounding environment into relevant details, even the most complex environments can be interpreted and navigated through.

> Certainty empowers Independence
> Maintain Contact with Assistance
> Convey Relevant Details of an Environment
> Navigate within a Given Time

3 Current Solution Analysis

With navigating as a visual impaired individual being a problem that has existed since the dawn of time, solutions to overcome this problem have been developed overtime. This chapter explores the primary and secondary types of navigational aids that exist, methods for indoor localization, how feedback and input are communicated and how risks can be overcome.

3.1 Navigational Aids

Current navigational aids provide guidance and real-time information, reducing the VIPs dependence on others for transportation and daily navigation tasks, thereby not only empowering them but also preserving a greater degree of control over their lives (Başgöze et al., 2020). Furthermore, navigation systems alleviate the stress and anxiety associated with travel, assuring VIPs that they possess a reliable tool to offer guidance in unfamiliar surroundings, thereby facilitating certainty and independence.

Navigational aids can be subdivided into two main types, primary aids, and secondary aids. Primary aids are those that the VIP always uses when navigating through an environment, and Users will rarely go out without them (Möller et al., 2009). They are as essential to VIPs as a wheelchair or cruches are to mobily impaired individuals. Secondary aids are used in combination with primary aids, and the Users ability to percieve and understand their surroundings as well as to navigate through it (Kunzler, 2023).

3.2 Primary Aids

3.2.1 White Cane

The only primary aid currently used by VIP in both their daily life and at airports is the White Cane (Yau et al., 2004). Seen in Figure 27 white canes are swept in front of the VIP from left to right, extending their ability to detect objects through touch by 1.5 - 2 meters (Wise et al., 2012). Through using white canes VIPs can pick up tactile information like blind paths, corners for turns, and feel different surfaces to know that they are entering a new area. In combination with sound VIPs can also use the white cane to verify what is being detected.

White canes however are primarily used to detect and potentially avoid obstacles, for the VIP. VIPs would need to rely on secondary aids to provide more information on navigation and what is around them. Furthermore while they can be used to percieve a room, large areas like the airside terminal halls of airports are much to difficult to percieve and process with just the usage of a white cane (Real & Araujo, 2019). Due to also only sweeping the floor, white canes do not have the ability to detect objects that are located above ones hips, or percieve them correctly (Ricciardi et al., 2009). At airports like Schiphol with information signs often being located ontop of poles, the information sign can be falsely identified as regular pillar or pole.

3.3 Secondary Aids

3.3.1 Guides

Human Guides

Human guides are a navigational aid for the VIPs as old as the dawn of human civilization itself. It is often a nice form of assistance, as type of assistance is quite flexible and can be adjusted to the unique needs of the VIP, though this is limited to how well the communication between both parties is (Yau et al., 2004). Human guides can come in the form of airport staff, cabin crew personnel, family or friends.

Human guides often walk next to the VIPs, and verbally tell the directions on how to navigate through an environment or directly guide a VIP through that environment (The Blind Life, 2019b). They can help clear an environment from obstacles, and take direct action to prevent a VIP from colliding with an obstacle. Doing so VIPs do not have to actively scan their environment all the time and can navigate through it in a more passive manner (Ricciardi et al., 2009).

While human guides are versatile navigational aid for the VIP, they come at an additional cost of financial resources. This is especially the case when requiring the guidance of family members, friends, or personal assistance from home, who now also require a ticket for travel. Furthermore overreliance on them can be frustrating for VIPs as they can lose a sense of independence.

Guide Dogs

Assistance can also come in the form of guide dogs who are specially trained to

Figure 27:
White Cane Usage Simulation

help navigate a VIP through a certain environment. Guide dogs rarely change from their owner, and the owner forms a special bond with their dogs overtime.

While guide dogs lead the way, they do not necessarily know the destination which is something the VIP has to know (Jeamwatthanachai et al., 2019). Hence if the VIP does not know where the destination is, it will become a challenge for them to navigate through an environment. Guide dogs also result in both hands being occupied by the VIP, one to hold their white cane, and another to hold the dogs leash (*Living With Blindness and Visual Impairment*). This could make it challenging when one needs to use their hands to carry out activites.

3.3.2 Wearables

Wearable devices are assistance devices that the VIP wears on either their arms, legs or body. They make use of a wide range of sensors and feedback methods to detect and inform the VIP of obstacles and navigational cues.

Glasses

Glasses are often equipped with cameras to detect objects, read text, or recognize faces. Doing so it can inform the VIP more on what is around them and give access to previously inaccessible information such as information screens (Matney, 2018). Glasses are beneficial as they are attached on the head and detect based on the heads turn. Hence it feels more natural when it provides information on what is infront of the VIP, and can be used to mimic and simulate sight. Since it is on the head, it is important that its weight should not be to heavy, as this can create discomfort over long periods of time.

Belts

Another form of wearable are belts, which can act like utility belts to attach an array of different sensors. Compared to glasses much heavier and complex sensor systems can be attached to them (Bai et al., 2019), however due to not being able to move with the direction of sight like the glasses, the direction relevant to the position of the VIP also needs to be informed to provide information on surroundings.

3.3.3 Mobile Apps

Aside from wearables, numerous mobile apps have also been developed to aid navigation for VIP. Often making use of a phones camera, they can describe environemnts and read out text to the VIP.

Navigation and Orientation

Navigation apps like Lazarillo, BlindMaps, SeeingAI and Bixby Vision, aid VIPs to provide them with more information on their surrounding environment (Hurst, 2017). This is achieved through a phones camera, and gps to reference ones location on what is around them. The limitation of these apps is that due to their overall reliance on GPS they do not necessarily work for indoor environments. Cameras often fail to detect and describe important key details in an environment like the airport, such as distinguishing a check in area from immigration, both can be identified as the same area (Okolo et al., 2024). What is described to VIPs in the description is also not always relevant to know (Abidi et al., 2024). To also operate a phone requires one to use both hands to scan the environment, which is troublesome when on the move at an airport, and already having both hands occupied with luggage and the white cane.

Assistance

Assistance apps like Aira and BeMyEyes, can contact a VIP to an agent or voluntary assistant. By being in contact with assistance, more information of surrounding areas can be provided, and certainty of navigating through it is increased (Bhagchandani, 2020).

3.3.4 Key Take Aways

In conclusion, white canes are always used in the environment when navigating through it in combination with secondary aids. Since VIPs are on the move in the airport, it is more desirable to have something that is hands free. Wearables exist to help detect and inform of the surroundings in a hands free way. However the way sensors are placed is important to keep in mind on what is detected and how it is conveyed.

Information on surrounding environments are currently provided through a number of means, through guides and apps. However how this information is provided is often not ideal, often containing irrelevant details. Current solutions also have trouble in distinguishing key areas at an airport that is crucial to know to determine ones position.

Figure 28:
Aira Smart Glasses

3.4 Localization

3.4.1 Outdoor vs Indoor Localization

Unlike outdoor localization, which is predominantly done using GPS, indoor navigation is carried out through a number of methods. This is often distinguished through two main methods, either through installing infrastructure to provide localization, or using the surrounding environment as a reference to determine localization.

3.4.1 Infrastructure Based

Infrastructure based localization makes use of Bluetooth beacons, RFID, Wi-Fi or QR to provide information on ones location (*Indoor Wayfinding and Navigation,* 2019). These localization solution have been used in several airports as described in Subchapter 2.5, and have empowered VIP to navigate more independently.

3.4.2 Reference Based

Another solution is to use reference based technologies, such as Dead Reckoning and SLaM. Without the need of infrastructure, they are less burdensome to be implemented at airports, however they do need a reference map and ability to distinguish certain landmarks in order to accurately determine ones location (McMinn, 2025). Through using sensors like LiDAR, IR, and or a camera, reference points of the environment can be picked up and processed to determine the location based on a preloaded map in the system (Bermudez, 2024).

3.4.3 Key Take Aways

While infrastructure based solutions tend to work, it can be a hastle and burden for airports to install and maintain such systems. This can cause such systems to fail and not work optimally, which can potential decrease the VIP trust in such systems. While reference based systems are not perfect themselves, they do eliminate the need to set up infrastrucuture systems and maintain such systems. Reference systems do need to know how to accurately identify and distiguish a certain area from another, or a part of an area from another area in order to work to a degree that they can be reliable. From Subchapter 3.3, current detection methods like camera based apps do work, but often struggle to provide the right amount of detail about a room. Detecting the necessary landmarks to distinguish an area from another area is still a challenge, and one necessary to overcome in order to get enough information of the right references to ensure the right localization and position can be determined to navigate through an area at an airport.

3.5 Feedback

Since sound and touch are the main methods to recieve information on an environment, they are also the main methods of providing feedback to a VIP.

3.5.1 Auditory Feedback

Auditory feedback can come in the form a simple notification sounds like beeps or having text or notifications read out by a certain system. This type of feedback is often used to convey navigational information and environmental information through apps in Subchapter 3.3.3. Due to auditory feedback being informed through speech, it is often a pleasant form of feedback as it requires less effort to percieve what the feedback means compared to haptic feedback (Kunhoth et al., 2019). This allows this type of feedback to also convey more complexed forms of information compared to haptic.

On the other hand, auditory feedback does require the usage of an earphone, which can block out sounds coming from the environment. Furthermore listening to everything after a long period of time can by itself be exhausting.

3.5.2 Haptic Feedback

Haptic feedback refers to feedback recieved through touch and vibrations. Unlike auditory feedback which can be easily percieved through speech, distinct vibrations and textures need to be understood first before one knows what they mean (Guerreiro, Ahmetovic, et al., 2019). Hence it can only be used to inform short be significant pieces of information, like entering a new area, that an obstacle is nearby or that one goes off course (Hurst, 2017).

3.5.3 Key Take Aways

While both forms of feedback are distinct from one another, they are both able to convey different types of information of an environment to the VIP. Due to this it is rather useful to combine the two forms of feedback so their functions can complement one another, and the VIP can also easily distinguish what kind of information is provided to them about an environment.

3.6 Input

Aside from feedback, a VIP also needs to be able to control and input certain settings in their device. Currently this is either done through voice command or touch.

3.6.1 Voice Command

Voice command input is a desirable form of input as it easily allows the VIP to communicate their command to a device. This reduces the effort to navigate to a certain option (Chelladurai et al., 2023). On the other hand distinguishing a voice to a certain command can be challenging, especially in crowded airport environments which can disrupt such commands.

3.6.2 Touch

Touch input is achieved by either pressing a button, or selecting an option on a screen. Unlike voice command it requires more effort for touch to navigate and select more complex options (Abidi et al., 2024) However it is suitable when selecting direct and simple options, which can be carried out with the press of a button. An example of this is pressing a button to request assistance.

3.6.3 Key Take Aways

Similair to feedback, both forms of input can be used to select different forms of input, hence both are complementary to another. With voice commands serving the selection of more complex tasks while touch is used for more direct and simpler tasks. Determining which tasks are which is still something to be developed further on in Chapter 9 & 10, where requirements and ideation on possible solutions takes place.

3.7 Risk Prevention

3.7.1 What Could Go Wrong?

Wrong Identification of Obstacles

Sensors often have the risk of identifying obstacles the wrong way. Hence this could confuse VIPs on what is around them, and what to do to avoid such obstacles correctly.

Battery Dies

This is a problem experienced by Smart Devices and like Smart Canes and Smart Phones, as they rely on a battery for power sources (Campese et al., 2016). Due to this risk, it is important to inform the VIP beforehand when the battery is low, or where the nearest charging station is. Furthermore if it needs a battery, it needs to be able to be charged easily and without aid of others.

Going off course

Walking into the wrong direction is a common mistake experienced by VIPs. This is often experienced in large spaces like the terminal building offering a lot of free movement (Pissaloux & Velazquez, 2017), where a sense of direction like moving straight can also be challenging.

3.7.2 What Happens if Things go Wrong?

Request Assistance

In the event that something goes wrong and the device can not correct the mistake, a last resort would be to ask assistance from strangers in the surroundings (Mashiata et al., 2022). In the event that no one is nearby, or it is difficult to reach out to people nearby, VIPs can request help from a guide via an app like Be My Eyes (Kunzler, 2023). Through this app a volunteer or trained professional can see the surroundings of the VIP through their phone camera and guide them accordingly.

3.7.3 Correcting Mistakes made by the System

Correcting Direction

Walking into the wrong direction is a common mistake experienced by VIPs. This is often experienced in large spaces like the terminal building offering a lot of free movement (Legge et al., 2017), where a sense of direction like moving straight can also be challenging.

3.7.4 Gaining Trust

Repetition and Success

Trust is gained through repetitive success rate granted by the navigational aid or any aid device in use. Repetitive successful uses guarantee higher trust (Golledge, 1999). The easier it is to use and learn the to reach a destination with the aid the more easier it is to trust it.

3.8 Design Implications

From this chapter solution implimentation for VIPs have been explored. Since the white cane is a primary aid it is not an option to replace its functionality with the development of an entirely new solution. Instead its functionality can be further enhanced through the development of a secondary aid.

Currently a number of secondary aids exist, that help the VIP obtain more information of their environment, and hence aid them in navigating through it independently. However most secondary aids, are either reliant on human guides to describe environments effectively. Solutions like apps using cameras and sensors still fail to convey and describe a large environment as an airport terminal building sufficiently to a VIP.

VIPs are constantly on the move and have both hands occupied in an airport environment with their white cane, and potential luggage. Wearables are a viable solution, however placement of sensors is important to obtain the right amount of information of an environment. This is also important to create reference points of locations in order to localize and navigate VIPs through the environment without the need of infrastructure.

Lastly both feedback and input should be designed using a complimentary approach, whererin the different types are used to convey distinct levels and types of information. Doing so there is always a back up if one method fails, creating trust in the system. VIPs can also distinct what information is provided and have more flexibility to input commands in the system.

> Wearables keep the Solution Hands Free
> Sensor placement Influences Information Provided
> Use Environment to Create Reference Points to Navigate
> Complimentary Feedback and Input

4 User Journey Analysis

From chapter 1, 2, and 3 and 16 interviews User Journey Maps were created to better understand the experience of VIPs at Schiphol Airport.

From these journey maps pain points were derived which are used to form a defined problem for the design brief.

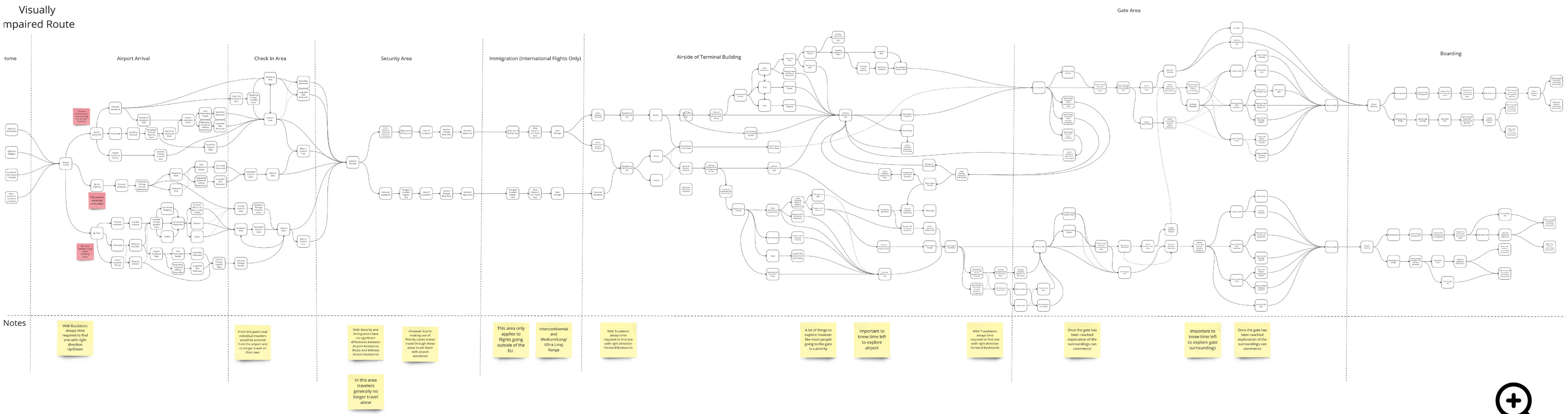


Figure 29
All Scenario Journey Map

4.1 User Journey Maps

From the findings of chapter 1, 2 and 3 as well as the 16 interviews a single journey map was created which highlights all possible scenarios VIPs can encounter at an airport, seen in Figure 29. From Subchapter 1.3, 2.4, and 3.3.1 it can be determined that the type of assistance VIP recieve greatly influences how they experience, navigate and percieve their environment. Furthermore it influences their control as well as ability to act independently in an environment, and why their dependency on others. This was used to divide them into 3 distinct journey maps which outlined the exerience with airport assistance, personal assistance and the individual route. From chapter 1.3 Dependency on Others, Frustration and Energy are determined to be parameters which influence the experience of the VIPs throughout their journey at the airport.

4.2 Airport Assistance Journey

The airport assistance journey seen in Figure 30 covers the journey from navigating indivually to the assistance pole, to then being assisted from there all the way to the seat in the airplane. Due to the airport staffs knowing the airport to a good extent there is minimal risk of getting lost, and VIPs can make use of priority lanes. Dependecy on assistance is one of the highest of all journey maps, due to airport assistant guiding the entire route. This journey can be described as ***Efficient*** and ***Reliable***, as the VIP is brought to their destination within a short amount of time with minimal energy.

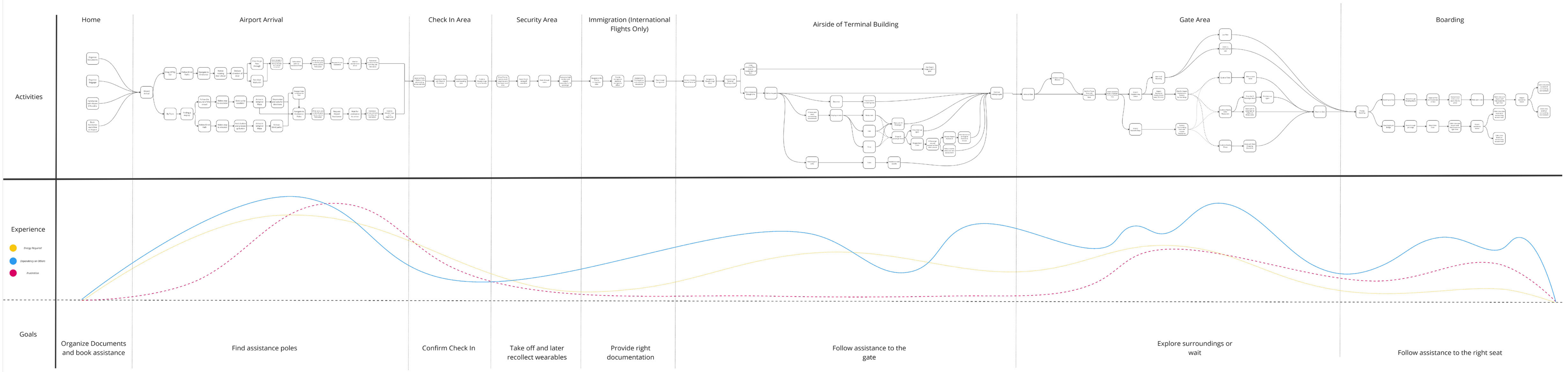


Figure 30
Airport Assistance Journey Map

4.3 Personal Assistance Journey

The Personal assistance journey seen in Figure 31 covers the journey when the VIP travels with family, friends or assistance staff from special organizations. It starts at drop off and ends at the airplane seat. Personal assistance give more flexibility during the journey, and can provide relevant details of the environment to the VIP. Though having a chance to not knowing an airport environment, personal assistance can risk getting lost as well. This journey can be described as ***Personalized*** and ***Flexible***.

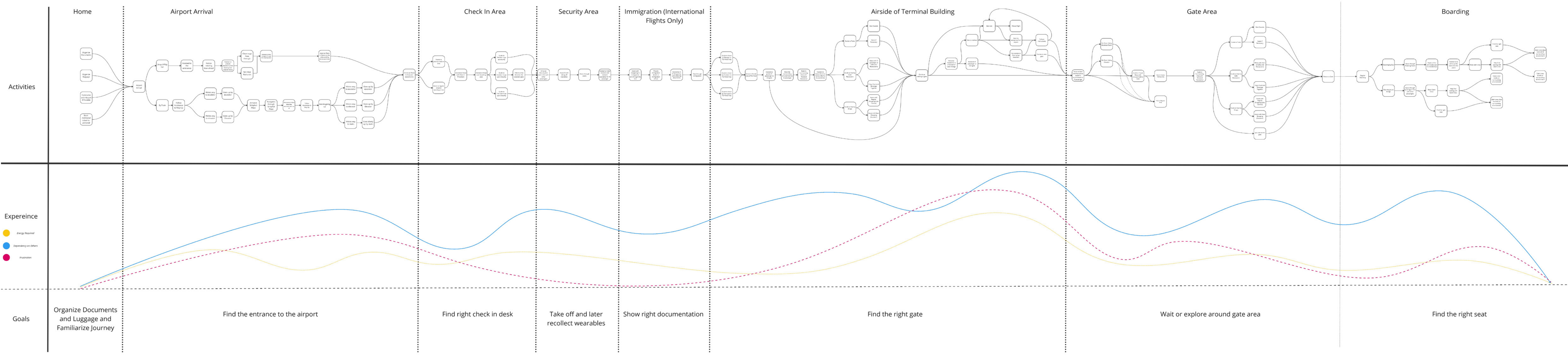


Figure 31
Personal Assistance Journey Map

4.4 Individual Journey

The individual journey as seen in Figure 32 covers the individual journey from the drop off zones to the seat in the airplane. While the **Enterance Area** and **Check In Area** are zones that are possible to navigate individually, the Airside is currently not done individually at all. Hence the Airside zone is a hypothetical journey map created based on findings of how to carry out activities from simulations in 1.6 and interviews. The activities done are similair to that from the other two Journey Maps, but due to them being done individually, it is noticeable that much more effort is required to carry out an activity and percieve a certain environment. This journey can be described as ***Independence*** and is desirable to be one of ***Control***.

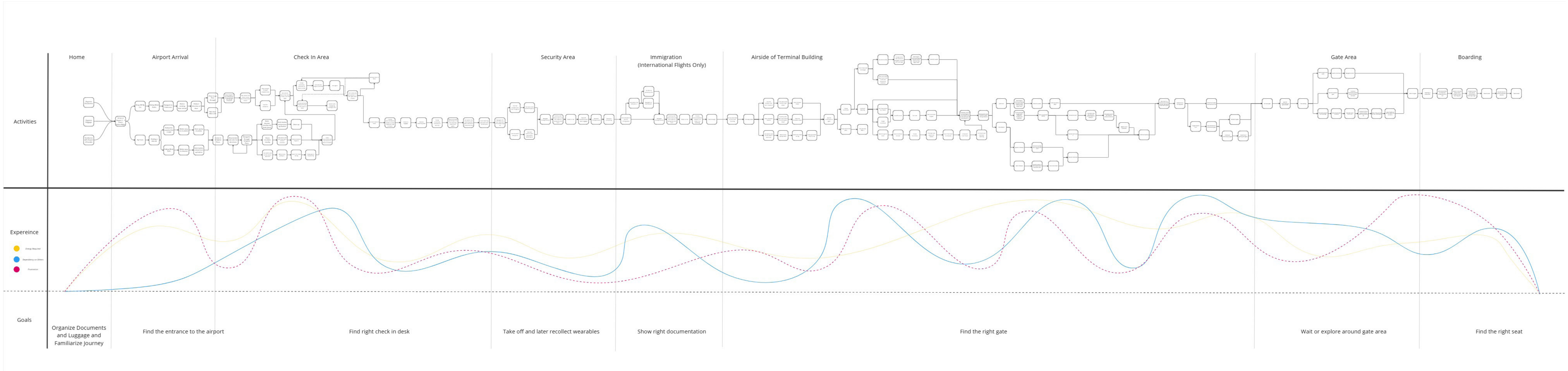


Figure 32
Individual Journey Map

4.5 Identifying Pain Points

4.5.1 Airport Assistance Pain Points

Problem Area: Airport Enterance

One of the main problems with airport assistance is the fact that when arriving at Schiphol, one needs to require assistance to get to the assistance. This task is achieved through asking people in the surroundings and overtime itself can cost energy and time in itself building up to frustration.

Efficient but Dependable

Due to having airport assistance, one can be guided and reach their destination within a given short time. This is why after the airport enterance, there are no more significant peaks for energy and frustration. Also a reason why assistance is prefered is because it gives a sense of certainty, and offers a more relaxed manner of travel to reach the destination. However like with all forms of assistance it comes with being dependent on another.

High Dependency on Others to Navigate

Whenever navigating complex environments, dependency on others is required to gain information of the surroundings. This is seen by the blue peaks which increase when wanting to explore and navigate large areas like the airside of the enterance, airside building,

4.5.2 Personal Assistance Pain Point

Problem Area: Airside of the Terminal Building

The airside of the terminal building is a problematic area, due to the fact that with personal assistance one can still get lost when navigating large environments. While personal assistance can then help reroute and find the way, the possibility of getting lost can get frustrating and consumes energy. Furthermore with no clear sense of ones surrounding as beind dependent on another, being lost creates a larger sense of uncertainty and hoplessness.

Personalized but Dependable

Like Airport assistance, dependency increases when needing to navigate through a room and find the destination like the check in desk, or gate. Though due to having personal assistance to help with such tasks, energy to carry out such tasks does not increase and it becomes less frustrating to do them. While dependent personal assistance still retains the problem of dependability on another.

4.5.3 Individual Pain Points

Problem Area: Airside of the Terminal Building

In general every area of the airport is problematic to navigate through individually. However the airside of the terminal building is difficult in a unique and unpleasant way for VIPs in a sense that it is large, unfamiliar and has to be navigated through in a limited amount of time. While the enterance presents similair issues, it is accessible at any time, hence it can be studied by the VIP even when they are not travelling. Personal assistance like family and friends having access to this area can also help familiarize them with it. This eventually gives them the possibility to build a mental map and navigate through the area overtime. This is not possible at the airside, which hence makes it more challenging to navigate through.

Exhausting and Time Consuming to Navigate

Energy peaks at nearly every area, and especially at the airside of the terminal. To carry out a task the VIP relies heavily on sound and touch. They need to feel and percieve everything very carefully in order to move forward, taking time to percieve an environment. Whether this be exploring the airside terminal building, finding the gate, and confirming that they have arrived at the gate. This costs a lot of energy overtime and with time being limited, causes frustration with each task.

Exhaustion and Uncertainty causes Giving Up Independence

With high levels of uncertainty and costing much energy for each task, a VIP opts to rather use assistance then navigate unfamiliar areas by themselves. While having less spatial awarenes, assistance as seen in Figure 30 causes significantly less peaks in energy and frustration.

Independent but still Dependanble

While the individual path is done alone, due to the lack of information of the environment, and difficulty to confirm and recieve feedback, dependency on others is still necessary. This is seen through the blue peaks which coincide with carrying out such tasks in Figure 32. Being already exhausted by trying to percieve the environment by themselves, the VIP is now tasked with finding an appropriate person to aid them, which is an exhausting task in itself.

4.5.4 Key Takeaways

From these findings it can be understood that the most challenging part to navigate inside an airport is the airside part of the terminal after immigration and up to the gate. This is particularly due to its large unfamiliar size, and inability to create a cognitive map out of it that would help navigate through it independently.

While independent navigation is possible to be carried out by VIPs, it takes time, energy, and guidance to gain information of the surroundings and where to go. Being large and dynamic it can cause a lot of disoreintation, leading to frustration and a lack of certainty in carrying out the challenge independently. At the airside time is limited, meaning effective and efficient orientation and navigation techniques are required. Current navigation solutions and techniques do not offer this efficiency and effectiveness leading to the reliance on assistance from others or airport staff to carry out such tasks.

Design Brief
Part 2

5 Target Group & Focus Area

From Chapter 1 and 4 the Target Group and Focus Area at the airport are determined. This target group is selected as they suffer the most with acting independently, while the environment is the most difficult to act independently in.

5.1 Target Group

Level 3 - 4 VIs Departing from Schiphol Airport

Novice VIs

5.2 Focus Area

Airside of Schiphol Airport

Goal is to Navigate Indepedently through the Airside of the Departure Terminal to their Gate

6 Drivers & Constraints

From the research conducted in Q3, the following requirements list has been made. This would assess the developed concept against the desirability, feasibility, design, viability and technical requirements, and also include possible wishes for its development.

6.1 Drivers

Chapter 1

> Perception of an Environment at Low Cognitive Loads
> Navigating through an Environment with Certainty
> To act Independently and be in Control in an Environment

Chapter 2

> Certainty empowers Independence
> Maintain Contact with Assistance
> Convey Relevant Details of an Environment
> Navigate within a Given Time

Chapter 3

> Wearables keep the Solution Hands Free
> Wearables should be pleasant to wear
> Sensor placement Influences Information Provided
> Use Environment to Create Reference Points to Navigate
> Complimentary Feedback and Input

6.2 Constraints

Chapter 4

> Time
> Energy
> Spatial Awareness
> Certainty

7 Key Requirements

From the key drivers and constrains, key requirements are formulated

Reduce energy to Percieve and Navigate

Reduce Time to Percieve and Navigate Environment

Create a sense of control

Create a sense of certainty

Comfortable Design

Reduce dependency on others

8 Design Goal

Eventually from all findings a design vision is formulated that acts as the basepoint to go further into the solution space of the project.

> “*To design a wearable that empowers more independent travel at the Terminal Airside of Schiphol for the VIP, through creating certainty, efficiency, and a sense of control.*”

Iteration, Evaluation & Integration

Part 3

9 List of Requirements

In this chapter the formulation of the list of requirements takes place. The list of requirements would act as a blueprint for the ideation and conceptualization phases.

9.1 Sources

A variety of sources were used to obtain the various requirements for the indoor navigation system for the VIP. Sources include organizations for standradization as well as associtations for the blind. Sources are numbered based on their origin, except for those from research articles that use the regular APA citation method.

International Civilian Aviation Organization (ICAO)

The ICAO focusses on requirements that deal with airport accessibility, such as integration with airport information to be informed of gate changes. ICAO requirements are designated as [ICAO X]

Schiphol

Schiphol provides specific airport requirements, that differ from the more general requirements from ICAO. For example requirements regarding its installation and implementation at the airport Schiphol requirements are designated as [Schiphol X]

European Accessibility Act

EAA focusses on standard requiremnts such as feedback and inputs. It focusses on how feedback and input is conveyed and what feedback and input should be conveyed

EAA requirements are designated as [EAA X]

International Standardization Organization (ISO)

ISO requirements focus on standardized requirements for button or interface designs used ISO requirements are designated as [ISO X]

World Blind Union (WBU)

The World Blind Union provides requirements into the needs and preferences of VIPs, which are crucial for designing effective obstacle detection systems. WBU requirements are designated as [WBU X]

Koninklijke Visio

Koninklijke Visio like the WBU provide additional requirements on the VIPs preferances and behaviour. Visio requirements are designated as [Visio X]

Other

Other requirements coming from other sources are simply indicated by normal APA In Text Citation

9.2 Requirements

R1 Dimensions & Weight

Wearables

- Head Mounted
  - Max Width 140 – 160mm (Pimentel et al., 2024)
  - Max Lens-to-Ear distance ~120mm (Pimentel et al., 2024)
  - Max Frame Thickness <10 mm (Pimentel et al., 2024)
  - Max Weight: < 80g (Pimentel et al., 2024)
- Vests
  - Max Width 69 – 76 cm (Pimentel et al., 2024)
  - Max Length 30 - 32 cm (Pimentel et al., 2024)
  - Max Thickness < 15mm (Pimentel et al., 2024)
  - Max Weight Distribution: Equal across the body (Pimentel et al., 2024)
- Smart Canes
  - Max Grip Diameter: 50 – 80mm (Husin & Lim, 2019)
  - Grip Thickness 25 – 35 mm (Husin & Lim, 2019)
  - Max Weight: < 750g (Husin & Lim, 2019)

R2 Obstacle Detection and Safety

Request for Assistance

- Be able to navigate to the nearest assistance desks [ICAO 1]

Margins of Error

- Path Planning & Navigation (Max 10 cm) (Iozzio, 2014)
- Obstacle Detection (1-5cm) (Martinez-Sala et al., 2015)
- Step & Drop Detection (Max 2 cm) (Martinez-Sala et al., 2015)

Obstacle Detection

- Distinguish between moving obstacles and static obstacles [ISO 1]
- Distinguish between large, small, and low and head on level type obstacles [EAA 1]
- The product must not cause physical injury [ISO 2]
- The VIP must not collide with any obstacles on their way [WBU 1]

Dynamic Obstacles

- Detect moving obstacles that are in front of the VIP, such as people from a minimal distance of 3 - 4 meters (Martinez-Sala et al., 2015)
- Detect rotating doors from a minimal distance of 2 – 2.5 meters (Martinez-Sala et al., 2015)
- Determine the direction of rotation of rotating doors [Visio 1]
- Determine when it is clear, and the rotating door can be entered [Visio 2]
- Determine when it is clear, and the rotating door can be exited [Visio 3]
- Detect low dynamic obstacles on the floor such as beginning and end of elevators or travellators from a minimal distance of 2 – 2.5 meters [Visio 4]
- Determine the direction of movement of escalators and travelators [Visio 5]

Static Obstacles

- Detect large static obstacles like pillars and walls that are in front of the VIP from a minimal distance of 2 – 3 meters (Martinez-Sala et al., 2015)
- Detect low obstacles on the floor such as curbs, end or beginning of steps from a minimal distance of 1 - 2 meters (Martinez-Sala et al., 2015)
- Detect head level obstacles like signs at a

minimal distance of 2 – 2.5 meters (Martinez-Sala et al., 2015)

Obstacle Feedback

- Use progressive feedback to indicate obstacle proximity [WBU 2]
- Far (2.5 > meters) low intensity vibration/ soft sound que [WBU 3]
- Medium (1.5 – 2 meters) stronger intensity vibrations / louder audio cue [WBU 4]
- Close (< 1 meter) Continuous vibration / urgent sound alert [WBU 5]
- Inform the VIP that there is a crowded environment [ISO 3]
- Inform on direction of escalators and travellators, moving up or down, or forward or backward [Visio 6]
- Inform the VIP where the escalator, travelator or staircase ends [WBU 6]
- Inform VIP on the direction of the rotating door, rotating clockwise or anti clockwise [Visio 7]
- VIPs should know when it is clear to enter and pass through a rotating door [Visio 8]

Warning and Labels

- The warning and information placards must not be able to be erased, disfigured or obscured [ISO 21]
- The warning and information placards can be felt by the VIP through using braille [ISO 22]
- The warning and information placards can be seen and read by sighted VIPs [ISO 23]

Operations

- The product should not generate smoke when being used [ISO 4]
- The product should not overheat when being used [ISO 5]
- Contain openings and for heat to flow out when [ISO 6]

R2 Usage

Operations

- Contain openings and for heat to flow out when [ISO 7]

Operations

- Contain openings and for heat to flow out when [ISO 8]

R3 Usage

Operations

- Feedback should be conveyed in real time, within a maximum of 2 seconds after the object has been identified [EAA 2]
- Product feedback should not cause additional clutter [EAA 3]
- VIPs should be able to distinguish different types of feedback with different methods the feedback is informed in [EAA 4]
- The product should use vibrational feedback for basic information such as reminding when to turn or the destination has been reached [WBU 7]
- The product should use audio feedback for conveying more complex information like describing distances, and areas, and destination information [WBU 7]

Learning

- The product can be used independently at its first use [EAA 5]
- VIPs should understand feedback when in busy environments [EAA 6]
- VIPs should understand feedback in one go [EAA 7]
- The product must be able to be integrated and used along with other navigational aids such as the white walking cane. [Visio 9]

Units

- Distances informed using metric units, in meters [Visio 10]
- Time informed in hours and minutes [Visio 11]
- After no hours are left, time is informed in minutes and seconds [Visio 12]

Comfort

- The product should be comfortable to be used for at least 3 hours [Schiphol 1]
- Wearable should be attachable and detachable to clothing/ head/ walking cane with ease [Schiphol 2]

Mobility

- Installation of the product should not hamper mobility of the VIP when navigating throughout the terminal building [Schiphol 3]
- The product should enhance independent mobility for the VIP throughout the terminal building [Schiphol 4]
- The navigational aid should be hands free [Visio 13]

Privacy & Data Security

- Data should be processed locally [EAA 8]
- Communication for voice commands should be encrypted [EAA 9]
- User data must be protected and anonymized [EAA 10]

Airport Infrastrucutre

- It should not require prior installation of infrastructure at the airport to aid in its navigation [Schiphol 5]
- The product can also be used in combination with airport assistance [Schiphol 6]
- The product should enhance the assistance experience of the airport [ICAO 2]

RF4 Orientation

Orientation Localization

- Provide real time location information with high accuracy (Husin & Lim, 2019)
- The position should be based on the landmarks in the surrounding environment [WBU 8]
- The product should determine direction the VIP is facing to give directional information [EAA 11]
- The product should be able to determine the location in an unknown environment (Husin & Lim, 2019)

Orientation Feedback

- Product should detect and read gate numbers that are being passed [WBU 9]
- Inform about gate numbers that are passed by the VIP when parallel to gate number signs [WBU 10]
- VIPs can also request information on the area they are in to orientate and obtain information about it. [Visio 14]
- Inform of nearby elevator, escalator, travelator when located 15 meters from them [WBU 11]
- Provide a choice for the VIP which method they would like to use when spotting an elevator, escalator, or travelator [Visio 15]
- Information about an area can be repeated when the VIP desires it [Visio 16]
- The product should be integrated with the information system at the airport to provide up to date information and departure information [ICAO 3]
- When entering a new terminal area, inform on terminal area they are in [ICAO 4]
- Shopping Area
- Food and Beverages
- Corridors
- Rest Zones
- Gate Area

Orientation Input

- Have an input to describe the surrounding area (Iozzio, 2014)
- Have an input to repeat information of surroundings (Iozzio, 2014)
- Recognize voice commands to provide more information for surroundings (Martinez-Sala et al., 2015)

RF5 Navigation
Localization
- Determine directional information based on the direction the VIP is facing in **(Martinez-Sala et al., 2015)**
- Determine location based on landmarks in the surrounding area **(Martinez-Sala et al., 2015)**

Navigational Feedback
- At the start inform the VIP of the time and distance it takes to reach the desired gate **[EAA 12]**
- At the start inform the VIP of the time they have left till the gate opens and closes **[EAA 13]**
- Navigate the VIP to primary destinations like the gate help desk independently **[Schiphol 7]**
- The VIP should arrive at the gate 15 minutes before it opens **[Schiphol 8]**
- Navigate to secondary destinations like the toilet entrance independently **[Visio 17]**•
    1. Restaurants entrances
    2. Cafes entrances
    3. Shops entrances
- Inform the VIP to continue to primary destination once the VIP wants to continue after reaching the secondary destination. **[EAA 14]**
- The product should be able to distinguish between primary and secondary destinations
- The VIP should easily distinguish what a primary and secondary destination is **[EAA 15]**
- Based on location of the VIP, time left till gate opens, and distance, inform the VIP that they must continue to the gate **[ICAO 5]**
- Inform about route progress to key destinations after 25%, 50%, 75% of the route has been covered **[EAA 16]**
- When the VIP goes off course provide continuous pulsed vibrations/ sound alerts **(Martinez-Sala et al., 2015)**
- Increase intensity of vibrations and sound alerts as they go off course **(Martinez-Sala et al., 2015)**
- Use the clock method in combination with left, right, front and behind for informing the VIP about objects in the environment relative to the VIP's position. **[Visio 18]**
- The product should be able to recognize landmarks in the environment **(Iozzio, 2014)**
- Use landmarks and distance to inform the VIP when they should take a turn **(Iozzio, 2014)**
- Inform about flight number, flight destination, and departure time when arriving at the gate **[ICAO 6]**
- The product should be integrated with the information system at the airport to provide up to date information on gate changes **[ICAO 7]**
- Inform about gate changes to the VIP **[ICAO 8]**
- The product should be able to redirect to new destinations independently **[ICAO 9]**

Navigational Input
- Have a specific button to navigate to primary destinations which are the gates **(Iozzio, 2014)**
- Have a specific button to navigate to secondary destinations **(Iozzio, 2014)**
- Have an input function to make choices for secondary destinations **(Iozzio, 2014)**
- Have an input function to make choices for escalators, elevators and travelators **[EAA 17]**
- Have an input to repeat navigational instruction **[EAA 18]**
- Recognize voice commands to navigate to primary and secondary destinations **[Visio 19]**

RF6 Components
Sensors
- Sensors should have at least a detection range of 10 meters to pick up information from the surrounding environment **(Martinez-Sala et al., 2015)**
- The product should have at least one sensor to obtain information about the surroundings **(Martinez-Sala et al., 2015)**
- Sensors should be able to detect all types of obstacles in the VIPs direction of movement **(Martinez-Sala et al., 2015)**

Processor
- The product should have a processing unit to process data into feedback for the VIP **(Husin & Lim, 2019)**
- The processor should filter out unnecessary information to prevent information clutter for the VIP **(Husin & Lim, 2019)**
- The processor should not overheat throughout the day 12 hours **[ISO 9]**

Buttons
- There should be an on and off button **[ISO 10]**
- Each button, switch, or input must correspond to one function **[EAA 19]**
- Different textures to distinguish different functions **[EAA 20]**
- Different shapes to distinguish different functions **[EAA 21]**
- Specific locations for specific functions **[EAA 22]**
- Max Diameter: 10 – 15 mm **[ISO 11]**
- Max Width: 12 – 18 mm **[ISO 12]**
- Height 1.5 – 3 mm **[ISO 13]**
- Spacing between buttons 12 – 15 mm **[ISO 14]**

Audio Component
- The product should have an audio component for audio feedback **[Visio 20]**
- Speakers in Wearables should be positioned towards the VIP's body for privacy **[WBU 12]**

Vibration Motors
- The product should have a vibrational component for haptic feedback **(Pimentel et al., 2024)**
- A vibration motor should be placed in the center or be even distributed so that it can be easily felt by the VIP. **(Pimentel et al., 2024)**

Voice Commands
- Microphone distance should be 10 – 15 cm from mouth for best speech recognition **[ISO 15]**
- Microphones should filter out noise of the environment to properly understand voice commands **(Pimentel et al., 2024)**

Power Unit
- Battery life should last for 20 hours or longer **[Schiphol 9]**
- Inform user if battery power is below 4 hours
- Calculate if battery power is enough for journey (battery power > 4 hours). **(Pimentel et al., 2024)**
- Do not allow system to be used when battery power is below 4 hours. **(Pimentel et al., 2024)**
- Request assistance when power is below 4 hours. **(Pimentel et al., 2024)**

RF7 Aesthetics Appearance and Finish
- The product must not have any sharp edges, trim strips and corners. **[ISO 16]**
- All edges, trim strips and corners of the product must be free of burst or protrusion. **[ISO 17]**
- All edges, trim strips, and corners of the product must be free of burrs or protrusions., trim strips, and corners of the product must be free of burrs or protrusions **[ISO 18]**
- The product should have a discreet and subtle appearance on the VIP when used **[Visio 21]**
- Use neutral colors to have a more subtle appearance **[Visio 22]**

9.3 Wishes
W1 Size and Weight
- It is desirable that the product is as light as possible

W2 Obstacle Detection & Safety
- Be able to navigate to assistance staff **[ICAO 10]**
- Alert the airport when the product breaks down **[WBU 13]**
- Inform of the location of the VIP to airport staff when the product breaks down **[ICAO 11]**
- In case of emergency or failure people in the

surroundings (within 10 meters) can easily help. **[Visio 28]**

- It is desirable that the product can request assistance from people in the surrounding area (within 10 meters) **[ICAO 13]**
- It is desirable that the product can request assistance from airport staff **[Visio 23]**
- It is desirable that the product informs when assistance will arrive **[Visio 24]**
- It is desirable that the product informs to assistance where the VIP was heading to enhance communication **[WBU 14]**
- It is desirable that the VIP can adjust alert distances based on their walking pace **[WBU 15]**

W3 Usage

- It is desirable that the product can adjust the volume of audio feedback depending on the noise in the surrounding area **[EAA 23]**
- It is desirable that the VIP can set the pace at which they walk **[Visio 25]**
- It is desirable multiple languages can be set for audio feedback **[ISO 19]**

W4 Orientation

- It is desirable that as little cognitive energy is used to perceive the environment with the product **[Visio 26]**

W5 Navigation

- It is desirable that the product can also navigate to emergency exits **[Visio 27]**
- It is desirable that as little cognitive load is used to follow instructions **[WBU 16]**

W6 Components

- It is desirable to have a special component to request assistance **[EAA 24]**
- It is desirable to have charging components that should be done magnetically **[EAA 25]**
- The product must have a minimum lifespan of 20 years. **[ISO 20]**

W7 Aesthetics

-

10 Exploratory Ideation

In the ideation phase the requirements defined and ranked in Chapter 9 are further explored into feasible designs through an iterative process. The aim of this iternation was to explore how a hands free indoor navigation device would be implemented for the VIP.

Focus was on the placement and attachment on the body, sensor placement, types of sensors, types and methods of inputs, types and methods of feedbacks, airport implementation. A combination of the various types was then done to create concepts.

10.1. Body/Cane Placements

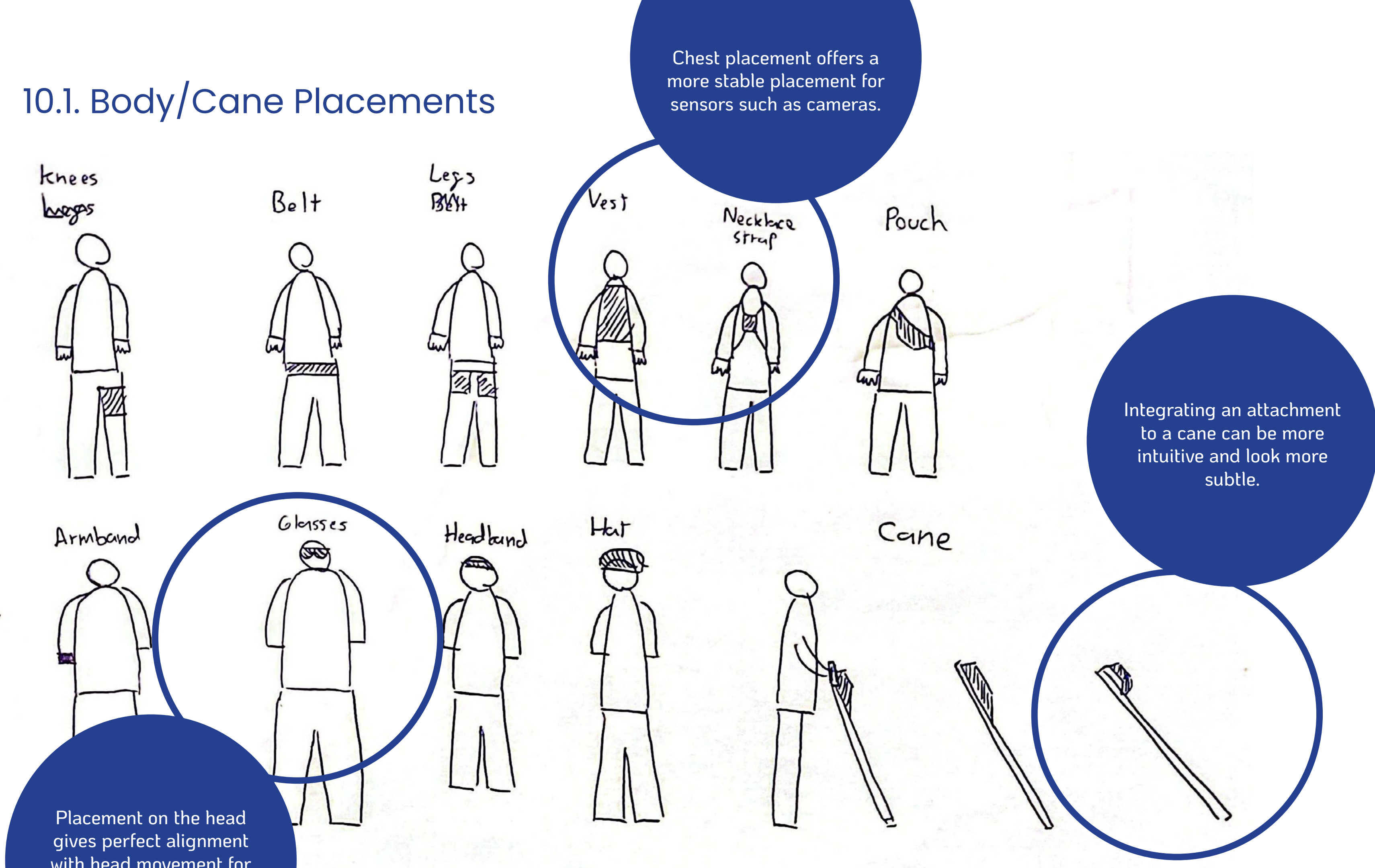


Figure 33
Placement Ideation

10.2. Sensor Placements

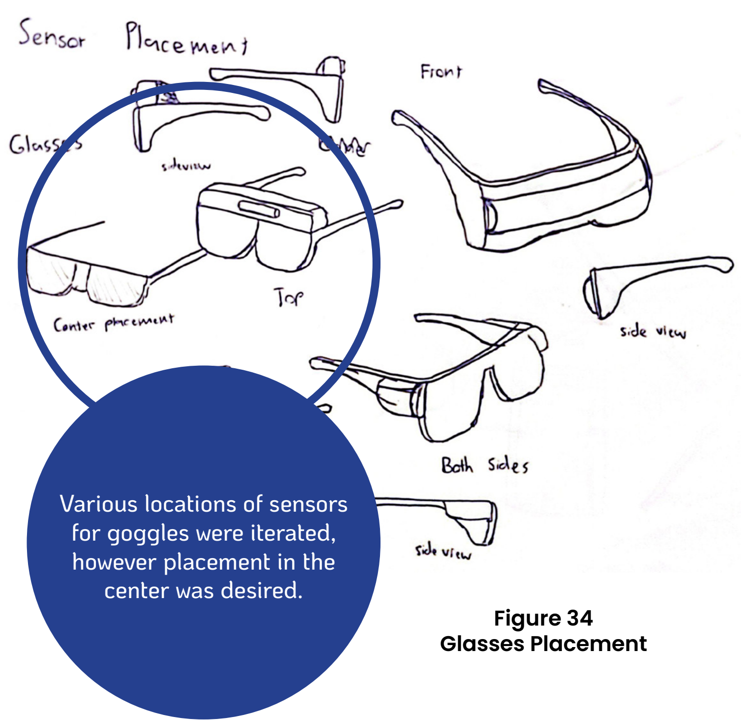


Figure 34
Glasses Placement

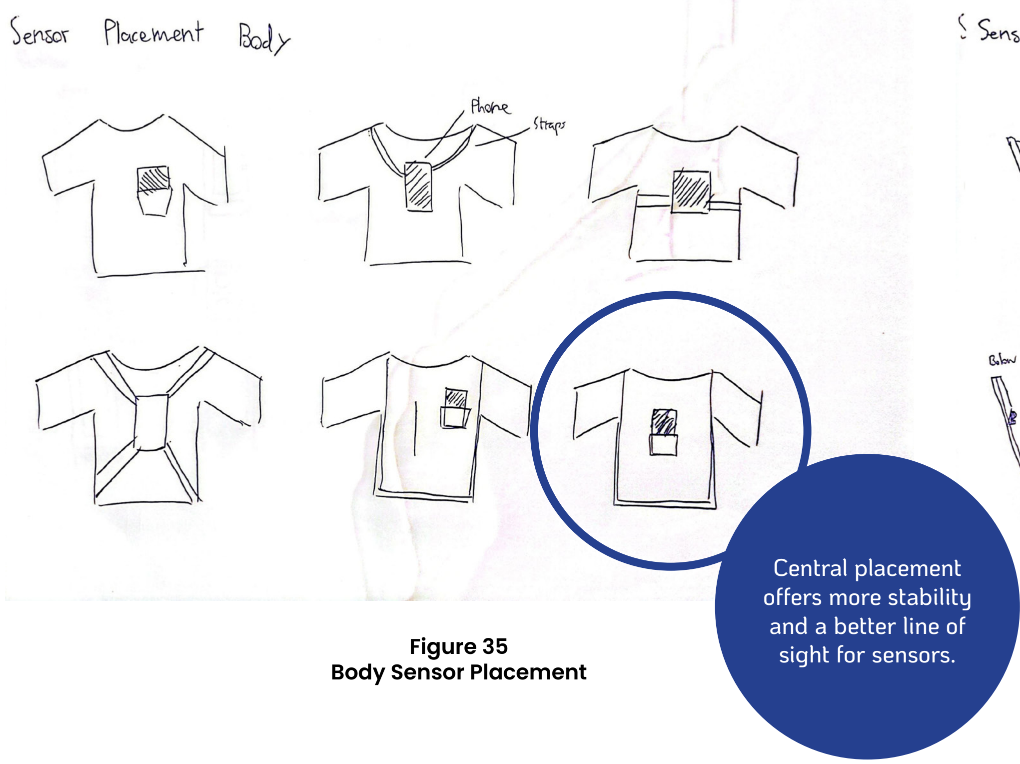


Figure 35
Body Sensor Placement

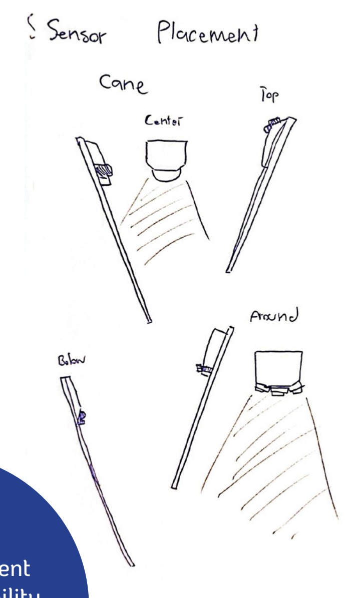


Figure 36
Cane Placement

Part 3: Iteration, Evaluation & Integration

10.3 Types of Attachment Methods

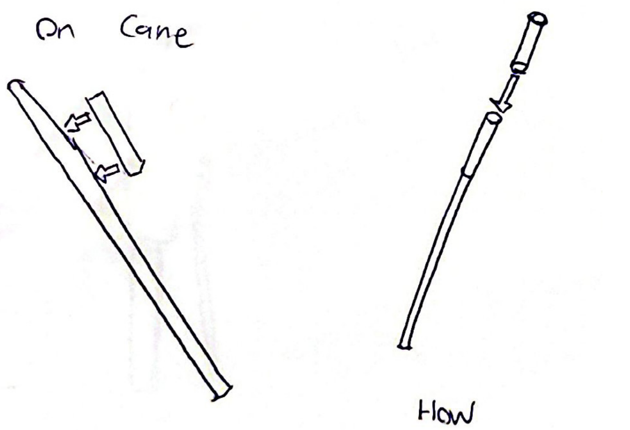
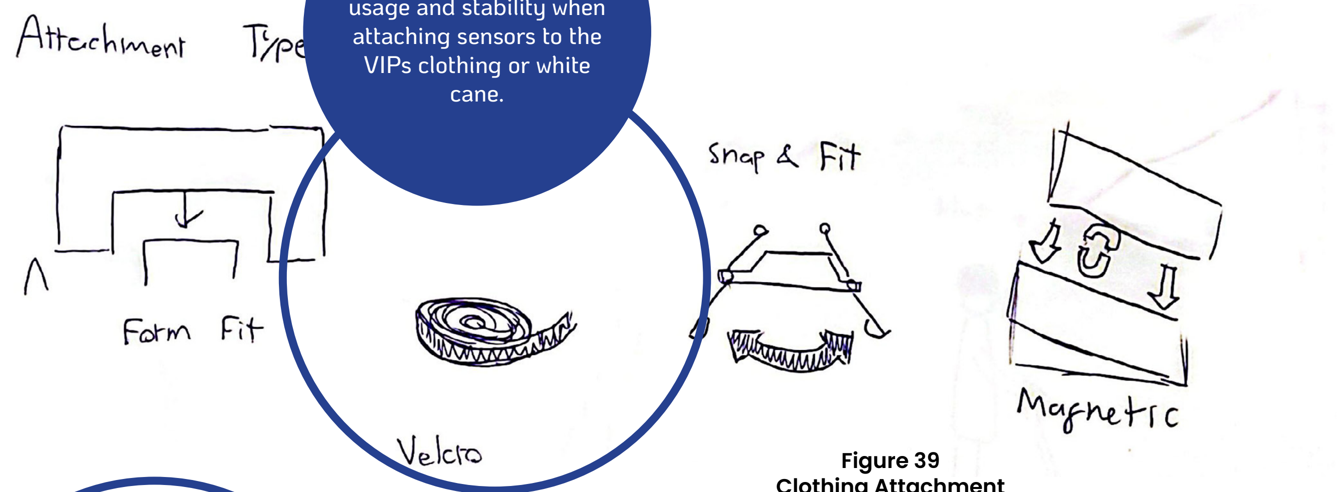


Figure 37
Cane Attachment



Velcro offers easier usage and stability when attaching sensors to the VIPs clothing or white cane.

Figure 39
Clothing Attachment

10.4 Types of Sensors

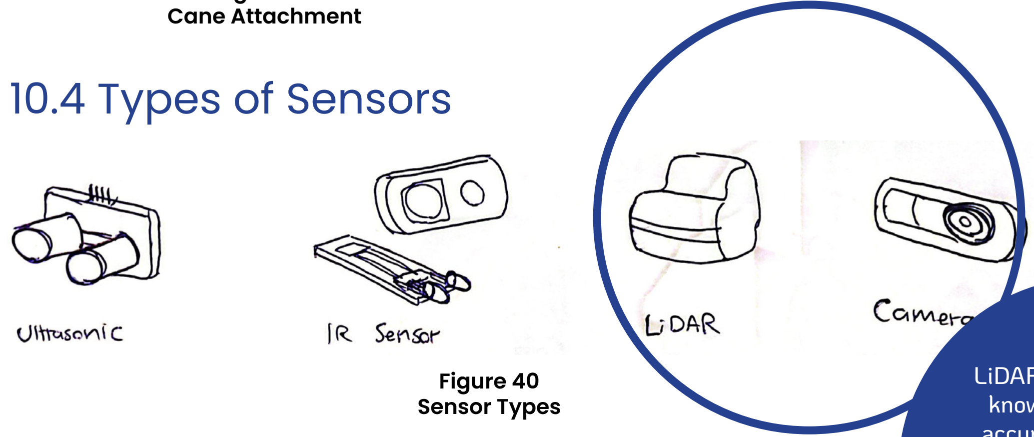
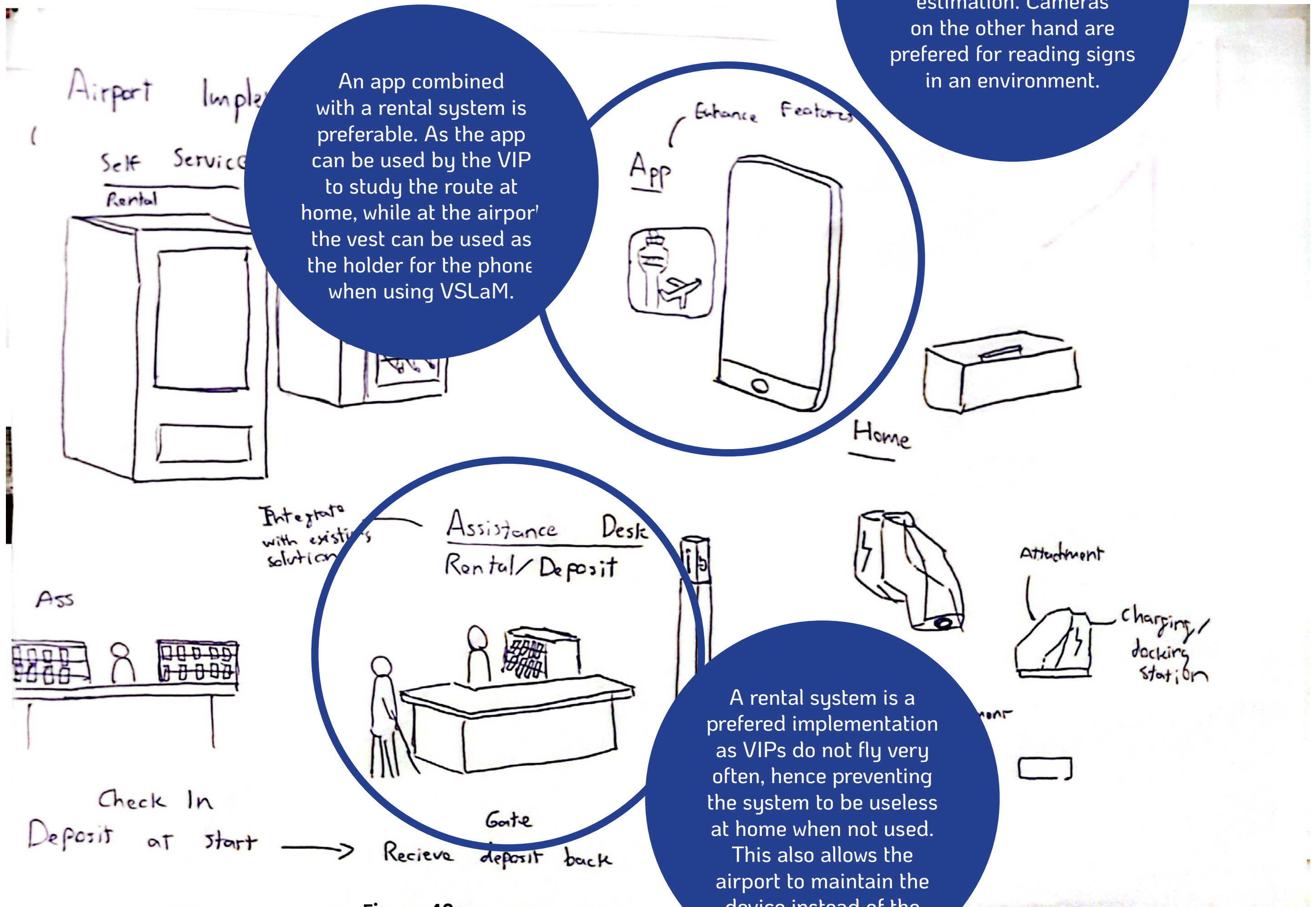


Figure 40
Sensor Types

LiDAR sensors are well known for their high accuracy for obstacle detection and range estimation. Cameras on the other hand are prefered for reading signs in an environment.

10.5 Airport Implementation



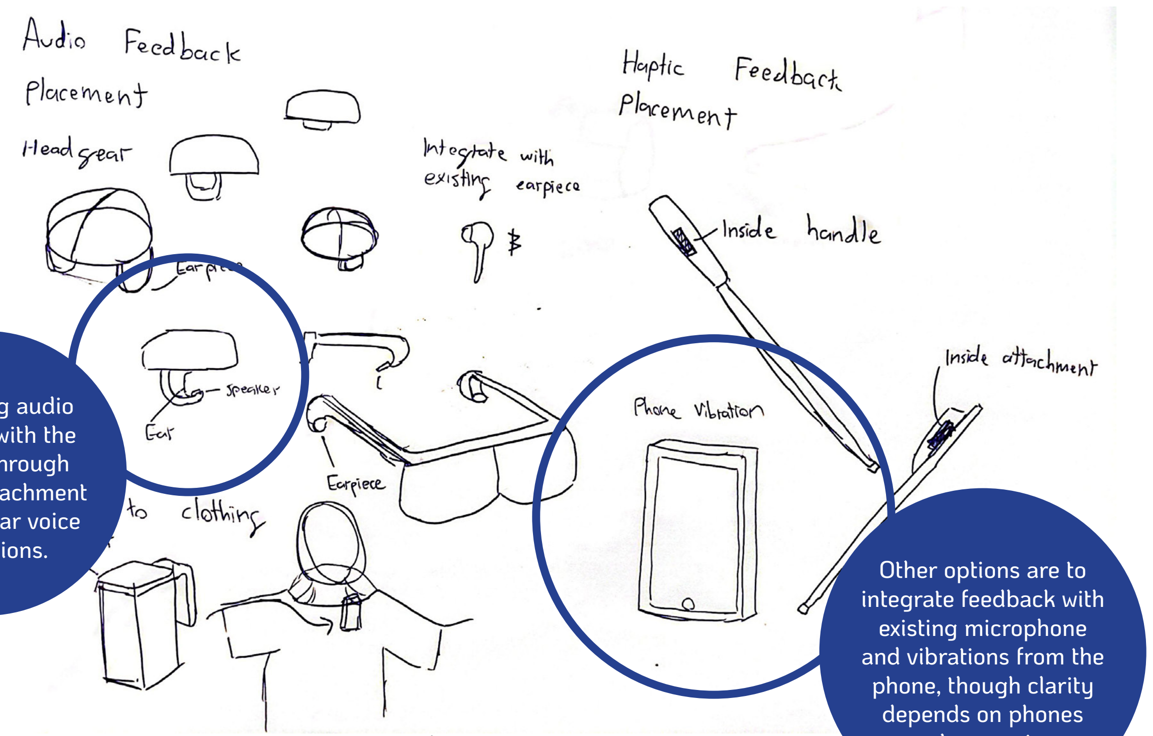
An app combined with a rental system is preferable. As the app can be used by the VIP to study the route at home, while at the airpor' the vest can be used as the holder for the phone when using VSLaM.

A rental system is a prefered implementation as VIPs do not fly very often, hence preventing the system to be useless at home when not used. This also allows the airport to maintain the device instead of the

Figure 40
Implementation Types

10.6 Audio Feedback

10.7 Haptic Feedback



Integrating audio feedback with the headset through speaker attachment to offer clear voice instructions.

Other options are to integrate feedback with existing microphone and vibrations from the phone, though clarity depends on phones placement.

Figure 41
Audio Feedback Ideation

10.8 Audio Input

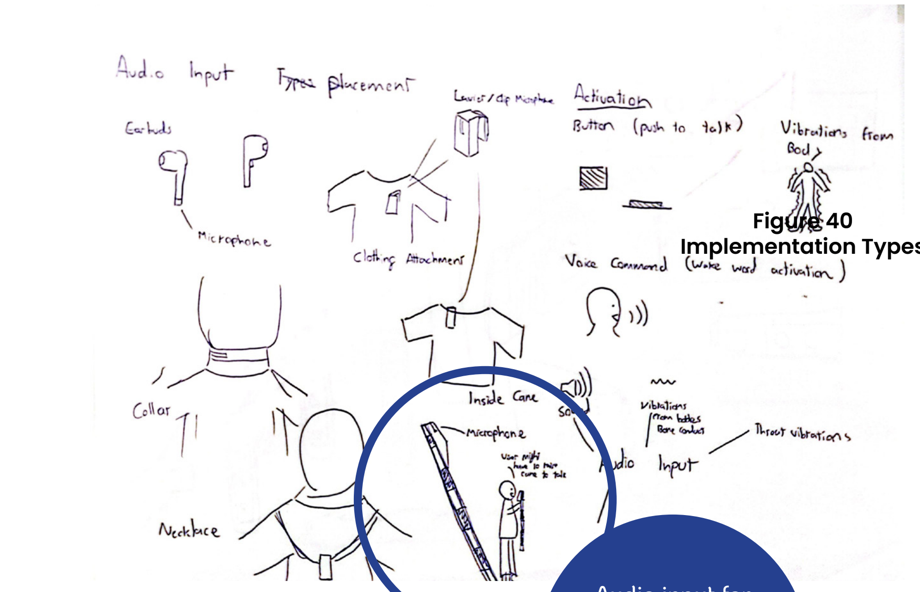


Figure 40
Implementation Types

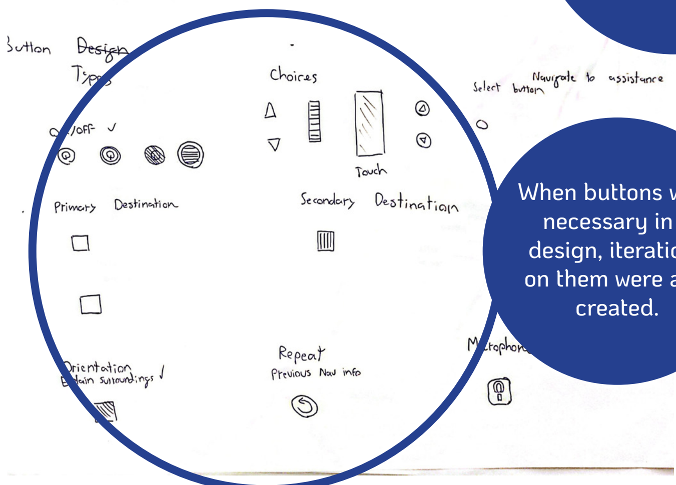
Audio input for voice commands could also be integrated into the cane's attachment.

Figure 42
Audio Input

Input through the phones microphone allows for not having to redesign an entire new microphone design, though placement of the phone is important.

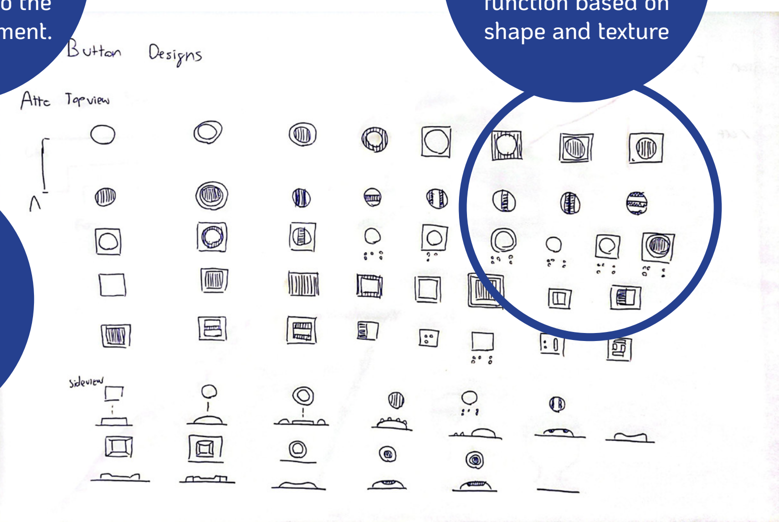
Figure 43
Audio Input 2

10.9 Button Designs



When buttons were necessary in a design, iterations on them were also created.

Figure 43
Types of Buttons



Button variant designs focussed on differentiating function based on shape and texture

Figure 44
Button Design

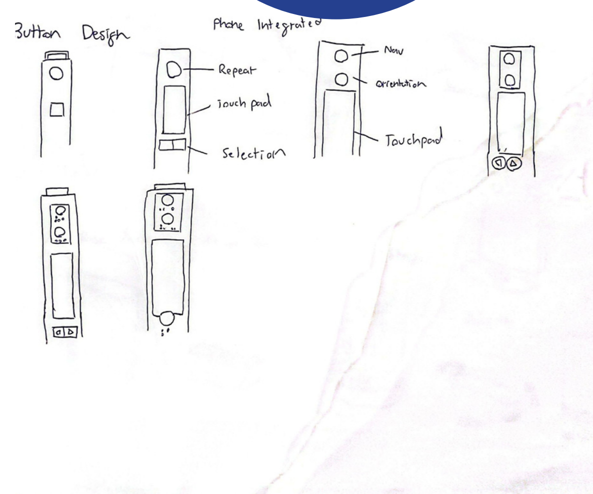


Figure 45
Button Layout

Concept Direction

After consulting the ideation phases with the VIPs. Three concept directions were derived. The first one being a vest which integrates the smart phone as the navigational sensor, while the other two were cane attachments and a goggle where the sensors were integrated into the attachment or the goggles.

It was desired to have these concept directions as they were subtle in design, easy to integrate with current aids such as the smartphone, white cane, and earphones. Most importantly they also offered audio feedback which made it easier to understand and process commands.

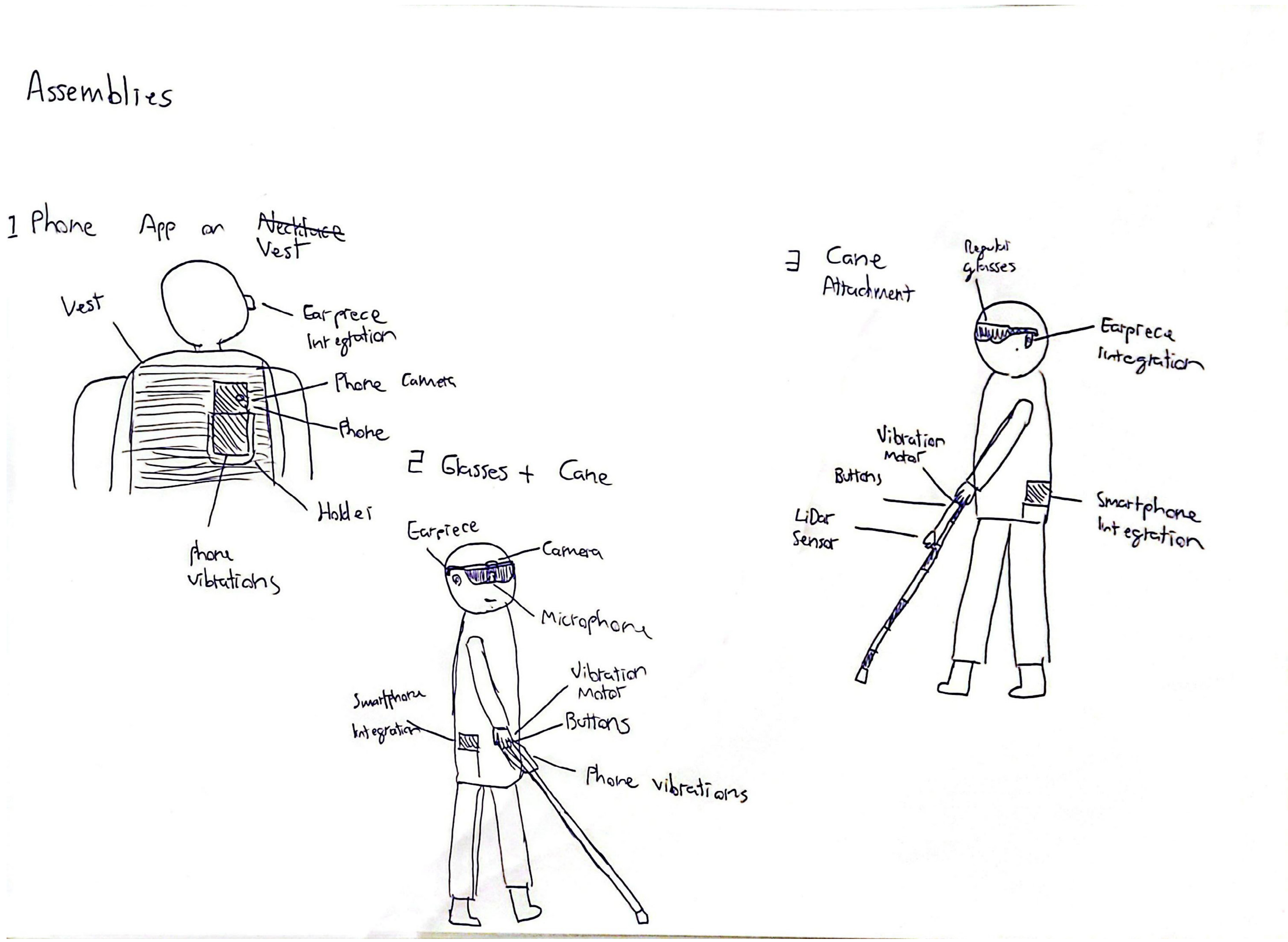


Figure 46
Pre-Concept Sketches

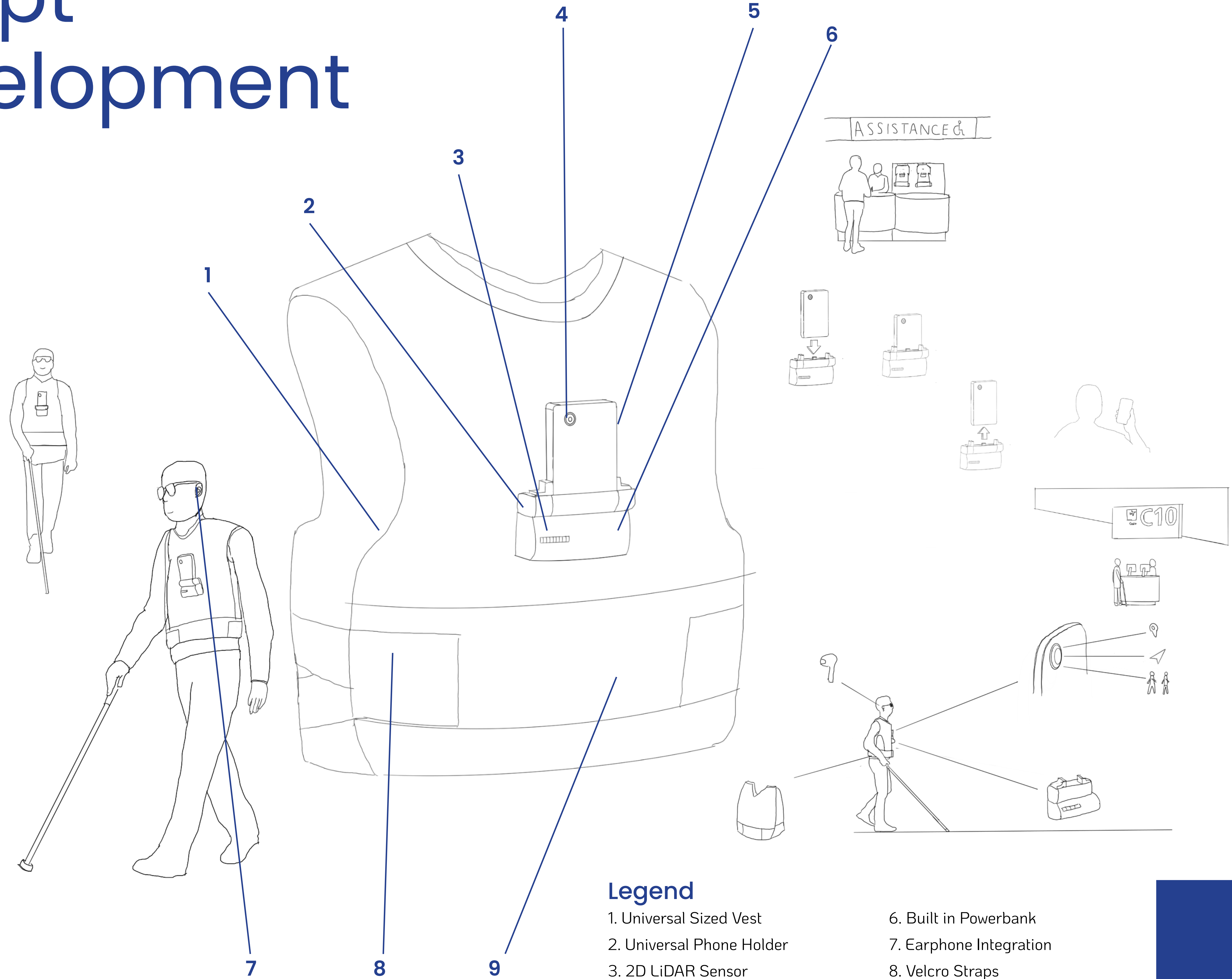
11 Concept Development

11.1 Concept 1
A Vest with a phone holder and 2D LiDAR

Concept 1 makes usage of a vest and integrates the smartphone RGB-D camera to be used to navigate and orient the VIP through their environment using VSLaM. Using the phones CPU, the information obtained can be processed. The phone makes use of an app, that not only displays navigational information to the VIP, but also information on gate changes and departures. Aside from the phone the vest acts as the holder for the phone allowing the VIP to have one hand free when they move around the airport. The holder is universal allowing different phone sizes to be held. Under the holder there is a power bank to provide additional power, and the 2D LiDAR sensor that can integrate with the phoen to more accurately measure distances. The vest also contains pockets for holding a passport, and ot in your environment. For feedback, the audio feedback that comes through your head is used. The app on the phone can be accessed any time while the vest is rented from the airport, and returned after boarding the plane.

Specifications

Sensor
Camera + 2D LiDAR
Input
Voice Command
Feedback
Audio
Environmental Description
Type I
Implementation
Hybrid Phone App + Rental



Legend

1. Universal Sized Vest
2. Universal Phone Holder
3. 2D LiDAR Sensor
4. RGB-D SmartPhone Camera
5. User' Smartphone
6. Built in Powerbank
7. Earphone Integration
8. Velcro Straps
9. Reflective Strip

Figure 47: Concept 1

11.2 Concept 2
A Cane Attachment + Goggles

Concept 2 is a two-part navigation system combining a cane attachment with a pair of wearable smart goggles. The goggles contain a small CPU that process information provided by the camera and IR sensor attached at the fronside of the goggles. The cane includes additional buttons to navigate and select as well as request information of the environment. Aside from that VIPs can also provide voice commands which will be recieved by the small microphone inside the goggles. Using the camera and IR sensor it makes usage of VSLaM to navigate the VIP independently from the check in desk to their gates and other destinations like airport amenities. The IR sensor is also used for proximity obstacle detection preventing the VIP to collide with obstacles. The device is also integrated with the airports api to provide real time information on departures and gate changes. This setup is designed to be rented at the airport, eliminating the need for personal device ownership, and usage of smartphones from the VIP. The device is returned once the VIP has boarded their plane.

Specifications

Sensor

IR Sensor + Camera

Input

Voice Command (Glasses) + Buttons (Cane Attachment)

Feedback

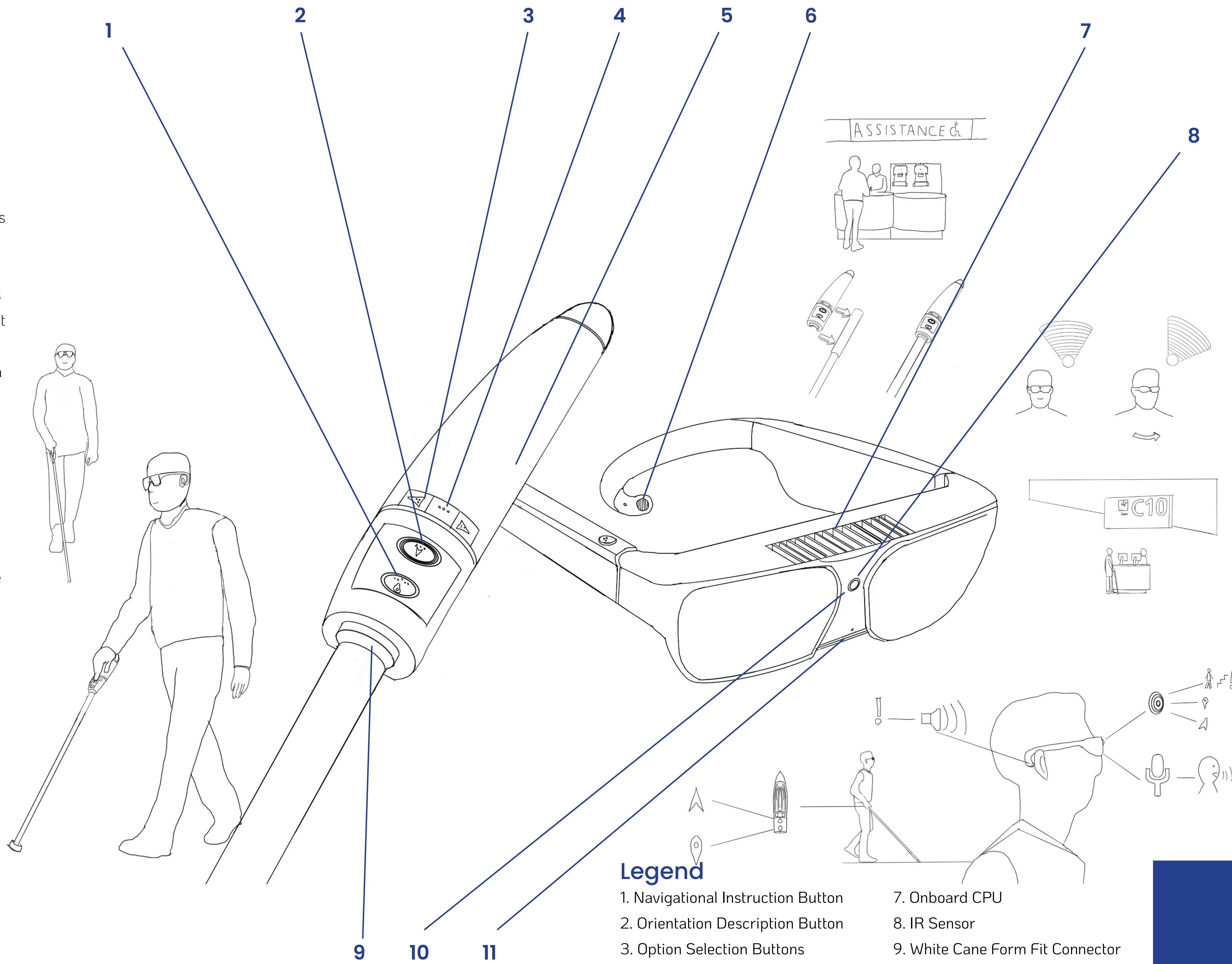
Audio + Vibrations

Environmental Description

Type II

Implementation

Airport Rental



Legend

1. Navigational Instruction Button
2. Orientation Description Button
3. Option Selection Buttons
4. Confirm Selection Button
5. Hand Grip
6. Speaker for Audio Feedback
7. Onboard CPU
8. IR Sensor
9. White Cane Form Fit Connector
10. RGB-D Camera
11. Microphone

Figure 48: Concept 2

11.3 Concept 3
A Vest with a phone holder and 2D LiDAR

Concept 3 is a smart cane attachment that uses a 3D LiDAR sensor system, offering advanced obstacle detection and spatial mapping for VIPs. Like concept 2 it operates independently of smartphones or external devices. The LiDAR scans the environment in real time, identifying obstacles, paths, and landmarks with high precision. Audio and vibration feedback inform VIPs of their surroundings, while voice commands or simple button and touch screen inputs enable navigation and interaction. Designed for airport rental, the cane provides a plug-and-play solution that empowers to move independently without staff assistance. This system enhances confidence and autonomy by offering detailed spatial awareness, responsive feedback, and hands-free control.

Specifications

Sensor

3D LiDAR

Input

Voice Command + Buttons

Feedback

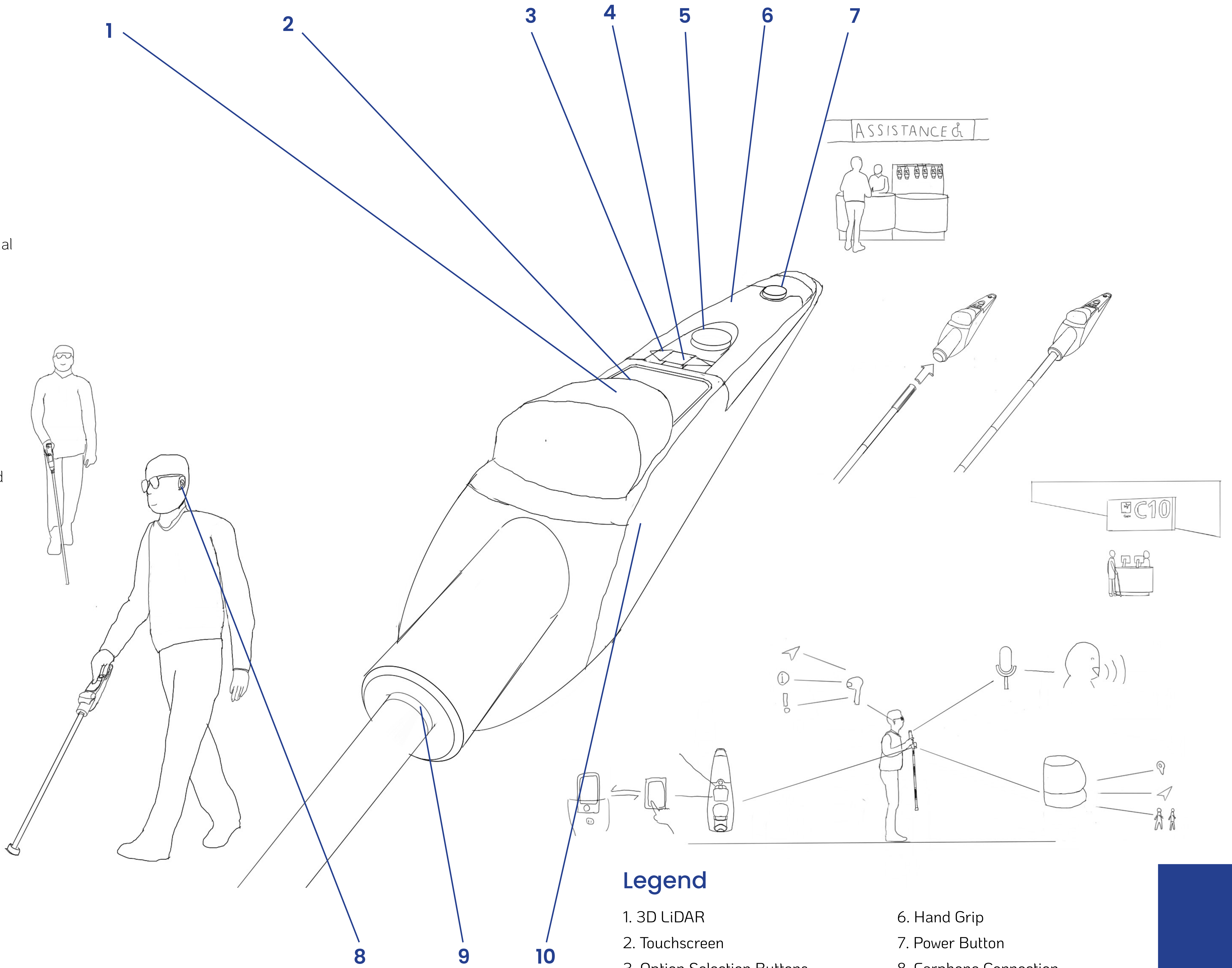
Audio + Vibrations

Environmental Description

Type III

Implementation

Airport Rental



Legend

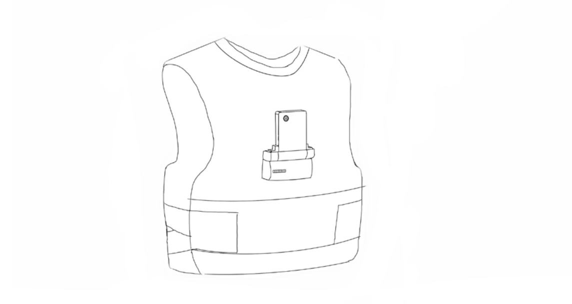
1. 3D LiDAR
2. Touchscreen
3. Option Selection Buttons
4. Confirm Selection Button
5. Orientation Button
6. Hand Grip
7. Power Button
8. Earphone Connection
9. White Cane Form Fit Connector
10. Vibrational Motor (Inside)

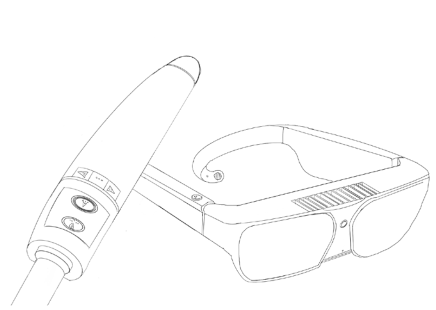
Figure 49:
Concept 3

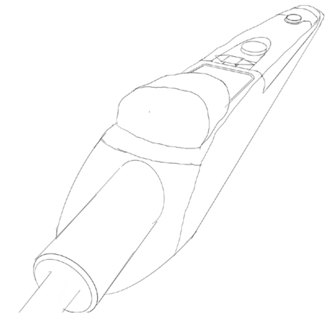
12 Concept Choice

12.1 The Harris Profile

Concept 1 was chosen as the preferred solution due to its strong alignment with both User-centered needs and practical deployment criteria, particularly in the context of a high-traffic environment like Schiphol Airport. Unlike Concepts 2 and 3, which rely on additional hardware such as smart goggles or advanced 3D LiDAR modules, Concept 1 utilizes technology already available to most VIPs such as their smartphones making it easily accessible and usable. Furthermore with its app integration it allows the VIP to study the device at home and familiarize with their route, compared to the other concepts. Its wearable vest design supports hands-free navigation, enhancing the VIPs mobility and independence. While Concept 3 offers superior technical performance with the usage of 3D LiDAR, its added weight on the white cane can create discomfort after a while of usage. Similarly, Concept 2's usage of goggles does make the movement and visibility of the sensor feel more natural as it moves with the movement of the head. However it can be less subtle in appearance, and also create discomfort but adding more weight to the head. In conclusion, Concept 1 ability to integrate the usage of VSLaM for localization and mapping into the VIPs phone and audio headset for feedback, as well as its ability for the VIP to study and familiarize with the device outside of the airport, makes it an appropriate concept to be designed further.







Criteria	Concept 1				Concept 2				Concept 3			
	-2	-1	+1	+2	-2	-1	+1	+2	-2	-1	+1	+2
Obstacle Detection				2D LIDAR is adequete			IR and Camera less accurate than LIDAR					3D LIDAR is excellent
Detection Range				Up to 30m			Less than 30m					Up to 30m
Localization & Mapping Accuracy				LiDAR offer higher levels of localization accuracy			Moderate localization accuracy					LiDAR offer higher levels of localization accuracy
Navigation Support				Audio guidance and app integration			Mixed Interface					Audio + VIbrations
Environmental Awareness				Can read signs				Can read signs			Only relies on map, cannot read signs	
Conveying Feedback			Only Audio based					Audio + Vibrations				Audio + VIbrations
User Input & Control			Only via voice commands					Voice + Buttons				Voice + Buttons
Ease of Use				App usage allows for studying at home		Has to be trained at airport				Has to be trained at airport		
Mobility			Vest offers good mobility				Glasses and Cane offer good mobility				Cane offer good mobility	
Comfort & Wearability				Lightweight and easy to wear vest			Lighweight but head mounted			Discomfort due to weight of system		
Aesthetic			Neutral appearance			Glasses look tech heavy					Subtle but visible tech	
Independence from Staff				Full User control		Might need help for set up					Requires a bit of set up help	
Scalability for Airports			Just requires VIPs phone				More appropriate for public use				More appropriate for public use	
Airport Deployment Feasibility				Integratable with the Schiphol App		More devices to charge and maintain					Just one device to maintain and rent out	
	+23				+9				+16			

Figure 50
Harris Profile Concept Selection

13 Pathfinder Mark I

13.1 Components

The Pathfinder is a hybrid wearable designed to help VIPs travel independently at airports. By incorporating the VIPs phone camera (Bermudez, L. 2024) it makes use of Visual Slam or VSLaM to navigate the VIP from a given starting point at the airport like the enterance or the check in desk to the destination, which is often the gate. The vest consist out of two main components, the VSLaM Navigation App, and the Vest itself.

13.1.1 VSLaM App

Both components are complementary to one another, though the VSLaM app is the primary component that is necessary for the VIP to have in order to navigate independently. The VSLaM is responsible to localize where the VIP is, map a route to the designated destination, and avoid hitting obstacles. Furthermore it should also provide audio feedback for both navigation and orientation ques, and understand simple voice commands from the VIP. One key difference between the Pathfinder Mark I to its concept 1 predecessor is the dissapearnace of the 2D LiDAR sensor. While this will lower the accuracy of the system, as LiDARs are very accurate and reliable (Bermudez, 2024), it would also simplify how the product works technically. Reducing one technical component and simplifying it to only the IMMU and RGB-Ds phone camera as the basis sensor, which work adequete for carrying out VSLaM (McMinn, 2025). LiDAR can still be implemented on the other hand later on and as an attachment instead of a basis component, as noted in the recommendations of Chapter 22. In this configuration, the VIP can use a LiDAR component if desiring greater accuracy and reliability, however can also still use the system without it. This in the end provides the VIP with greater flexibility and reliability when using the system.

13.1.2 The Vest

The Vest on the other hand is a secondary component that holds the phone in the right position in order for the VSLaM to be carried out successfull, such as that it properly knows what the frontside is, and can correct paths accordingly to the VIPs movement. With the vest other people in a terminal building know that a VIP is moving in the area, allowing people to make way, and reducing the chances of the User crashing against a person. Lastly the Vest also gives the User to ability to travel hands free. This is preferable by the VIP as it allows the to use one of their hands to carry other stuff or use it to scan passports and boarding passes when necessary (Bai et al., 2019). Lastly a special pocket under the phone is used to carr a powerbank to provide continues power to the phone while the it carries out VSLaM. The charger prevents the phone from running out of power, allowing the VIP to reach the destination reliably.

13.2 Indoor Navigation

Like all other concepts, the Pathfinder offers indoor navigation through using the SLAM principle. Doing so no additional infrastructure is required for the VIP to navigate through the airport, except for a preuploaded 2D map of the terminal building in Schiphol for referencing. When explaining indoor navigation distances are provided in meters, and directions provided using the clock method. The time and distance required to reach a destination, are always provided. The system also distinguishes between primary and secondary destinations. With the primary being the gate, and secondary being airport amenities and facilities. By having a fixed primary destination, the Pathfinder always knows where the VIP eventually has to end up at, or return to the primary destination. For example when the VIP is at a secondary destination like a restaurant, the Pathfinder should let them know that they have to return to their primary destination, the gate, when the boarding time approaches, preventing the VIP to miss their flight.

13.3 Environmental Awareness

Aside from navigation the travel vest also provides information on ones surroundings. This is done passively when VIPs for example pass an area like the a gate and it informs them what gate they just passed and area the VIP is in, or actively where it describes the room when the VIP demands it via voice command. The system should also calculate and estimate the VIPs distance from a certain gate, to estimate how long it would take to reach it. This allows the system to determine if the VIP has time to explore and what is possible to explore, or should continue their journey when they are waiting somewhere which is not the gate. In other words the system informs the VIP that their gate is opening so they no that they have to head back or continue their journey.

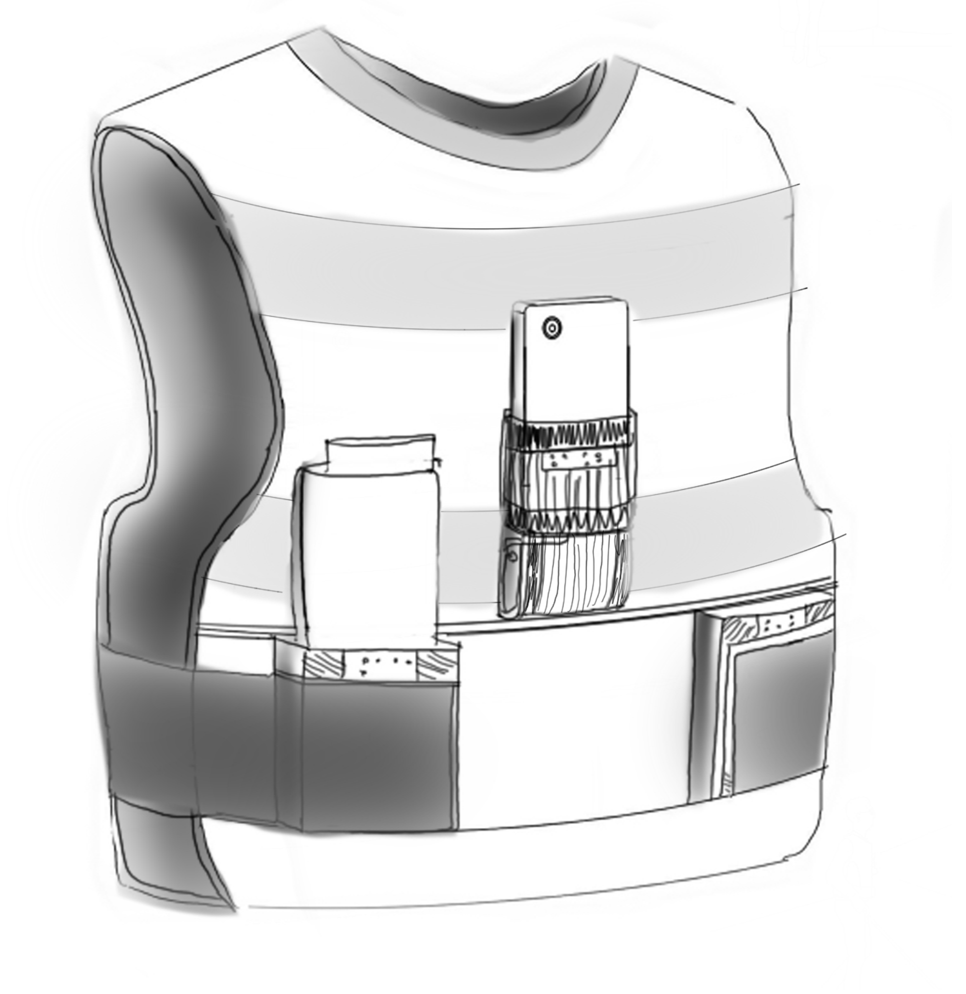


Figure 51:
Final Design Sketch of Mark I

Prototyping & Testing

Part 4

14 Prototype Building

14.1 Vertical Prototyping

Due to the complexity of a creating a VSLAM navigation system, the system was divided into smaller segments based on their functionality and ability to test, also known as vertical prototyping. Doing so parts of the product could still be tested on certain function without having to work out other more complex functions. This is seen in Figure 52 on the right.

Since time and energy are important factors for VIP when they navigate through an airport independently. Feedback systems are the main focus for the prototype, due to the way information is provided and processed being related to the amount of energy required to act and move indepently in an environment (Golledge, 1999)/ Furthermore the focus is primarily on the feedback systems, as those are the ones the make this system stand out to other systems currently in deployment. While current systems also include feedback, information in this feedback is sometimes lacking or unclear (Abidi et al., 2024).

To achieve this two lo-fidelity prototypes are created, one for the vest that holds the phone as intended, and one for the VSLaM navigation system itself. A two level iterative process is used for the prototyping stage starting with Mark I for prior testing and ending with an improved Mark II.

14.2 Technological Readiness Level

As seen in Figure 52 the TRL level of each system layer is defined based on the NASA and the Dutch Ministry of Economic Affairs (Manning, 2023). This TRL Level defines what the theoretical TRL level of the prototype will be when a certain system layer has been implemented. By knowing this, one can know what to further work out and implement in order to reach a certain TRL Level. If all systems were carried out the prototype could potentially have reached TRL level 5. However for the current prototype, though it carries out the intended feedback, voice commands and makes use of the vest, its TRL level is 3.5 instead. This is because most technological functions like the VSLaM are simulated and the RGB-D camera isn't fully integrated into the VSLaM system.

Prototype TRL if Completed	System Layer	Status	Notes
3	Audio Feedback	**Ready**	*Though simulated by person but matches intended function*
3	Voice Command	**Ready**	*Though simulated by person but matches intended function*
4	Vest	**Ready**	*Though as a Low Fidelity Prototype, that carries out the main functions*
4	Obstacle Detection	**Simulated**	*Simulated Function simulated by person instead of by RGB-D Camera*
4	VSLaM Navigation Logic	**Simulated**	*Simulated Function simulated by person instead of VSLaM*
4	VSLaM Position Estimation	**Simulated**	*Simulated Function simulated by person instead of VSLaM*
5	Sensor Input & Integration (Camera + IMU)	**Not Ready**	The only system not worked out to its full potential, due to technical complexity

Thesis Prototype TRL		Notes
3.5	VSLaM Navigation System App and Vest	

Figure 52:
Vertical Prototyping Table

14.3 Prototype Mark I Features

14.3.1 VSLaM App

While the prototype was a low-fidelity one, it had the ability to simulate and carry out its main functions like feedback and voice command functions for the VIP. Figure 53 lists the types of feedbacks and voice commands provided by and for the VIP. The prototype also simulated obstacle detection, and the VSLaM navigation done by a person instead of by sensors. Furthermore it also carried out these tasks with a functional phone camera as intended by the actual system.

14.3.2 Vest

The vest itself was a modified reflector vest, that was lightweight, and had the elastic phone pocket to hold the phone, and two additonal pockets for the charger and other supplies as intended. It looked similair to how it would have been designed though it did not include any markings to tell people that the VIP of a vest is blind. Furthermore no modifications to its design, like the color were made, as its main function was to test if it could hold the phone in such a way that VSLaM can be carried out successfully. Figure 53 visualizes the set up of the Vest.

Figure 53:
Prototype Set Up

Phone Camera with Simulated VSLaM Navigation System

VSLaM Navigation

Progressive Turn by Turn Navigation

Turn in 15 meters, 10 meters, 5 meters, now turn at the McDonalds

Landmark Based Navigation

Turn at the McDonalds

You have passed Gate 2 on the left

Enhanced Destination Feedback

You are travelling to Gate 3 for your flight GA88 to Jakarta Indonesia departing at 11:00 AM, it is now 9:45 AM

Enhanced Arrival Feedback

You have arrived at Gate 3 for your flight GA88 to Indonesia departing at 11:00 AM, it is now 10:30 AM

VSLaM Orientation

Area Indicator

You have now arrived at the gate area

Progress Indicators

You have now covered 50% of your route, continue to reach your gate

Departure Information

Your flight will depart in 30 minutes, please continue to your gate.

Departure Updates

Travel Update! Your Gate has been changed to Gate 5, system will reroute you now to Gate 5

Voice Commands

Area Explorer

User *: Please tell me where I am*

VSLaM System : You are currently at the gate area near Gate 2 navigating to Gate 3. There are shops and restaurants near by, as well as a toilet. have now arrived at the gate area

The Vest

Elastic Phone Holder

Pockets for Supplies

15 Prototype Testing

15.1 Prototype & Test Aims

Airports such as Schiphol are large and complex dynamic environments. Current solutions do exist both in the form of assistance provided by Schiphol, or other VSLaM or assistance methods as highlighted in Chapter 2 & 3. However often these solutions result in the dependency of others, and navigational aids providing either too much or too little information to allow one to navigate through the environment independently *(Analysis of Navigation Assistants for Blind and Visually Impaired People: A Systematic Review, 2021).*

The aim of the test is to compare the performance of the VSLaM Navigation System lo-fidelity prototype against the current airport assistance services provided by Schiphol, focusing on travel efficiency, User experience, and ease of mobility. Ultimately answering the following three main questions

1. *How does a VSLaM Navigation system with its feedback fair against the current assistance provided by airports?*
2. *Why such a technology has not been implemented earlier by others?*
3. *What can ultimately be improved to offer more independence and certainty for Users to use the system?*

and prove or disprove the following hypothesis in 15.2. Focus was placed on evaluating the quality and necessity of the system's feedback, and understand whether they could enhance the VIP' ability to navigate more independently within a simulated airport environment.

15.1.2 Hypothesis

> ***"Using the Pathfinder VSLaM Navigation System prototype will result in improved travel efficiency, enhanced VIPs experience, and greater ease of mobility for VIP compared to traditional airport assistance services."***

15.3 Variables

To test the effectiveness of the Pathfinder VSLaM Navigation Prototype, a number of variables were used, divided into the control, independent, and dependent variables. Control variables such as the route taken, location of obstacles, type of feedback recieved, and phone camera made sure that the test remained consistent between the two scenarios presented. The independent variables, which was the mode of navigation, was changed between the two scenarios to understand its impact on the VIP. To understand the impact of the change for the VIP, dependent variables, were chosen based on relevant factors that affect a VIP when navigating. These factors included travel efficiency, that measured the time and energy used by the VIPs to navigate(Jones et al., 2018), the VIPs experience, that measured the VIPs sense of independence and control and the overall usefuless of the system (Kamelska & Mazurek, 2015) , and the ease of mobility which measured the ease of following instructions, walking along the path, VIPs ability to localize where they are, and avoid obstacles (McDonnall & Sui, 2019)

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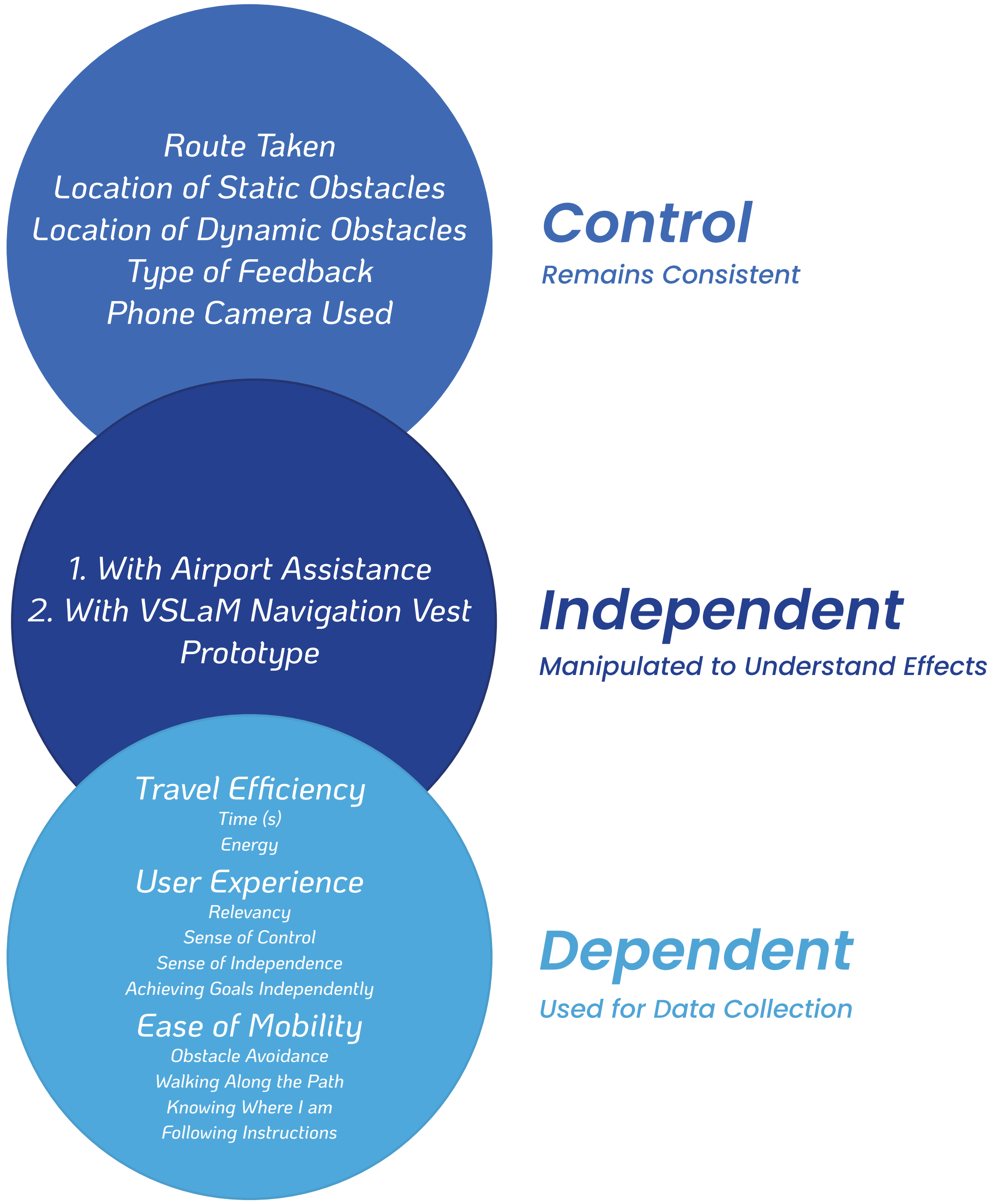


Part 4: Prototyping & Testing

15.4 Methodology & Set Up

Focus was primarily set on the two largest challenges VIPs face when departing from Schiphol, which from the journey map in Chapter 4 and Figure 54 was to navigate through large unfamiliar open spaces, and obtaining the right information to localize (Iozzio, 2014). To mimic Schiphols environment the large hall in the IDE building and the corridors were used. The test itself was split in three parts, the first part was a pilot test, necessary for regular VIPs to get familiar on how to navigate with a blind cane and do that blindfolded. The second part, or Act I was to navigate from a point A after the check in to the gate, with the vest. The third part, or Act II was to navigate the same route but with assistance. Data was only collected from the second and third part, using questionnaires from (Minge et al., 2007). The detailed procedure is presented in Appendix A7.

Pilot Test

Act I
With the Vest
and VSLaM System

Act II
With Assistance

Figure 54:
Test Parts

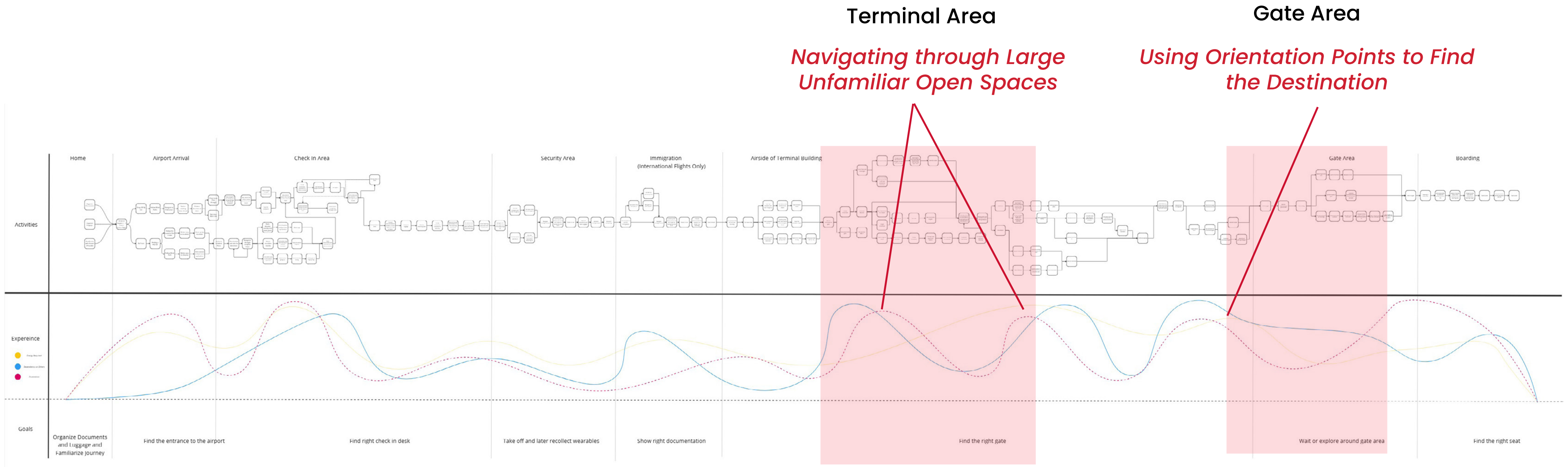


Figure XX:
Focus Areas

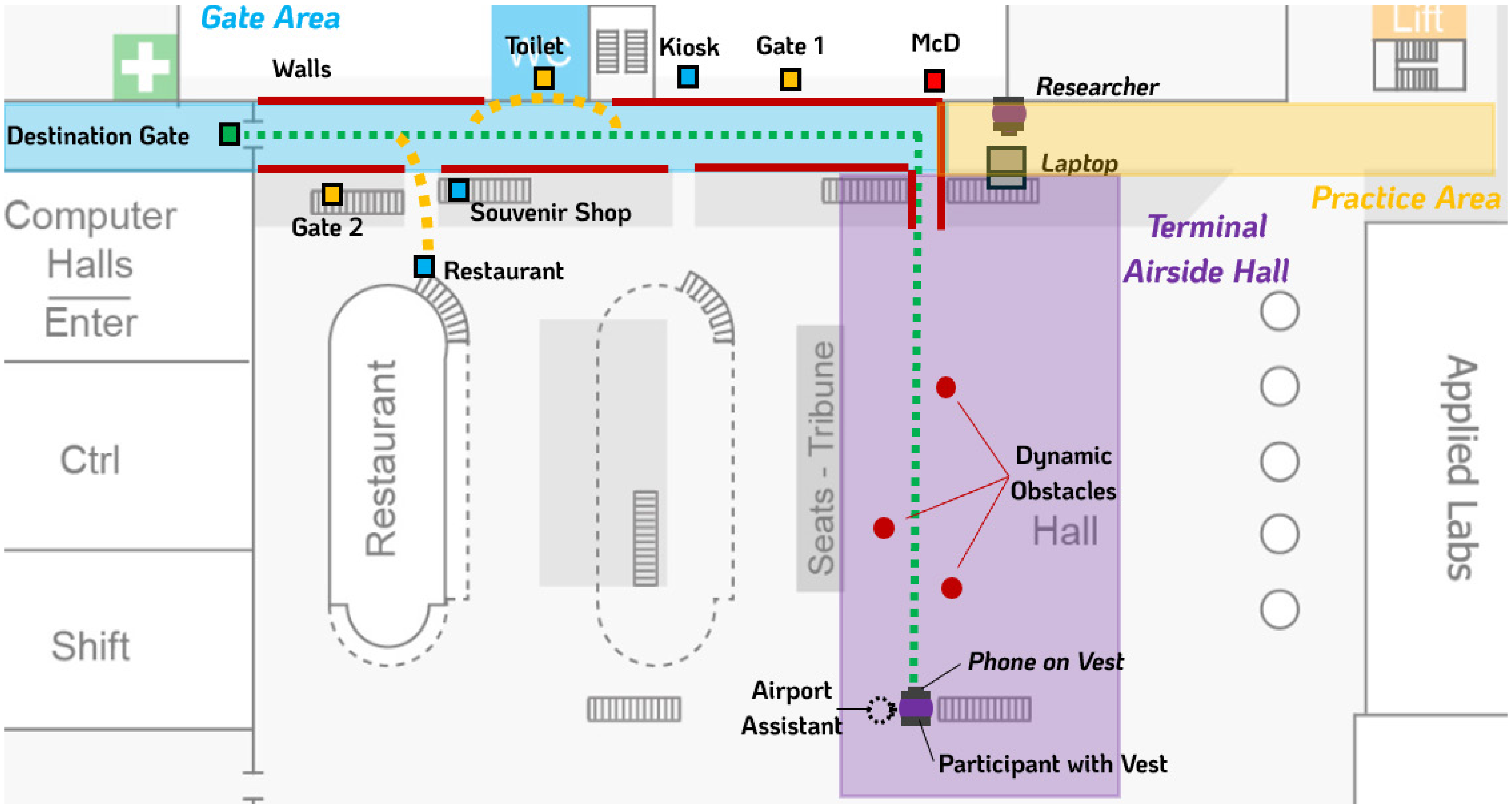


Figure 55:
Test Set Up

15.5 Participants

A total of 16 participants were recruited for the prototype test based on the G*Power Statistical Method (G*Power, n.d.) which identified this number as the minimum required for producing scientifically meaningful results. Participants were primarily students and acquaintances recruited from personal or close networks. From the participants demographic data was collected, that reflected their gender, age, technological proficiency, and languages they spoke. The participant group was largely male (69%) aged 25 - 34 years old, and had a high technological proficiency (63%), suggesting that the group was familair with using mobile devices and apps such as the prototype. All participants also spoke English, though for most it was a secondary language which could impact on how clear and familiar they were with understanding instructions provided in English by the Pathfinder Navigation system. One important note is that participants were not VIP, and simulated blindness using a blindfold. This was primarily done, as being the very first test, many unknown risks could still be present that could potentially injure an actual VIP. Furthermore it also allowed faster and easier recruitment of participants. While the participants used do not fully reflect the behaviour of those who have VI. Inputs provided by participants were still valuable to the understand what could be improved by the system, and how it performs against current assistance. Though testing with actual VIPs is necessary for more accurate results.

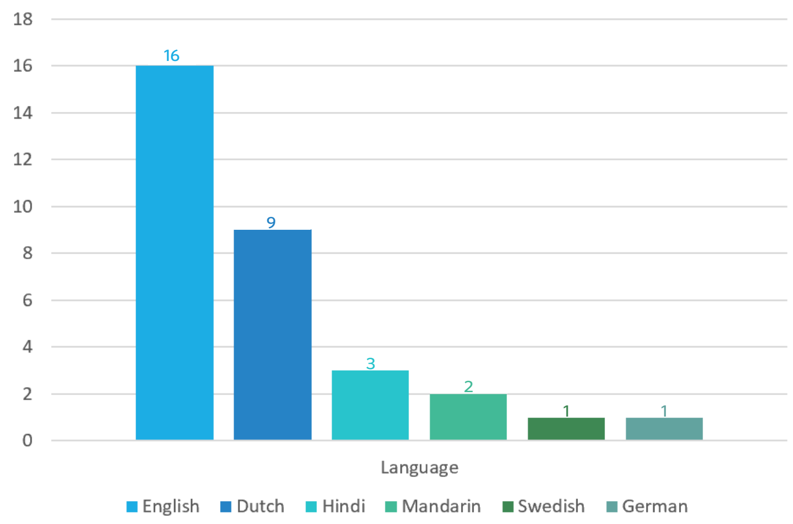


Figure 56:
Languages Spoken

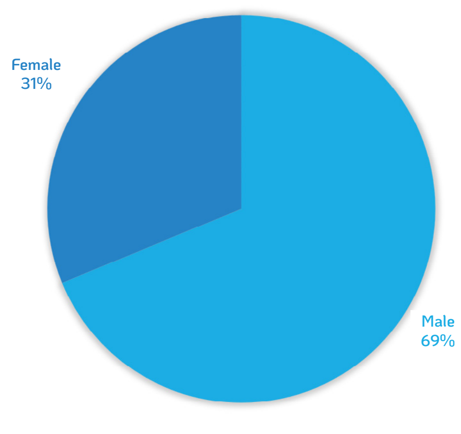


Figure 57:
Gender Distribution

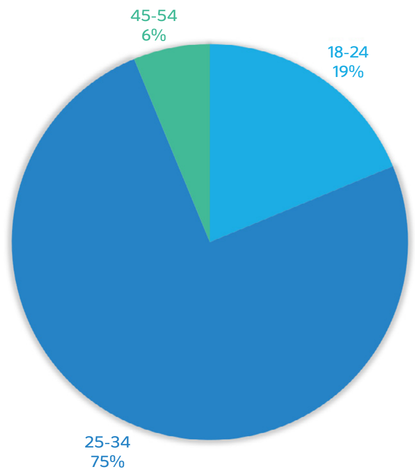


Figure 58:
Age Distribution

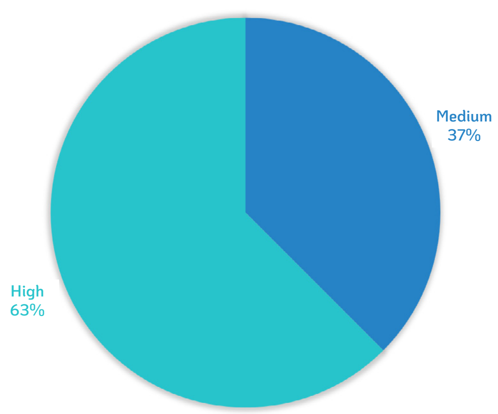


Figure 59:
Technological Proficiency

15.6 Results Travel Efficiency

15.6.1 Time to Reach Destination (s)

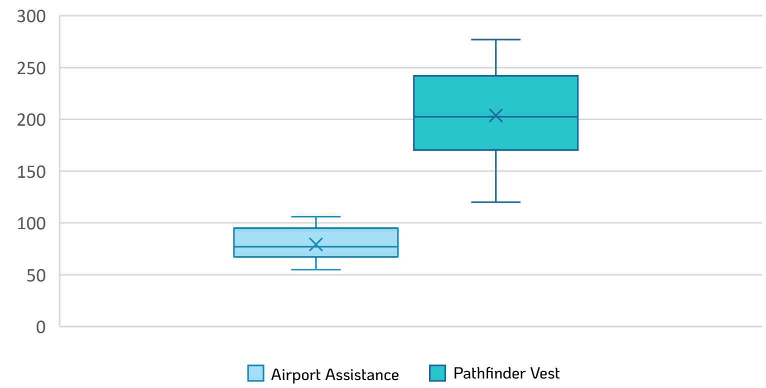


Figure 60:
Elapsed Time Chart

This chart clearly shows that it is still faster to reach the destination with airport assistance than with the Pathfinder VSLaM system. With the average time with assistance being 75 seconds, and that with the Pathfinder VSLaM system being 207 seconds The chart also shows that the time travelled with the Pathfinder VSLaM system varied much greater, reflecting the different speeds at which VIPs walked. Some speeds were slower as more adjustments were required and time was required to process information.

15.6.1 Energy Usage

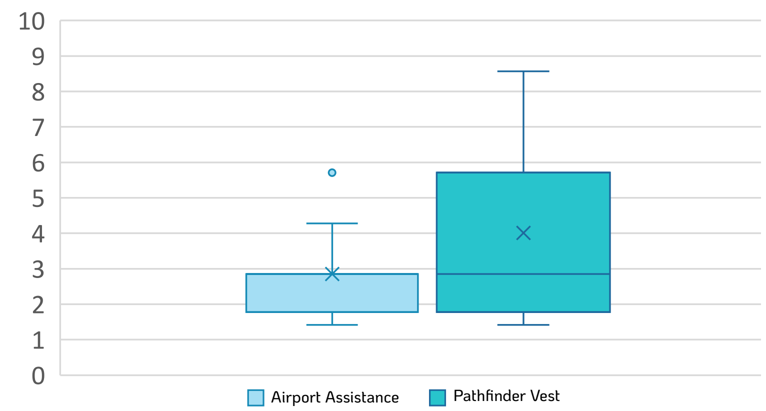


Figure 61:
Elapsed Time Chart

Energy usage has a lower average with assistance being rated 2.97 when compared to using the Pathfinder VSLaM system which is 4.01 This is primarily caused as with assistance the User acts passively in the environment compared to with the Pathfinder, which required less energy in general. The large Inter Quartile Range of and range with the Pathfinder also reflected that VIPs had a greater variety of energy usage when navigating, with some using signficantly more energy than others.

Design Implications

To improve the Pathfinder VSLaM system, and account to the large ranges of speeds two main improvements could be made. The first one is to adjust the speed at which feedback is provided to account for the speed at which one is moving. Hence the feedback comes at the right time and can be understood and be reacted upon at the right time. Secondly, feedback like path correction should be made more clearer, as processing and correcting ones path often costed the most time for those travelling individually.

***Key Points:** Adjustable Feedback Speed, Enhanced Path Correction Feedback*

Like time, one of the main causes that energy usage was significantly higher when travelling with the vest, was because of processing and correcting ones path. The more path corrections were required the more energy was required to navigate. Additional energy was also used for processing obstacles and locating their position. Hence it is essential that path correction feedback becomes more intuitive for VIPs, as well as that more information on an obstacles location and type would be provided.

***Key Points:** Intuitive Path Correction, Enhance Obstacle Feedback*

15.7 Results User Experience

15.7.1 Relevancy

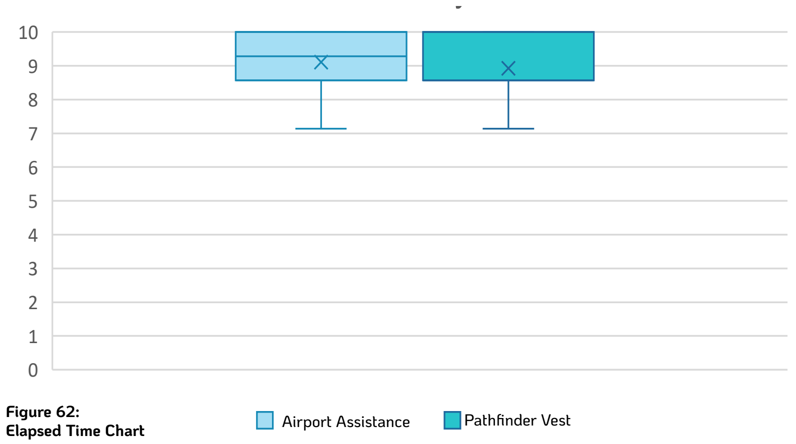


Figure 62:
Elapsed Time Chart

Both the Airport Assistance and Pathfinder VSLaM system are rated very highly in terms of relevancy, with similar medians and tight interquartile ranges. This indicates VIPs felt that both systems were appropriate and useful for the navigation task. However additional feedback on relevancy did reveal that when tasks had to be completed at a short amount of time, such as reaching the gate in a short amount of time, assistance was more preferable due to passive guidance behaviour and the lower need to explore and act independently.

15.7.2 Sense of Control

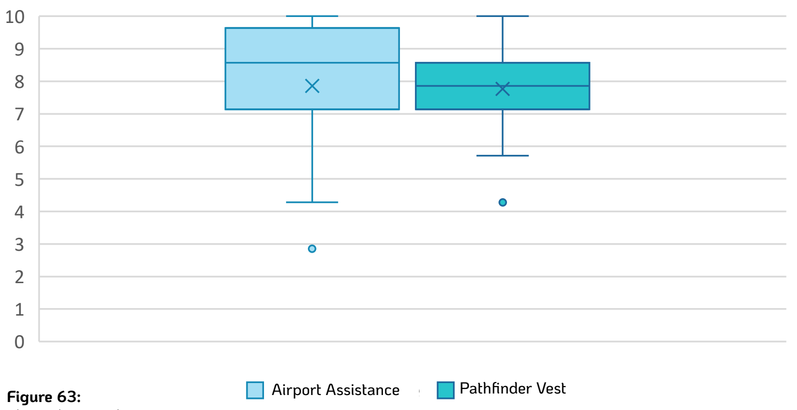


Figure 63:
Elapsed Time Chart

The narrower IQR for the Pathfinder indicates that participants had more consistent experiences regarding their sense of control, with most responses clustered closely around the median. In contrast, the wider IQR for Airport Assistance shows a broader range of experiences, meaning VIPs felt varying levels of control depending on the situation.

Design Implications

While the charts indicate that both methods are already relevant. Relevancy for the VIP with the Pathfinder VSLaM system can be further enhanced through additional features, such as personalization. Through personalization the system can inform of the VIPs own preferable restaurants, cafes and shops that they pass by or are nearby to. A preview system would also enhance the relevancy, allowing the VIP to study the route from before and familiarize with it to enable the creation of rough but valuable mental maps for navigation. Lastly the addition of a call for assistance button would be desirable for VIPs if they opt to reach their destinations quicker or are stuck.

Key Points: *Personalized Feedback, Route Preview, Request for Assistance for Efficiency*

The Users sense of control can be enhanced for the Pathfinder VSLaM system with higher feedback precision, error handling, and route adaptability. Doing so it could allow it to match or exceed traditional assistance, particularly in edge cases where VIPs felt less confident. Reducing uncertainty and enhancing real-time support will be key to elevating the overall control perception.

Key Points: *Personalized Feedback, Route Preview, Request for Assistance*

15.7.3 Achieving Goals Independently

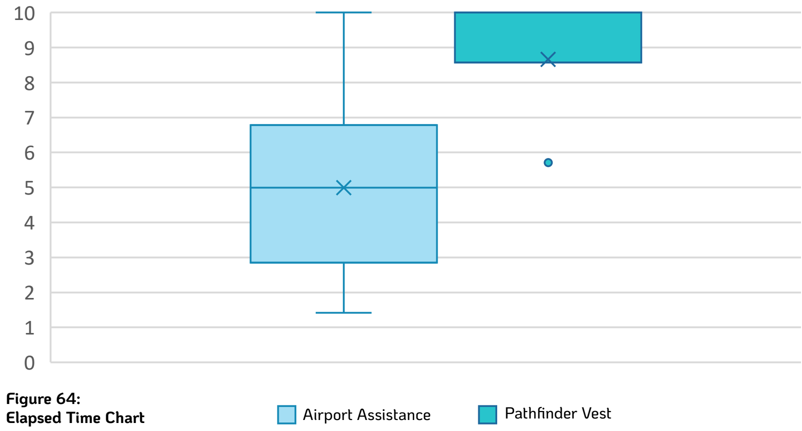


Figure 64:
Elapsed Time Chart

The Pathfinder VSLaM scored significantly higher in achieving goals independently, with a high average nearing the maximum score of 10. This validates that the proposed solution offers a more independent method of travel at airports like Schiphol for VIPs, when compared to airport assistance.

15.7.4 Sense of Independence

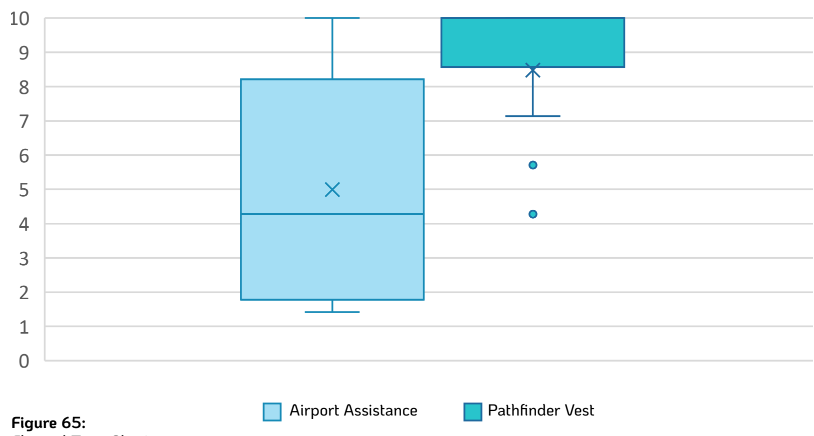


Figure 65:
Elapsed Time Chart

Aside from achieving goals more independently, the Pathfinder VSLaM system also shows high, consistent independence ratings, for a sense of independence of the VIP. This shows that VIPs feel more empowered when they control their journey through using the proposed solution.

Design Implications

This is a major strength of the proposed solution. It is important hence to maintain and further enhance features that enhance independence of the current prototype. This includes enahancing features that allow the VIP to make choices and act in their environment, like identifying different methods of travel like elevator and escalator and providing a choice for the VIP. Providing additional information such as giving information on crowdedness in areas could also enhance a VIPs ability to chose and act where to go and what to avoid when wanting to explore.

Key Points: *Enhance Choices provided to Users, Enhance Orietnational Feedback on Relevant Factors*

While the sense of independence is important for the VIP, trust and certainty are also key. Therefore to further enhance the sense of ones independence it could be handy to add an additional help request function, for in the case that things might go wrong. This would further empower independence, without undermining the VIPs autonomy.

Key Points: *Request for Assistance to Empower Independence*

15.8 Results Ease of Mobility

15.8.1 Walk Along Path

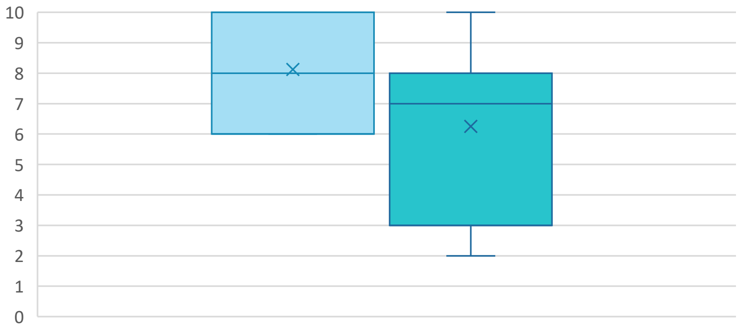


Figure 66:
Elapsed Time Chart

This chart shows better performance for Airport Assistance, with higher medians and a tighter range. This is obvious as following someone is easier than navigating a path alone. The Pathfinder VSLaM System had more variability and lower mid-range scores, possibly due to uncertainty that often caused the VIP to veer off course. Furthermore it became hard for the VIP to understand on how to correct themselves again.

Design Implications

Improvements here can once again be made in terms of path correction. By enhancing the clarity of path correction and also instructions on how to follow the path, VIPs are more certain that they follow the path correctly and know how to correct it better. Instead of just using the clock method to correct the path, which is sometimes confusing as turning 1 o clock can mean different sizes of turns for different people, a more dynamic system can be developed that indicates when the person should start to turn and when to stop to correct their path.

Key Points: *Enhance Path Correction, Use more Dynamic Correction Methods*

15.8.2 Obstacle Avoidance

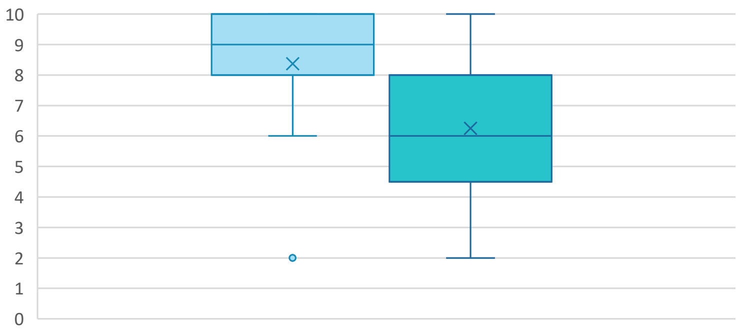


Figure 67:
Elapsed Time Chart

Airport Assistance outperformed the Travel Vest in obstacle avoidance, which is expected since a human guide can actively anticipate and react to hazards. The Travel Vest had more variation and lower scores.

While Obstacle detection is integrated into the Pathfinders VSLaM system, it still has room for improvement. One major one being to inform the direction of obstacles and the type. It would also be handy when navigating through narrow areas at airports like quene lines or hallways to inform the VIP of walls and fences on the sides. This would allow the VIP to know to be wary on not to collide to the sides, or use the sides as a reference to navigate further.

Key Points: *Enhance Detail on Obstacles, Inform if Obstacles can be Useful*

15.8.3 Knowing Where I am

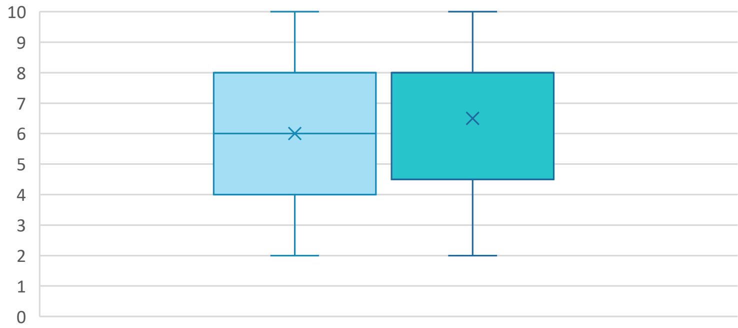


Figure 68:
Elapsed Time Chart

Both systems perform similairly when it comes to informing the VIP on what is around them. The slightly higher average of the Pathfinder indicates that it performs a bit better when describing the surroundings to the VIP to help them orient themselves. While the higher bound shows that some VIPs clearly knew where they were, the lower bounds on the other hand, indicates that there is room for improvement.

Design Implications

Improvements to enhance spatial awarenes can be made on landmark recognition and clearer, more frequent contextual audio prompts like “you are now entering the gate area”. Due to the wide ranges on orientation clarity for the VIP, an additional feature on adjusting amount of information provided can be added. Doing so Users can adjust the detail and frequency on orientational information to their own desire, preventing information overload and the lack of information.

Key Points: *Adjusting Amount of Information Provided*

15.8.4 Following Instructions

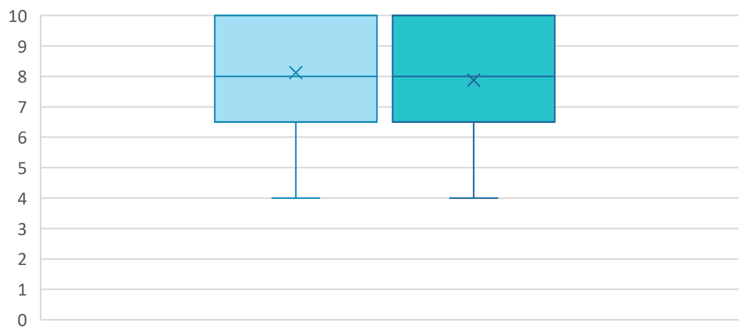


Figure 69:
Elapsed Time Chart

Both systems performed similarly here, with high and consistent scores. This suggests VIPs found instructions easy to follow in both cases, indicating that your feedback design is already quite solid.

While instructions are known to be quite clear, improvements can still be made in adjusting the speed in which information is provided in terms of walking pace. It is also important that a repeat function is present in the event that information is unclear or missed and the VIP desires to listen to it again.

Key Points: *Repeat Instructions, Adjusting Information Speed*

Finalization & Implementation
Part 5

16 Pathfinder Mark II

16.1 Evaluating the Hypothesis

Based on the hypothesis and questions as well as the charts in Chapter 16, the Pathfinder Mark I greatly improves the VIPs experience through enhancing their autonomy when navigating through the simulated airport environment. This is indicated through enhanced sense of independence and control (15.7.2, 15.7.3, 15.7.4). With the Pathfinder Vest and VSLaM system VIPs could travel more flexibly through the airport. However it still faces limitations in travel efficiency and ease of mobility. In these areas, airport assistance significantly promised faster travel times, lower energy usage on average, and easier method of following the route and avoiding obstacles. Another area of importance, is that the amount of information obtained from the environment varied for each VIP. Some VIPs preferred more information, notably landmarks, while others just preferred the directions to their final destination. Hence in the end the Pathfinder proves the hypothesis that it enhances user experience through improved autonomy, but can still be improved in terms of efficiency and ease of mobility.

16.2 Relevancy of Producing Mark II

Due to higher efficiency with assistance, airports like Schiphol opt to use assistance. It is a rather inexpensive and reliable way for guidance of VIPs to the gate. While some airports like those stipulated in Chapter 2 and 3 have implemented infrastructure based solutions, like BLE beacons or RFID, these solutions can often be complex to install and maintain overtime (Mashiata et al., 2022). Reference based solutions like VSLaM, are promising but also still challenging to implement (R. R. A. Bourne et al., 2017). However that does not mean that there is high potential in a VSLaM system as it does promise higher autonomy and flexibility. Hence the improvements in Mark II, would layout the framework on how this system can be implemented in a more flexible way, integrating current solutions already available at the airport, as well as enhancing the flexibility and autonomy of the user.

16.3 Improvements

Figure 70, describes what improvements are implemented in Mark II, from the testing results of Mark I in Chapter 15. Their integration in the design are also gradually explained throughout Chapters 17, 18 and 19.

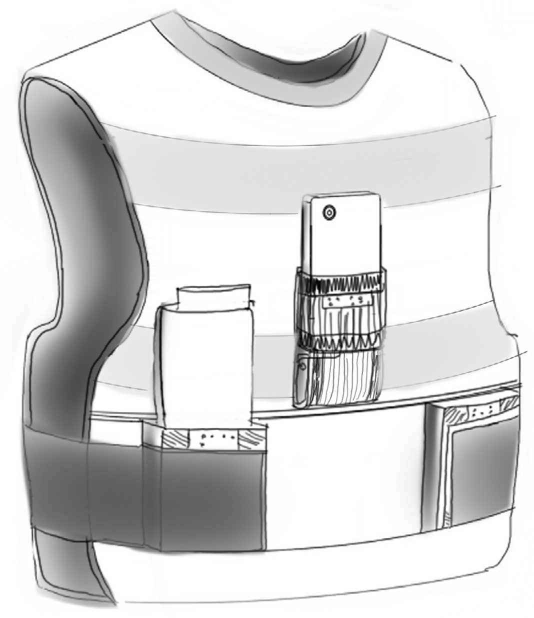
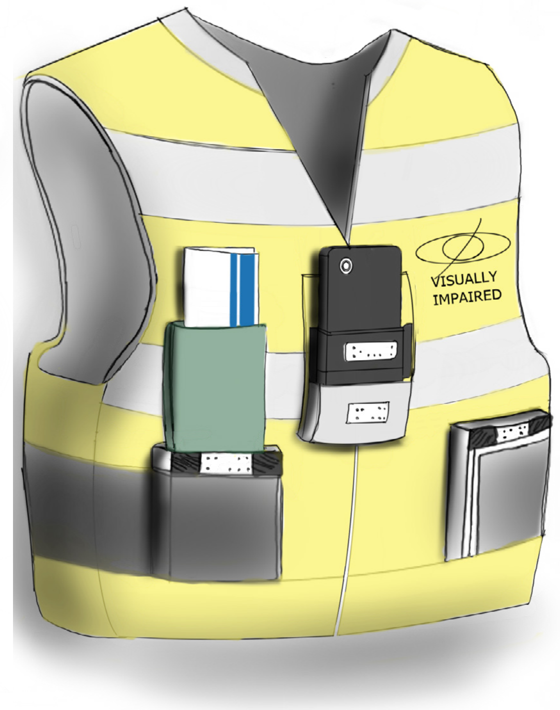
	Mark I	Mark II
		
Landmark Feedback	Not Adjustable	Personalized
Feedback Speed	Not Adjustable	Adjustable
Path Correction	Clock Method	Clock Method + Continous Feedback
Obstacle Detection	Type + Direction	Type + Direction + Distance
Assistance	Not Implemented	Implemented
Route Preview	Not Implemented	Implemented
Airport Implementation	Rent Based System	Personally Owned

Figure 70:
Mark I and Mark II Comparison

17 Mark II Usage

17.1 Mark II Vest Usage

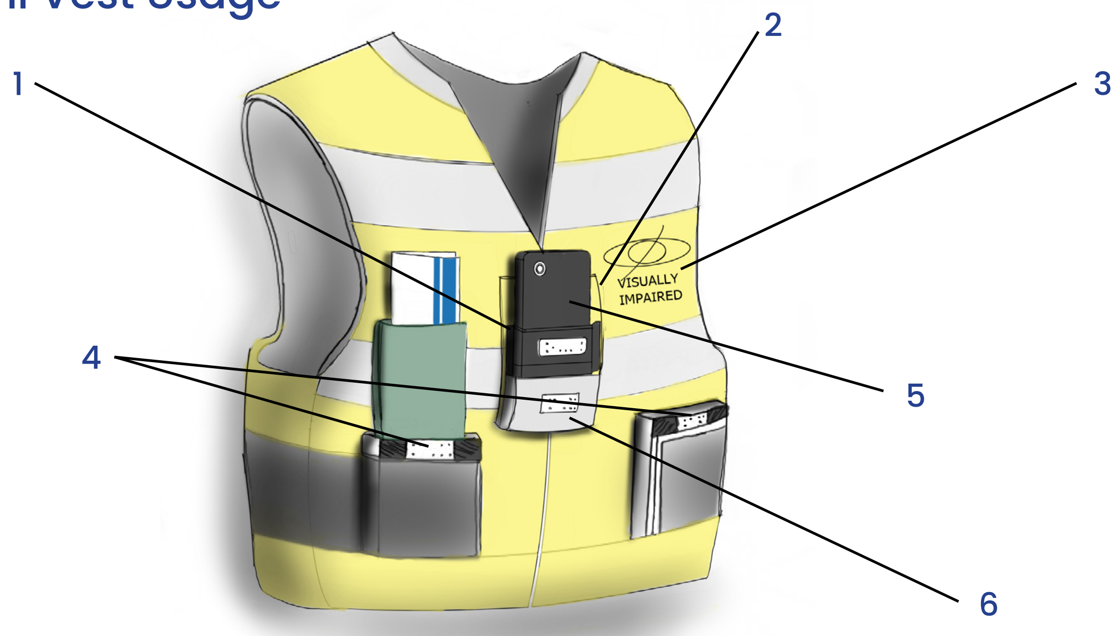


Figure 71:
Mark I and Mark II Comparison

In appearance the Mark II Vest does not contain major changes to its Mark I predeccessor. One change being that the velcro connector straps are now connected at the center instead of the sides, as this was easier for the VIP to put on (Jeamwatthanachai et al., 2019). Some other changes were slight redesigns to the phone holder which is made out of one large elastic strap instead of multiple, with a harder base, as this was easier to accomodate the phone and take it in and out (Aap, 2023).

Legend

1. Elastic Phone Holder
Universal phone pocket holder to firmly hold the phone in place and accommodate a variety of phones.

2. Velcro Straps
To attach and detach the vest with ease velcro straps are used in the center of the vest.

3. Signage
Behind the vest and infront at the side a logo of the VIP is placed to inform and warn other Users that a VIP is walking through.

4. Pockets with Braille Labels
Braille labels are used to identify pockets for the VIP.

5. Phone for VSLaM
See Next Page

6. Integrated Charger Hold
To provide continous power to the phone during usage

Figure 72:
Final Design Sketch

17.2 VSLaM Calibration

Prior to using the Vest, the Pathfinder VSLaM system carries out calibrations. This is done in order to know if the position of the phone is correct and facing forward in order for the VSLaM to be used and carried out successfully. Calibration works by comparing the newest frame to the previous frame and from the RGB-D Camera relating that to the position of the VIP through the IMMU. If the VIP starts from a certain frame seen in Figure 73, and they move forward, the system expects the next frame to be a closer version of that frame, as seen by the blue screen. Anything that does not look like a closer version like when the camera suddenly shows a frame of the right side without the VIP having moved to the right, means that the position is wrong, and the calibration has not been carried out successfully. Two types of calibrations exist, a preliminary calibration, which checks if the system works for the first time, and determines if the VIP actually needs a Travel Vest to stabilize the phone for VSLaM, and regular calibrations which are done everytime the VIP starts the app afterwards to see if everything is positioned correctly. Preliminary calibrations are ideally done at home, while regular calibrations are done at the airport. When regular calibrations fail multiple times, it will also redirect and advice the VIP to order a Travel Vest. For both types of calibrations when things fail for a number of times, assistance from airport staff and or the emergency contact will be requested.

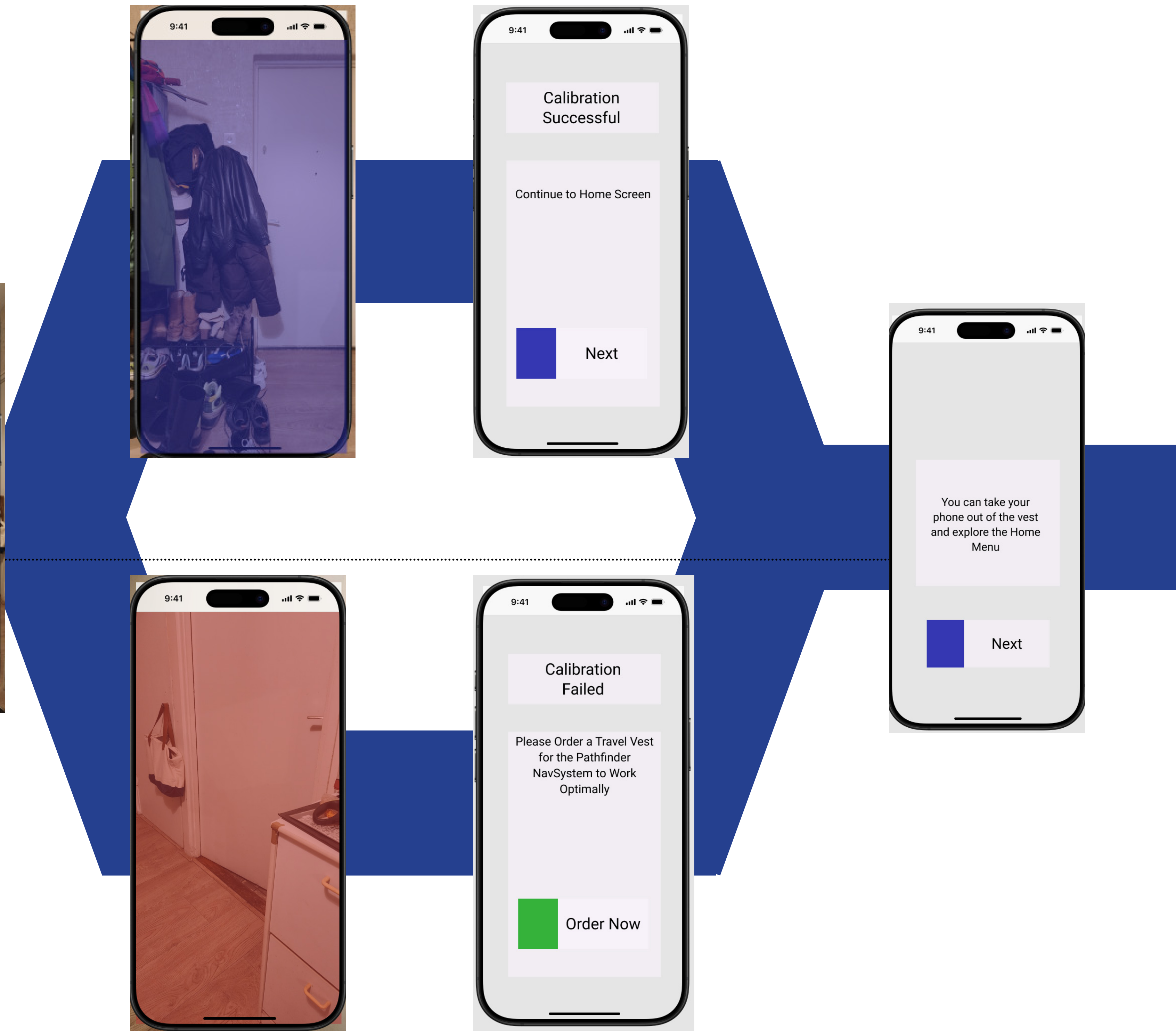


Figure 73:
Usage Flow Diagram

17.3 App Usage

17.3.1 Navigation Interface

After calibrations are completed the VIP enters the Home interface, which is navigationable through both touch and voice command of the VIP. It is based on IBMs NavCog interface (IBM NAVCOG) due to its already tested interface design, though it also integrates additional functionality of the Pathfinder. When using touch screen, options would be read out loud through a phones built in text to speech function. Both types of inputs are taken into account to accomodate if the VIP either uses the app when stationary and exploring it on a seat or when standing, or when they are actively moving around through the airport.

The home menu has several navigational options, namely the navigation, explore, settings and shop option.

17.3.2 Navigation Interface (1 -> 2 -> 3 -> 4)

The navigation option, leading to the route planning and preview option. If a VIP chooses Route Planning, they can either through voice command or their touch keyboard provide their date, flight number, and destination. The system then confirms the destination to the VIP. Afterwards a last check is done asking if the VIP is travelling with assistance or not. Finally the VIP is requested to use place the phone in the vest. Once this is achieved the VSLaM navigation will commence. From there the VSLaM system would automatically have to work out based on a VIP's position and time how to get to their primary destinations, which for departures would be the Check In Hall, and the Gate. Unlike regular destinations where navigation terminates when the destination has been reached, a primary's destination navigation only terminates when the time has passed. This also takes into accound boarding delays and gate changes. More on that in Chapter 18.4. If the check in hall has already been passed, it would have to navigate to the Gate area only.

Whenever navigation takes place it should always navigate a VIP to a place where they can be assisted. For example to the boarding agent at the desk, or to a counter at a restaurant. From there a VIP can be further assisted to their needs. A reason why this is done is primarily to avoid VIPs going to areas and then not be able to do anything. Or to go to a restaurant but not be helped as no staff failed to notice the Users arrival.

17.3.3 Preview (1 -> 2 -> 3 -> 3A)

VIPs also have the option to preview their route whenever they are at home or anywhere else and the flight information is available. Doing so the VIP can study areas and landmarks they pass. This could help familiarize them with the complex environment of the airport, especially the airside which usually is not possible. Enhancing the VIPs ability to create mental maps.

17.3.4 Explore Interface (1 -> 1A -> 1AB -> 2AB)

Users also have the option to explore the airport, both at home or when navigating through the airport. This is possible either by calling out through voice command when they navigate or through touch. Here a VIP can explore different types of points of interests also known as landmarks, and also save them. Once they are saved they will also be actively mentioned to the VIP when they pass them. They can also inversely be removed if a VIP is no longer interested in the landmark. Doing so a VIP can adjust the amount of information they recieve when navigating, preventing information overload or a lack of it. VIPS also have the option to adjust call out options, to adjust the distance of what landmarks will be revealed to them when they call out explore. Through the explore interface VIPs can also navigate to the landmarks by selecting them. More about how VIPs are reminded to navigate back to their primary destination in Chapter 18.4.

17.3.5 Settings Interface (1 -> 1B -> 1AB)

In the settings interface VIPs can adjust their travel pace, usage of vibrations, language, units, volumes and saved landmarks. From here the VIP can also access their saved landmarks, and add or remove them from the list. This allows the VIP to personalize their route experience more, and adjust it to their own preference.

17.3.5 Shop Interface (1 -> 1C)

Here a VIP can order a Pathfinder Vest if they dont have one yet, as the app can also be operated independently from the vest. In the future additional attachments can also be added here, in order to enhance a VIPs travel experience.

17.3.6 Back Up Interface (1 -> 1C)

Legend

1. Repeat Instruction

Figure 74:
Navigation Touch Interface

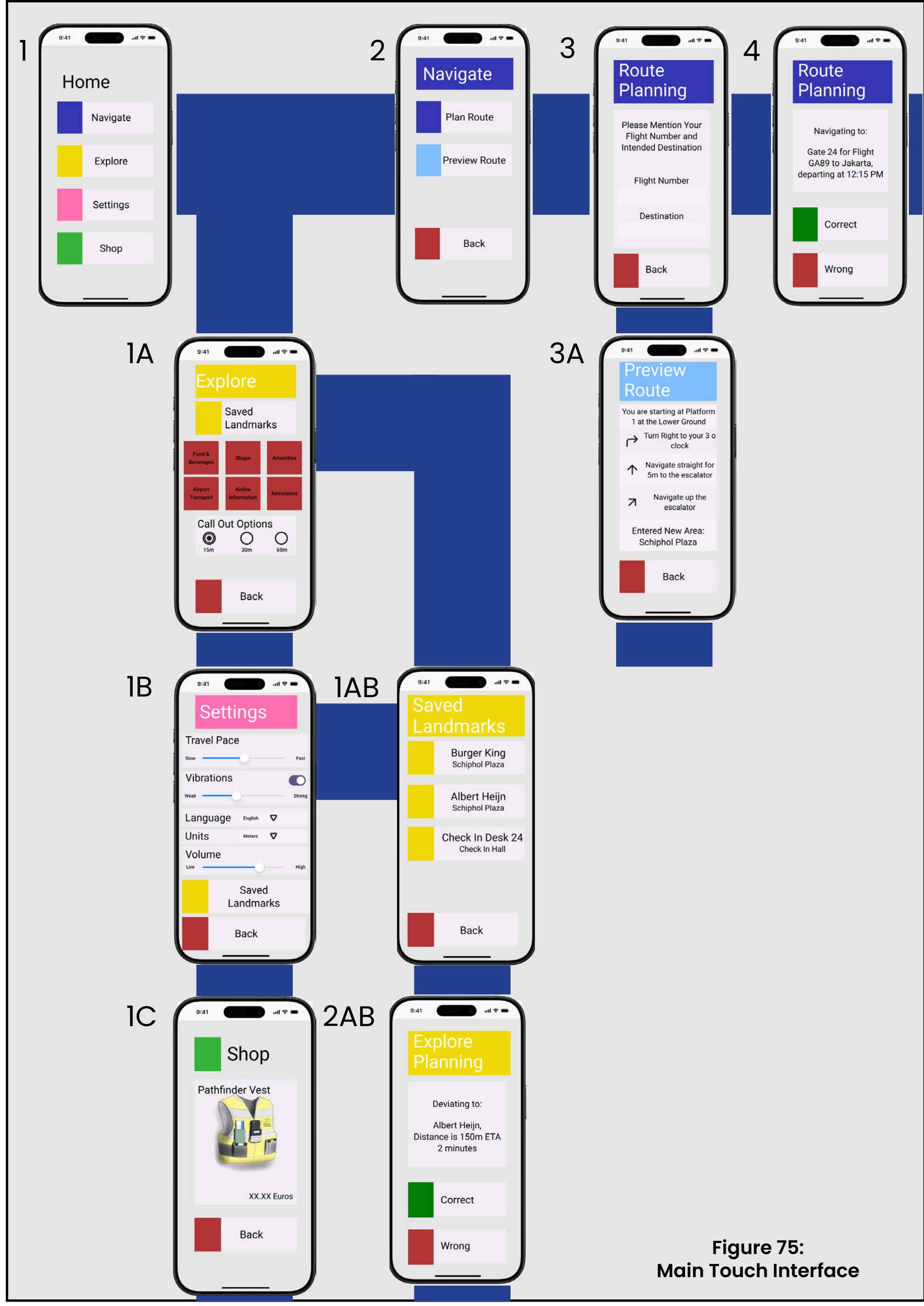


Figure 75:
Main Touch Interface

2. Call for Assistance

3. Explore

4. Return to Home

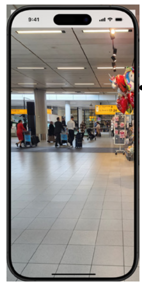
During Navigation, when voice commands fail, VIPs can also access a touch screen interface, where they can navigate back to the home menu, explore, repeat instructions for navigation, and call assistance when required. Doing so VIPs can still make use and interact with the VSLaM system when primary systems fail. Furthermore if audio feedback fails, the system would switch speaker mode of the phone to relay instructions until the headphones are connected again.

17.4 App Features & Flow

Flowchart Block Key

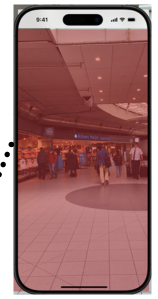
User Input	Processing	User/ System Choice	Environmental Input	Audio Feedback	Assistance Request

Obstacles

The system warns Users of obstacles that pass near them. Explaining the type of obstacle and its location relevant to the VIP. When an obstacle is about to collide with a User, the system warns the VIP to stop to prevent a collision.

Route Correction

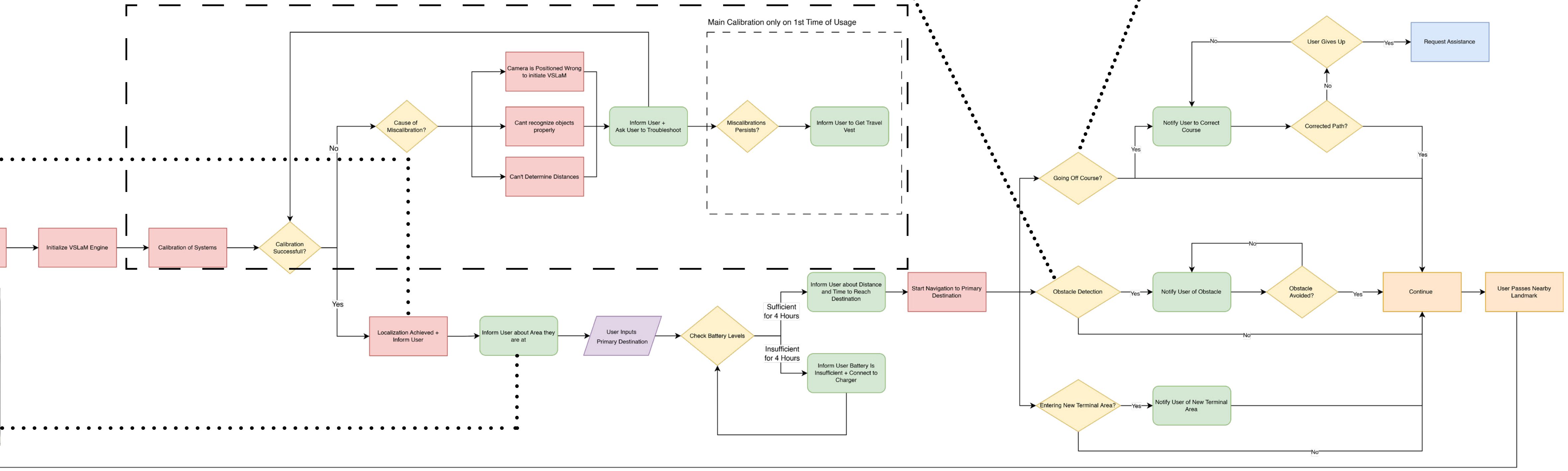


When vearing off course, the system automatically corrects the path, by providing a warning that the VIP is going off course, and then a correction course. The system will also confirm if the VIP is back on track once they have done so successfully.

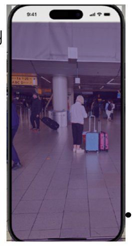
Part 1

Start Point

When starting the system informs the VIP of their intended destination which is the gate as well as the VIPs flight details like the flight number, airline boarding time and destination.

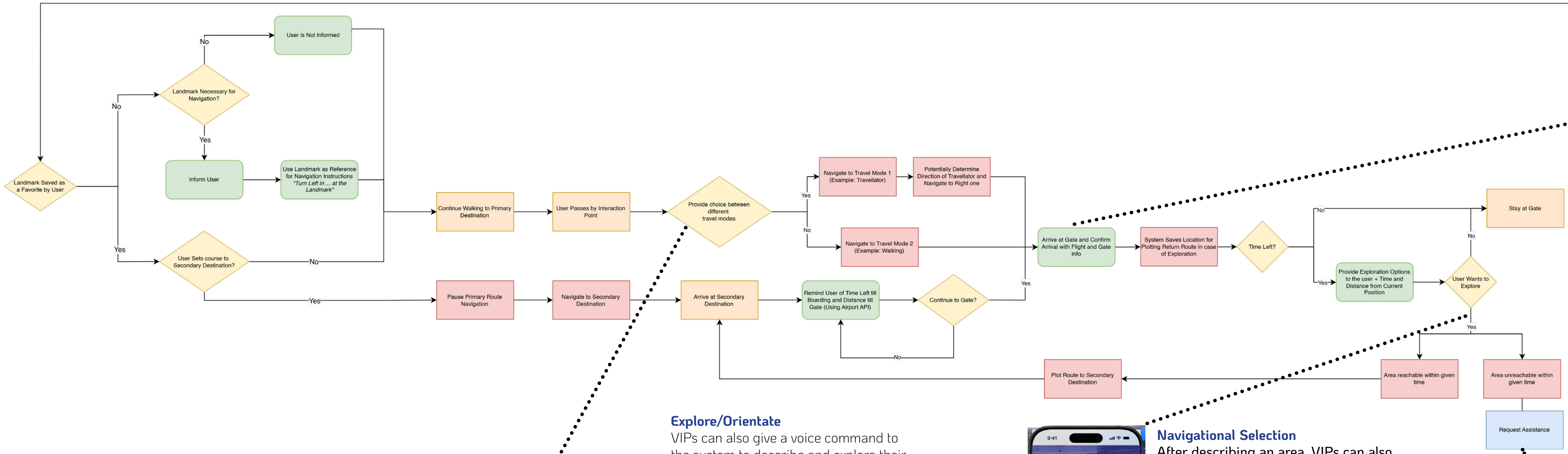


Building Area

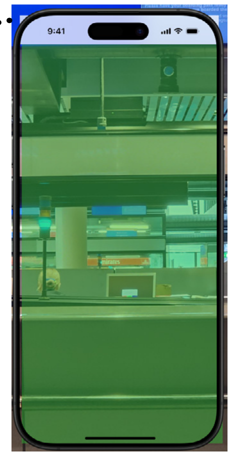


The system also explains passively where the VIP is in when entering a new area, such as the terminal the beginning and end of the terminal airside, and gate area. Furthermore it describes relevant key areas that are being passed like gates to give a sense of orientation.

Part 2



Destination

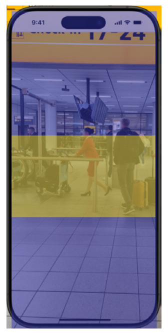
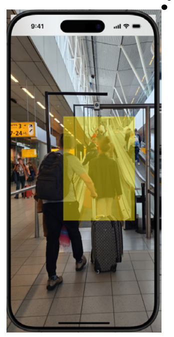


Once reaching the destination the system informs the User of their having reached their inteded gate number, along with their flights details. such as their flight number, airline, boarding time and flight destination. Doing so the VIP can confirm with higher certainty that they have reached their inteded destination. It furthermore tells the time and if there is a significant amount left, gives the VIP the ability to explore.

Explore/Orientate

VIPs can also give a voice command to the system to describe and explore their surroundings, informing them on what is available in the surroundings and tell them where they are. Generally describing the type of room they are in first, before describing amenities, and then relevant objects like chairs and pathways on the floor. When exploring the system keeps in mind the destinations relative to the boarding gate and only provides options that the VIP can reach in time and spend a significant amount of time in.

Interactive Landmarks


When coming close to elevators, escalators and lifts, or ports for checking boarding passes, the system provides feedback on how to interact with such landmarks. Either giving a choice on what can be chosen, or informing the VIP that they have to prepare their boarding passes.

Navigational Selection

After describing an area, VIPs can also select a certain place they want to navigate towards from a selection provided by the system.

Return to Gate

When exploring, the system actively tracks the location of the VIP relative to the VIPs intended gate and departure information. When it is near boarding time, the system informs the VIP that it is time to return to their gate, and describes the distance and time to reach it. Read More about how APIs ensure this in

Assistance

Additionally assistance can guide the Visually Impaired user to their destination by taking over the camera view on their own individual phone. They would know the Visually Impaired position using the map on the bottom of the screen and the projected screen of the visually impaireds phone.

Figure 76:
Usage Flow Diagram

18 Technological Realization

18.1 Block Diagram

The Block diagram is a static snapshot showing how all relevant components of the system would communicate with and are related to one another. The most important components are described in the following paragraphs. Furthermore the flowcharts on the following pages go into more detail how these system work dynamically in the environment.

CPU & GPU Processors

The phones CPU and GPU are the heart and mind of the system, responsible for processing the camera frames, sensor data from the IMMU and localize as well as map. Furthermore by processing the environmental and user input it should provide the appropriate feedback to the VIP through audio, or contact assistance through the phones connectivity module.

RGB-D Camera

The RGB-D camera, captures both color and depth from the environment extracting features that are relevant for localization and navigation as well as obstacle avoidance in the airport layout (Kim et al., 2016). Along with the IMMU it is crucial to carry out VSLaM in real time with the phone.

IMMU

The IMMU (Inertial Measurement Magnetometer Unit) in a smartphone measures acceleration and rotational movement, helping estimate the VIP's orientation and motion even when visual data is limited. Furthermore the magnetometer provides the orientation relative to the Earth's magnetic field, helping the system better know which direction the VIP is facing (Automaticaddison, 2021). This is especially important in the beginning or when starting from a known reference point. The IMMU sensor stabilizes the VSLAM system, fills in gaps when the camera has low visibility, and ensures smoother tracking while the VIP moves through dynamic spaces like terminals, making step-by-step guidance more reliable and responsive.

Microphone

The microphone enables voice command functionality, allowing the VIP to interact with the navigation system without needing to touch the screen. They can request directions, ask for their current location, or reroute to amenities like toilets or cafés. This hands-free interaction is important for the VIP, as it allows one hand to remain free when navigating which they can use to interact with the environment, as the other hand is already used for their blind cane.

Earphone Bluetooth Connectivity

Lastly the system can communicate externally using bluetooth to the VIPs headset to provide audio feedback for navigational cues, as well as feedback in general from the system.

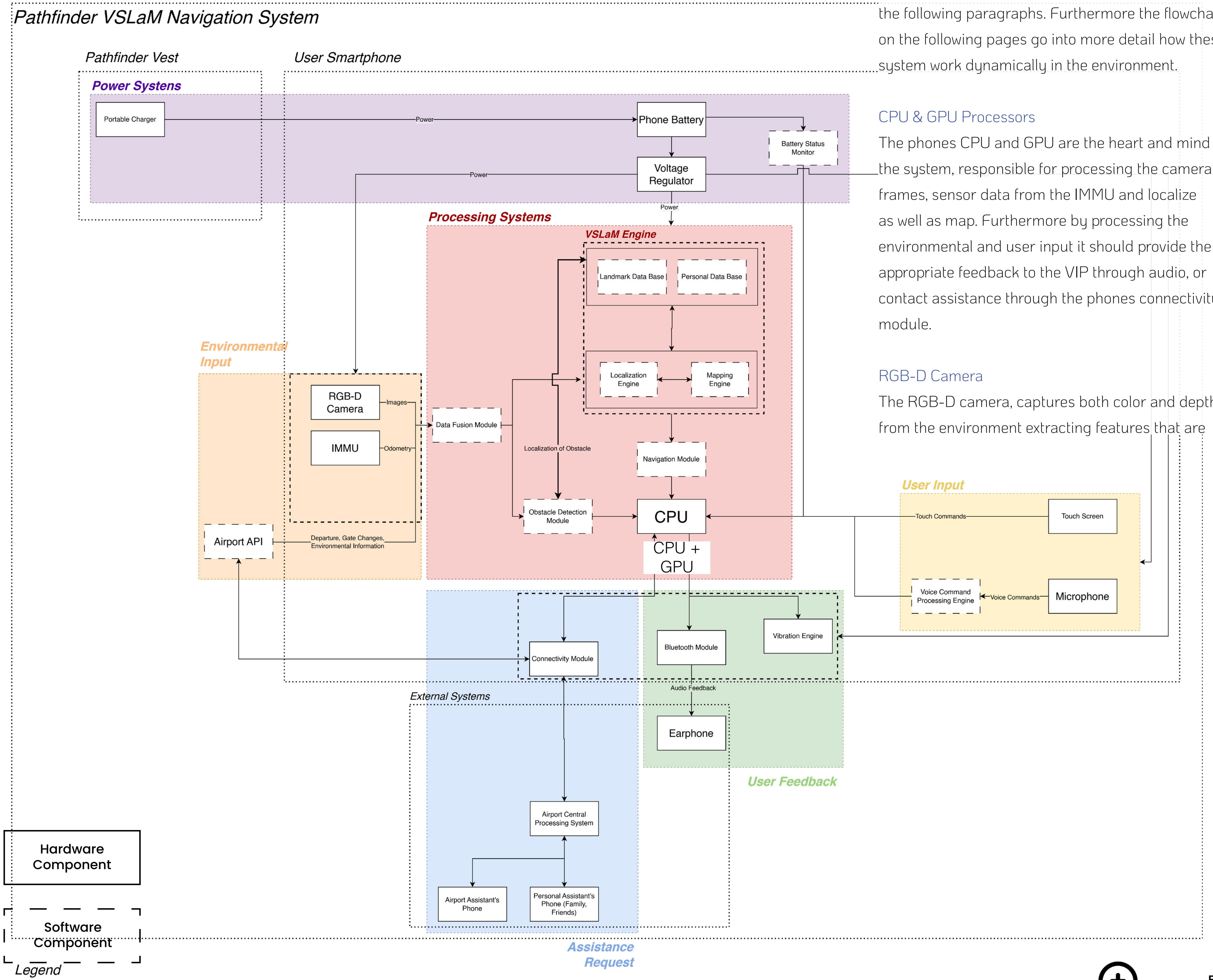


Figure 77: Block Diagram

18.2 VSLaM Working Logic

This flowchart breaks down how the VSLaM navigation system works for guiding VIPs through an airport. It starts with collecting data from the phone's RGB-D camera and IMMU sensor. The camera captures images of the surrounding environment, while the IMMU records motion and orientation. These inputs are used to predict the VIP's position and extract visual features from the images.

The system then tries to match these features with those in its database. If it succeeds, it refines the VIP's position and checks if the person is on the correct path. If not, it calculates how far they've veered off and corrects their route using a process called a loop closure. If the system can't recognize the environment at all, it begins a new mapping session. If that also fails, a backup system kicks in, allowing the VIP to request assistance.

At the same time, the system monitors for five types of landmarks. Navigational landmarks are necessary for the VIP to navigate to their destination. Destination landmarks are the intended destinations for the VIP, they are subdivided into primary landmarks which are check in desks and gates, and secondary landmarks which are any other destination at the airport. Orientational landmarks are landmarks around the VIP at a given position, which are only revealed when the VIP calls out the system to explore their surroundings. Personal/Saved landmarks are saved by the VIP and provide custom guidance. Interactive landmarks offer the VIP an action while navigating, like choosing between stairs or an elevator, or that the VIP has to prepare their boarding pass when passing boarding gates. They als trigger a different type of audio feedback for the VIP to help distinguish what they are hearing.

As the VIP moves, the system constantly updates their position and checks if they are on the right path. If they deviate, it calculates the deviation to know how to get back on the route. If anything fails—like matching or localization—the system informs the VIP and asks if the VIP requires assistance.

The system also dynamically has to recalculate a path when there is an obstacle in front of the VIP that does not move away, for example a trolley or large box. It works in a similair way as the path deviation, requiring the system to recalculate the pathway to avoid the obstacle and continue to the intended destination.
If this fails or the obstacle somehow blocks the path leaving no alternative, assistance will be requested.

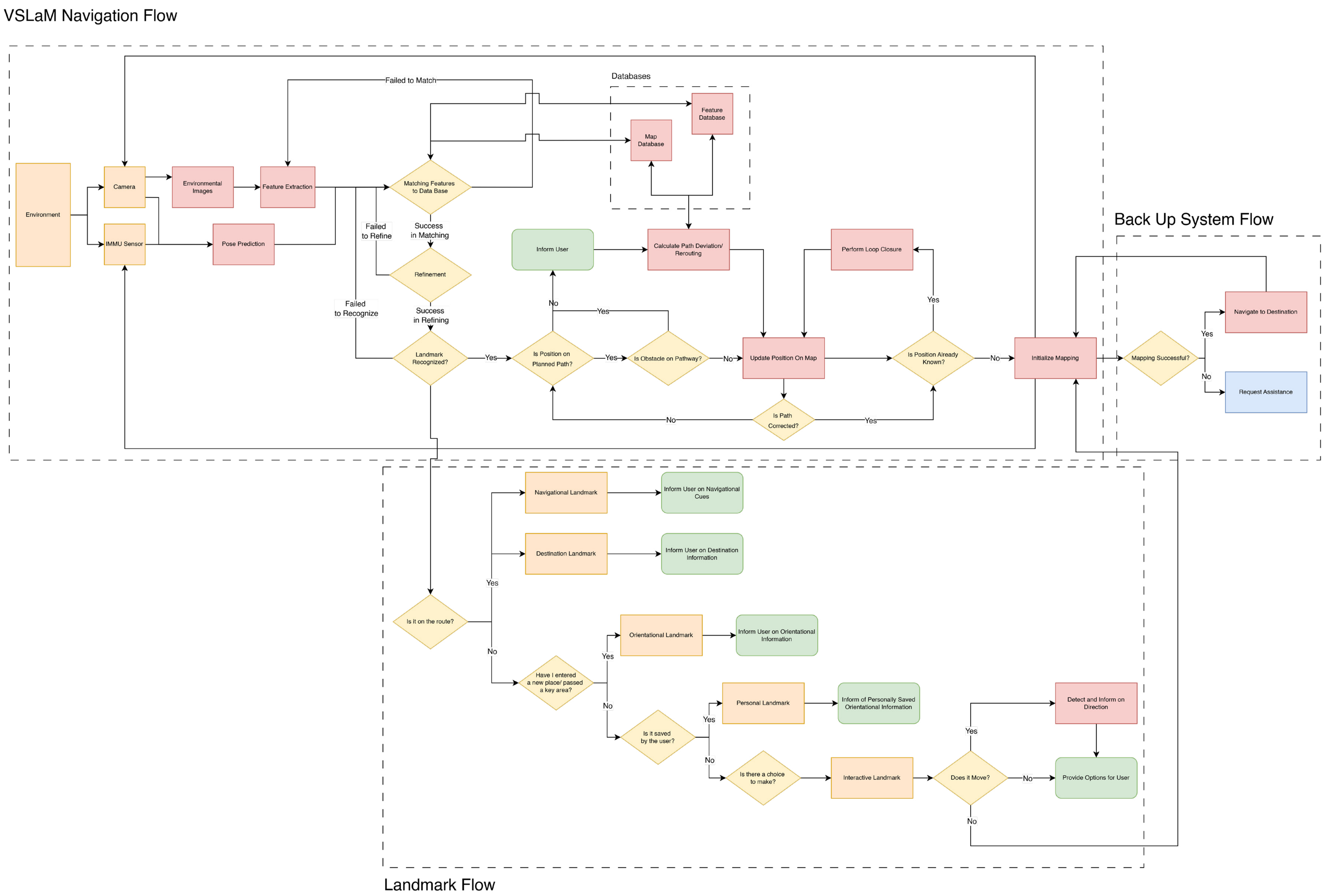


Figure 78:
VSLaM Logic Flow Diagram

Obstacle Detection

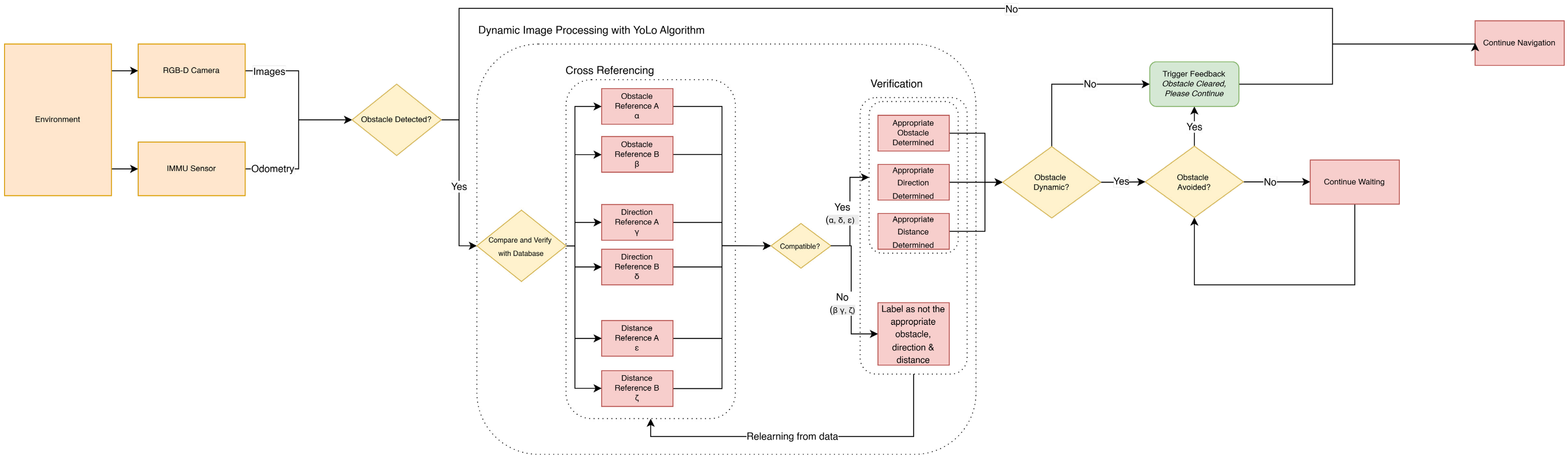


Figure 79:
Usage Flow Diagram

18.3 Obstacle Detection

The obstacle detection logic makes use of the YOLO algorithm to identify, reference, verify and inform the VIP on what obstacles are within their given path. It works similair to feature recognition as described in the VSLaM system logic in 18.2, but does not account for the location of the obstacle in reference to the map, but instead the distance in reference to the VIP. The YOLO algorithm works by feeding and training it a set number of images and videos of a given environment with the obstacle and adding markers to obstacles, to identify and distinguish them in that given environment (Kundu). When encountering obstacles for VIPs it is important that not only the type of obstacle is identified, but also the direction and distance in meters is also known. (Golledge, 1999). Doing so the VIP can take more appropriate actions to prevent colliding with the obstacle. By training the system with a variety of images and videos of that given obstacle, it would learn how to identify it when operating in real life.

When operating in the real airport environment the system would scan for obstacles with the phones RGB-D camera, identify them and compare them based on the reference data it has recieved. Multiple reference data is used, and the most similair one, will be used and informed to the VIP. Reference data that does not pass will be 're-learned' back into the system in order to inform it that these reference will not match the next time a similair obstacle is faced in the future. Doing so it fine tunes the system to distinguish the variety of obstacles in the airports environment.

Finally the obstacle is informed to the VIP through audio feedback, and also explained when it has passed and the VIP can proceed to move along their path.

Part 5: Finalization & Implementation

Airport API Integration

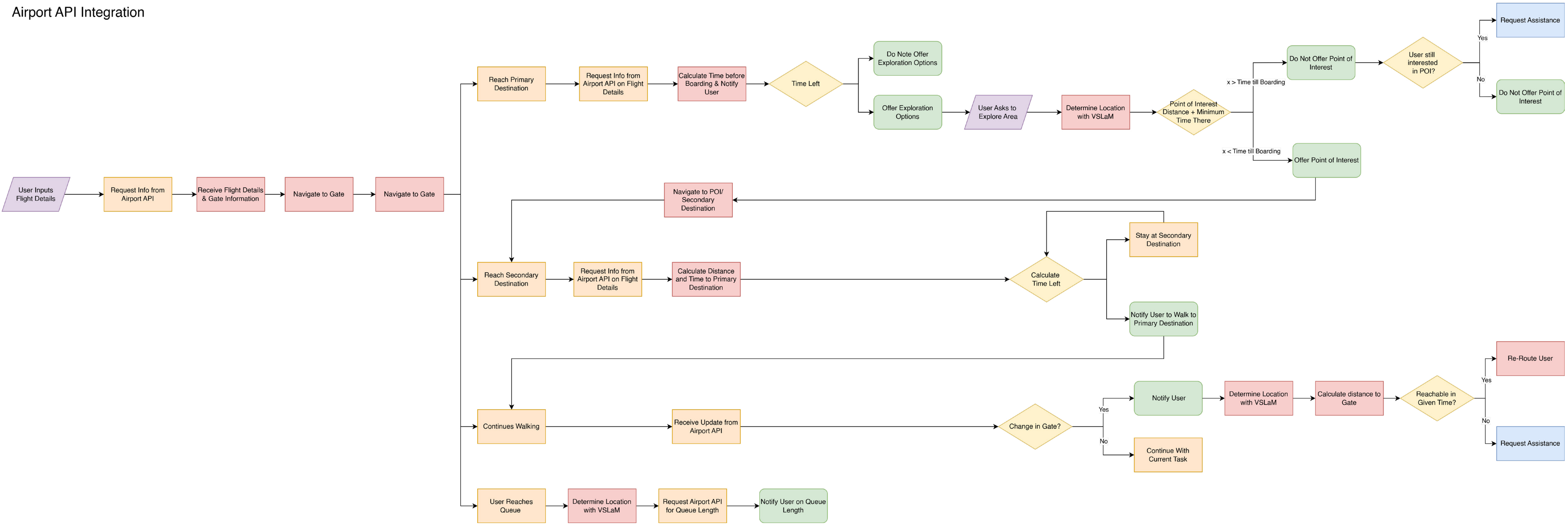


Figure 80:
Usage Flow Diagram

18.4 Airport API Integration Logic

The Pathfinder system makes use of integrating 4 of Schiphols 6 main APIs, which are the Flight API, Wait Times API, Wayfinding API, and Beacon Registry API (Schiphol | Explore All Schiphol's APIs.). These APIs are crucial for the system to provide up to date and dynamic information for the VIPs on their departing flight, gate changes, quene line information, and crowded areas. This allows VIPs to stay in control of their environment more.

When gate changes occur, the system will automatically redirect the VIP to theri new gate. This ensures that the VIP does not have to understand necessarily input it by themselves, and input wrong information if the information was understood the wrong way. It is similair to how human assistance would also 'automatically redirect the VIP.'

Furthermore, APIs are crucial in keeping track of time, and together with the VSLaMs systems localization inform the VIP when they have to head back to the gate if the time is running short. This also works the other way around when the VIP wants to explore, and based on the amount of time left, the system only provides options within reachable within a given time with the addition of a default time the VIP stays there. When VIPs desire to reach an area outside this limit, or cannot reach their gate in time, the system automatically contacts assistance in order to guide the VIP to their intended destination. It would also automatically inform ground staff that the VIP has left the gate area or hasnt arrived yet.

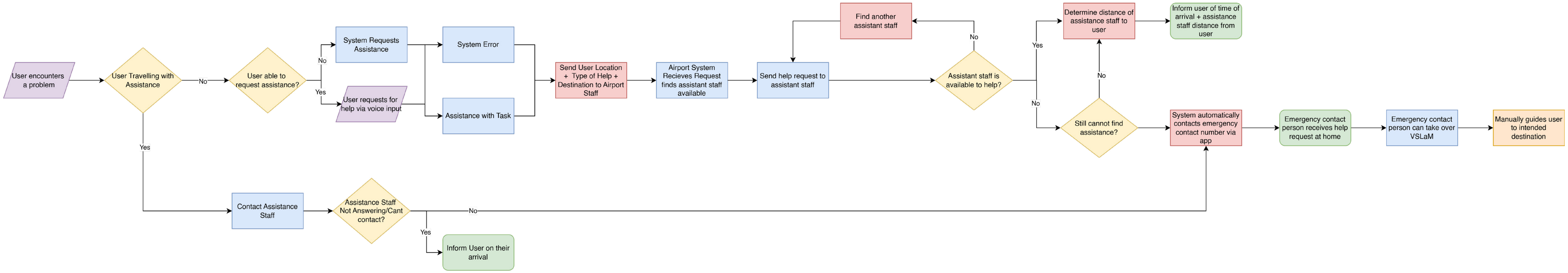


Figure 81:
Call for Assistance Flow Diagram

18.5 Back Up Systems

Considering that there is always a risk that something might go wrong, a rudementary back up system in the form of requesting assistance has also been added to the app. This system can be triggered either manually or automatically, and requests the assistance from airport staff as well as an emergency contact person saved by the VIP, in the event airport staff is not available. VIPs can use it to reach destinations at faster paces, as seen evident in the test results carried out in chapter 15, and also to reach areas that are not accessible in the a given time. Furthermore by having a back up system it is easier for the VIP to adopt and make use of the system at an airport where a lot of unknown risks can arise. It gives the VIP certainty that there is still a way out when things do not go as planned.

The system can also be used in complement with human assistance, in a way that it keeps the VIP in contact with them once they have left the VIP after dropping them at the gate. Assistant staff can also localize and get into contact with the VIP when they plan to go on their own somewhere, in the event they need to reach and find the VIP. This is achieved by letting the VSLaM system ping the location of the VIP to the assistance staff. Implementing this hybrid assistance system allows for assistance to be implemented in a more flexible way without undermining the VIPs ability to also act independently in their environment. Furthermore it also enhances trust of the VIP in the system and creates a 'safety net' that ensures certainty when things go wrong.

19 Implementation Plan

19.1 System Overview and Goal

The goal of this implementation plan is to deploy the Pathfinder VSLaM navigation system for theVIP at Schiphol Airport.

19.2 App Development and Integration

For the first iterations of the Pathfinder VSLaM Navigation app, will be developed as a standalone app independent from the current Schiphol App. Later on when the app has been polished more effectively, it will be integrated into the Schiphol App, and be accessible as an additional feature on the homescreen. This is done to avoid technical dependencies at first. The core modules of the app are specified in the Block Diagram of Chapter 18.1, they include but are not limited to:

- SLAM Engine: Visual localization + IMMU sensor fusion
- Navigation Module
- Obstacle Detection Module
- Connectivity Module
- Schiphol Public API (for Flight Times, Gate Data)

19.3 Vest Design and Distribution

The travel vest will be designed with a stable chest pocket optimized for camera positioning. It will be lightweight, and washable for the VIP. Unlike the previous iteration in Chapter 13, where it is rented out to VIPs by the airport, the final vest design is personal property of the VIP. This is done, so that users can also make use of it outside of the airport. While the navigation system does not work outside the airport, as there is no reference point to carry that out. The obstacle detection module and assistance request from emergency contacts can still be used by VIPs. Having the vest also as a personal item enhances its versatility, and can potentially allow the VIP to customize it and personalize it for their own needs. For example attaching their own sensors on it. Due to the lightweight and small dimensions of the vest, it can be stored at the airports storage compartments, or if not possible at third party storage facilities.

As mentioned in Chapter 18 the VIP can order the vest online via the app. From there the vest will be shipped directly to the VIPs home. When arriving the vest comes together with a text and a QR code, which explain the set up instructions. The reader can scan the QR code or the text to have the instructions read out loud. Braille instructions should also be present but at the box, for if the VIP can interpret Braille.

19.4 User Testing and Training

To implement the product at the airport, the testing will be done and carried out in phases.

Testing Phase 1: Simulation
Starting with simulation testing, volunteer VIPs can test it out in a controlled environment at the airport. For this phase it is wise to first divide the entire journey into smaller segments, such as the enterance to check in desk from car, enterance from train to check in, security zone, terminal airside to gate area, and immigration. By breaking it into segments, unique issues from each area can be derived more easily derived and addressed, before testing and studying the entire route as a whole. When all parts are adressed, a single controlled route can be tested by the volunteers. Here they start from the enterance and navigate through the controlled route to the gate for a hypothetical flight. From this controlled route and environment, feedback can be obtained, similairly as the tests in Chapter 15. Like in Chapter 15, the dependent variables will be used to compare how the Pathfinder performs against the airport assistance, and additionally personal assistance from the VIP. From the feedack findings, Schiphol can use it to improve the prototype, till a sufficient success rate and confidence rating by the VIP is achieved.

Testing Phase 2: Pilot
When simulation testing is completed, a pilot rollout can be conducted for a specific flight, where visually impaired passangers can volunteer to use the system, to see and evaluate how it would perform under real but controlled circumstances. It is advisable to pick a shorthaul flight with high frequency, as when things go wrong, the VIP can still catch another plane at the same day. Furthermore compensation for the volunteer would also be significantly lower if things go wrong and they miss a flight.

Testing Phase 3: Real Situation
When pilot tests are conducted, Schiphol can gradually move to test out the system at a single terminal for more flights, and then move to test out the system at the entire airport. By doing it in phases, feedback can be recieved from each phase, to polish and make it fail proof. Furthermore risks can be split into different phases, and training of staff can be improved over a period of time allowing staff to adjust and gain more experience overtime.

19.5 Supporting Infrastructre

In parallel with the system's technical development, a support infrastructure is planned to ensure long-term usability and safety. A key component of this is staff training at the airport. Staff will be educated about how the system works, how to assist users if needed, and how to troubleshoot basic issues with the app or vest. Training materials will be made available both in digital format and through short instructional workshops for each phase.

19.6 Implementation Timeline

Phase 1

Preperation and Planning

Objectives:
Finalize system requirements, define VIP needs, and confirm integration goals with

Activities:
Analyze feedback from initial VIP tests (e.g., navigation accuracy, deviation handling, audio clarity).

Identify technical constraints for integrating with the Schiphol app (e.g., API access, security).

Form partnerships with relevant departments (IT, accessibility services)

Output:
Final requirements document, stakeholder alignment, integration feasibility report.

Phase 2

Mapping and Environmental Modeling

Objectives:
Create the airport reference map for the VSLaM system using real-world data.

Activities:
Conduct in-terminal 3D scans of the necessary areas beginning from the enterance area to the gate in the controlled route, to gradually the entire airport.

Process SLAM data with tools to create a feature-rich reference map.

Annotate key landmarks (gates, toilets, service desks, intersections).

Output:
Structured and annotated 3D feature map of key airport areas.

Phase 3

System Development

Objectives:
Develop the core software and hardware components of the system.

Activities:
Build the stand alonemobile app with integrated SLAM engine, voice interaction, and route planning.

Add audio-haptic feedback layers and emergency support functionality.

Finalize travel vest design (sensor alignment and comfort).

Output:
Mark I (Alpha) version of the app and wearable prototype ready for closed testing.

Phase 4

User Testing and Iteration

Objectives:
Validate the system's performance with VIPs and refine usability.

Activities:
Test with both blindfolded and VI participants in a controlled environment.

Measure success rate in navigation tasks, landmark recognition, and response to off-route correction.

Improve voice guidance clarity, fallback options, and system responsiveness.

Output:
Mark II/III (Beta) system with refinements from VIP insights.

Phase 5

Deployment and Training

Objectives:
Launch the system in a limited airport area and train support staff.

Activities:
Deploy the app and vest system at selected Schiphol zones.

Train airport personnel on system functionality and VIPs support protocols.

Establish emergency response flows and feedback channels.

Output:
Staff-ready soft launch environment with in-situ VIP trials.

Phase 6

Public Rollout and Monitoring

Objectives:
Open up the system to more VIPs and gather real-world performance data.

Activities:
Enable public access through the Schiphol app or standalone installation.

Collect performance data (navigation efficiency, app usage logs, reported issues).

Plan for future updates, broader map expansion, and partnerships with other airports.

Output:
Public-facing, operational VSLaM navigation solution with monitoring pipeline.

Figure 82:
Implementation Phase Diagram

19.7 Implementation Areas

Alternatively, Schiphol can also implement the Pathfinder VSLaM Navigation system in two ways. Either implement it for the entire journey, from enterance up to the gate, which is Plan B, as originally intended, or implement it only to the enterance up to the check in, which is Plan A. While Plan B addresses the entire problem, of empowering a VIP to travel to the gate more independently. The large area and complex dynamic environment of Schiphol, might make this a difficult way to technically realize the system. This route might have to many unknown variables and technical issues which can make a initial system roll out challenging. Due to these possible constraints, Schiphol can alternatively focus on a single but still probablematic area as shown by the journey map, which is from the enterance up to the check in area. Here often users experience the problem that assistance of the airport is provided, but difficult to contact at the beginning. Or in other words you need assistance to use assistance at Schiphol. Plan B also carries more risk, with it being a more dynamic and time constrained environment, hence users will only opt to use the system if it is fully worked out. By focussing on this area, Schiphol would offer a hybrid type of assistance solution using VSLaM and based on the results of Plan A, see if it is feasible to be implemented in Plan B.

Implementation Plan A

Enterance --> Check In

Adressed Problem:
Requiring Assistance to Get Assistance at Schiphol

Areas to Map
Final requirements document, stakeholder alignment, integration feasibility report.

User Primary Goals
Reach the Check In Desk

Assistance Available
Schiphol Airport Assistance, (Non Travelling Friends and Family), Airport Visitors

Implementation Plan B

Enterance --> Gate

Adressed Problem:
Travelling more Independently as a VIP to the Gate

Additionbal Areas to Map
Security Area, Immigration (for International Flights), Terminal Airside, Gate Area

User Primary Goals
Schiphol Airport Assistance, (Travelling Friends and Family), Fellow Passangers,

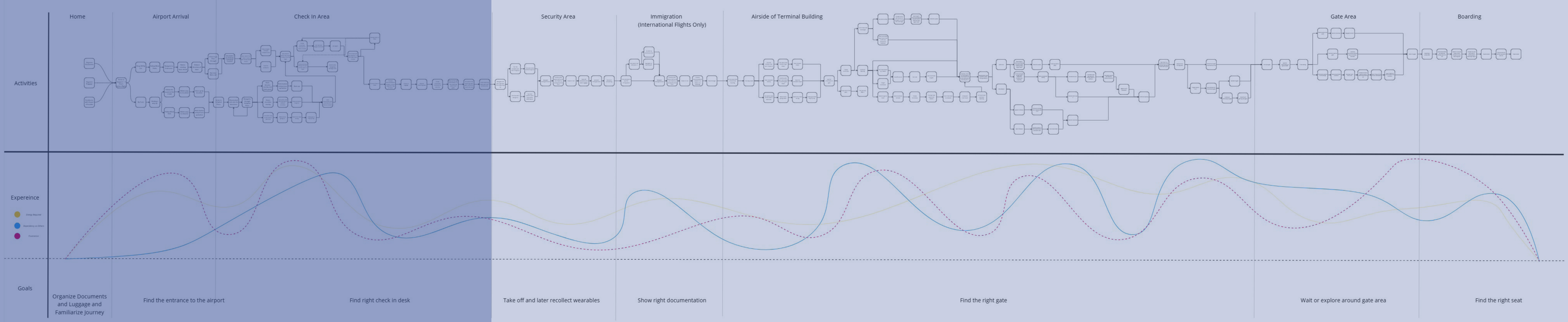


Figure 82:
Implementation Plans Diagram

Limitations Recommendations & Conclusion

Part 6

20 Limitations

20.1 Product Limitations

20.1.1 Dependence on Preloaded Maps and Landmarks

One of the major limitations in using the VSLaM system is its dependency on preloaded maps to determine the location of landmarks as well as the VIPs position. While the usage of maps and their databases significantly reduces the airports need to rely on other localization infrastructure like Bluetooth or WiFi Beacons, the reliance on maps does require teh airport to consistently update the maps in order for them to remain accurate. If for example the environment changes, and certain landmarks are missing, localization accuracy significantly decreases reducing the VIPs ability to navigate independently in the environment and their trust and certainty in using the system. Accurate localizalization also requires the airport to make clear distinctions on landmarks and their unique features which might require a lot of fine tuning in the beginning.

20.1.2 Overreliance on RGB-D and IMMU Sensors

Another limitation of the VSLaM system is the over reliance on the phone's RGB-D camera and IMMU. While both sensors can be used to determine and localize and navigate the VIP indoors, they lack sensor richness of more advanced sensor systems. One of these sensors which has also been mentioned in the research and iteration phases of the prototype is a LiDAR sensor. With LiDAR, more accurate information of an environment can be obtained, and it complement the RGB-D's weaknesses. An example of such a weakness it that the system can function more accurately in low-light conditions where RGB-D cameras would struggle in depth perception and become inadequete. The only problem with sensors like LiDAR is that they are often not included in most smartphones, and hence require additional hardware and software to process their data in order for them to work.

20.1.3 RGB-D Accuracy Across Phone Models

For the VSLaM system to work accurately, a reliable RGB-D Camera and IMMU sensor is required. The reality is that the accuracy of the phone camera and IMMU is significnatly dependent on the phone's model. While newer smartphones often include cameras that have high resolutions that are adequete to carry out VSLaM, this generalization has to be kept in mind when working out the system technically in order for it to work accurately and with high precision. Similair to the LiDAR, additional high resolution cameras can be provided as attachments to be used instead of the phone's camera if the camera is not reliable enough. However this too would require additional hardware and software for the system to work.

20.1.4 Latency and Processing Limitations

Smartphones, while advanced, have limited real-time computational capacity. Delays in image processing, localization updates, or route recalculations due to path deviation can cause navigation lags. Users with visual impairment need consistent and immediate feedback to act safely and confidently, which can be compromised by such latency.

20.1.5 Audio Feedback Overload

The system is primarily reliant on audio feedback to inform the VIP about the environment around them and how to navigate through it. While audio feedback is often preferred as it allows the VIP to directly understand the feedback, without having to percieve what it is such as with haptic feedback, it can lead to information overload. The system has measures to reduce this such as that VIPs can set the amount of information that they system can and will provide. However there is still possibility it can overwhelm the User. Furthermore if the method fails through either having unclear instructions or difficulty in hearing them in the chaotic airport environment, it can lead to confussion and mental fatigue for the VIP.

20.2 Testing Limitations

20.2.1 Generalization to Real World Blind Users

Testing was carried out using blindfolded individuals instead of real VIPs. Blindfolded individuals can simulate and mimic the behaviour of real blind people and often navigate even worse then blind individuals due to their unfamiliarity with it. This allows them to simulate a worst case of blind navigation which still results in valuable feedback for improvement. However due to not being blind, blindfolded individuals cannot simulate the movement strategies and tricks blind individuals use to navigate in their everyday life. This could potentially skew the results and limit the real-world reliability of the tests.

20.2.2 Use of a Low Fidelity Prototype

Using a lo-fidelity prototype allowed the system to be compared and tested against current systems to an extend. In a way that the system could be tested when a VIP travels individually with a system and acts on the environment on their own against when they are guided and have someone else like an assistant act on the environment. However due to it still being a lo-fidelity prototype other crucial systems like the tracking accuracy or the systems ability to follow a certain path and prevent the VIP to deviate could not be tested. These would also be crucial to know and compare in order to see how well the system works when comparing it to current solutions.

20.2.3 Testing Environment

The last limitation was the usage of a controlled testing environment, which was namely TU Delft's IDE faculty's main hall and corridor to simulate the open spaces of airports and long corridors at gate areas. These areas to an extend simulate these environments, however lack the complexity and chaotic environment airports present. Airport halls are much more crowded, and larger than the universities hall, and much more noisier that can affect the VIPs ability to understand feedback, which was not too often the case inside the university hall. On the other hand an airport environment might contain too many influencing factors that can make it difficult to understand what influences the results for a first round of testing.

21 Recommendations

21.1 Product Recommendations

21.1.1 Move Toward AI-Driven Feature Matching Instead of Static Maps

To overcome the reliance on preloaded maps for referencing and localizing the VIP, future systems could use AI-driven feature recognition models trained on dynamic airport data. Instead of needing maps, the system would "see" and understand spaces using machine learning, learning new layouts on-the-go. By training the system on a diverse range of datasets from the different areas of the Schiphol airport, it can eventually improve the systems ability to generalize and adapt to the ever dynamic environment of the airport.

To allow the system to become even more dynamic, it can be integrated with crowd-contributed databases. With this previous VIPs can provide feedback on the route they take, and the system can "learn" from this feedback to predict and provide more optimal routes for future VIPs, while also taking the VIPs preferences into account, such as if they want to take a fast but crowded route or a long but quite route.

21.1.2 Incorporate LiDAR and Depth Cameras for Enhanced Obstacle Detection

As mentioned in the Limitation 20.1.2 & 20.1.3, adding additional attachments for LiDAR sensors, ToF sensors and more higher resolution and accurate RGB-D cameras could significantly increase the accuracy, precision and reliability of the VSLaM navigation system. It would also provide the system with improved obstacle detection, reducing the VIPs chances to collide with obstacles. These additional sensors can come in the form of additional vest attachments, also enhancing the versatility of the vest, which now is only used for holding the phone in the right place and storing additional relevant items. On the other hand including additional sensors does increase the processing requirements of the entire system, which is can cause additional latency and laggs due to a smartphones limited processing capacity. To do this an additional processing attachment could be integrated, or alternative processing methods can be included.

21.1.3 Cloud-Assisted or Edge Computing for Heavy Processing

To address processing limitations of the smartphone, especially when handling additional data from sensors like the LiDAR, it is possible to offload these tasks to cloud based or edge based devices. Doing so heavy processes would not overburden the processor of the smartphone, preventing lagging and slow reponses from the system. In the end ensuring faster local processing, and higher accuracy as well as faster time responses. This would prevent the VIP to get delays in information, and make the system more reliable for them.

21.1.4 Adding Redundant Feedback Channels

To prevent total failure from audio feedback, more feedback can be provided through haptics. While haptics are now only used in a basic manner, such as that only a single vibration exist to notify the VIP, or multiple vibrations exist when the VIP goes off course. Haptics can be used in a more diverse and improved way for the VIP in future iterations. Furthermore it would be handy if the VIP can determine and adjust between the two modes of feedback based on their own preferences, allowing the VIP to use the system adjusted to their own liking.

21.1.6 Broader Integration with Public Transport and Accessibility Ecosystems

Currently the VSLaM system is only limited to be used at the airport, due to its reliance on the airports map for localization and mapping. Due to using object recognition using trained YoLo Models it can in theory be used outside the airport as well for obstacle detection. It would also be nice though to increase this scope into other applications. By allowing the system to be integrated with public transportation APIs, it can be used to also inform VIPs on what train to take to the airport from their home and by integrating it with existing apps it can also be used to call assistance outside of airport environments, with Be My Eyes and explore other environmentswith Lazarillo. In the end it creates a small supporting eco system for VIP that support their to travel independently.

21.2 Testing Recommendations

21.2.1. Real-User Testing and Longitudinal Studies

One recommendation for the testing is using real Users next time in order to derive data from a VIP that more accurately represent the entire user group. Even when testing with 16 people, not all have to be VIPs, but if a portion of them already is more accurate and scientifically viable data can be used, furthermore the two groups can be compared to see how blindfolded individuals perform in simulating VIPs, and if their data is viable.

21.3 Implementation Recommendations

21.3.1. Implementation Set Up

Additionally to the implementation plan described in Chapter 19, if Schiphol decides to not follow it, it can still implement a more simpler and still desirable solution. This solution namely being an improved method of communication between VIPs and other disabled Users with their respected assistant staff. This can be integrated by having a call for assistant function in the current Schiphol app, where if the assistant is gone, the VIP can still contact them when they need them. Doing so VIPs would not be abandoned and feel anxious when they are left alone at a part of the airport to wait before their flight departs.

21.4 Research Recommendations

21.3.1 Cost Analysis Research

Additionally to the research already done, a well thought out cost analysis can also be studied, to further understand and explore the financial feasibility of such a system in the context of Schiphol Airport.

Conclusion

This thesis set out to explore the viability of Pathfinder—a VSLaM-based wearable navigation system—to support VIPs in navigating Schiphol Airport more independently. With airports being complex and unfamiliar environments, especially for those with limited or no vision, Pathfinder aimed to offer an alternative form of mobility that could reduce dependency on assistance services and increase the sense of personal control.

Testing—albeit with blindfolded sighted participants—revealed that Pathfinder showed promise in key areas such as travel efficiency, user experience, and route awareness. The audio-haptic feedback system and structured navigational flow helped users stay oriented, respond to changes in their environment, and navigate toward both primary and secondary destinations with greater flexibility. Compared to existing airport assistance, the device enabled a more autonomous and confident travel experience.

However, limitations remain. Pathfinder currently depends on static environmental maps and ideal sensor conditions, which may not reflect the unpredictability of real-world airport conditions. Furthermore, testing did not yet include real VIPs, which leaves open questions about long-term usability and inclusiveness. These gaps must be addressed in future iterations.

The recommendations provided—including airport API integration, advanced landmark recognition, and multi-sensor fusion—offer a clear pathway for the development of Pathfinder Mark II. Future work must prioritize inclusive co-design, rigorous testing with actual VIPs, and seamless integration within airport ecosystems.

In conclusion, Pathfinder demonstrates the potential of VSLaM technology to transform the airport experience for blind and visually impaired travellers. By moving beyond traditional assistance models and investing in user-centered navigation technology, airports like Schiphol can take an important step toward greater accessibility, dignity, and independence for all passengers.

Figure X:
Set up for Plan B & C

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R2 ChatGPT References

Literature Review Prompts

Visual Impairment and Air Travel

"Act as an academic research expert. Read and digest the content of the research paper titled 'Examining the Air Travel Experiences of Individuals with Vision Disabilities' that I just uploaded along with this prompt. Produce a concise and clear summary that encapsulates the main findings, methodology, results, and implications of the study. Ensure that the summary is written in a manner that is accessible to a general audience while retaining the core insights and nuances of the original paper."

- ***To extract and communicate the core insights of a key academic study to inform your background research and User need framing.***

"Can you summarize the main points of this document in bullet point format? What are the biggest issues for the User in wayfinding at the airport?"

- ***To quickly identify the major wayfinding challenges faced by User as highlighted in external literature.***

"Can you summarize the issues VIP face in airport terminals and aircraft cabins?

- ***To gain a focused understanding of the unique difficulties across both airport infrastructure and in-flight experiences.***

"What challenges do VIP face when navigating indoors?""

- ***To capture general indoor navigation barriers applicable to environments like airports.***

"What types of obstacles VIPs encounter when navigating through the airport to their gate from the entrance of the airport?"

- ***To map out the step-by-step journey challenges from entry to boarding, guiding your journey mapping and pain point analysis.***

Navigational Aids

"What are current mobility and navigation devices for the User?"

- ***Assist in listing current navigational aids used by VIP in the general context.***

"What are some issues with current solutions for navigating VIP in terminal buildings at airports and inside the cabin of an airplane?"

- ***To identify the practical limitations and User experience challenges of existing navigation systems in real travel contexts.***

"Can you list the limitations mentioned in this paper for navigation aids such as applications and wearable devices?"

- ***To gather concrete shortcomings of current digital and wearable assistive tools from academic sources.***

"What types of sensors are used to detect obstacles in navigation aids?"

- ***To explore the technical components used in current assistive devices for safe mobility.***

"What kind of sensors or methods are used by current navigational aids to detect obstacles for VIP?"

- ***To understand the functional mechanisms enabling obstacle detection in existing solutions.***

"Can you elaborate more on mobility and navigation devices?"

- ***To gain a broader overview of assistive technologies that support independent movement for Users.***

"What indoor navigation methods exist aside from GPS?"

- ***To investigate alternative technologies for positioning and routing in GPS-inaccessible spaces like airports.***

"What about RFID and Wi-Fi how does that technology help with the localization for User, what are its advantages, limitations and applications?"

- ***To evaluate the feasibility of RFID/Wi-Fi as localization tools in indoor environments for assistive purposes.***

Airport Configurations

"What types of configurations does an airport terminal have, like you have linear and pier, what other configurations exist?"

- ***To understand the architectural layouts of airport terminals and how they influence wayfinding and navigation design.***

"For the Linear, Pier, Satellite, Decentralized (Multiple Terminals), Transporter, and Open Apron configurations can you state the challenges VIPs might face when navigating through them?"

- ***To identify specific navigation challenges tied to different terminal configurations, which helps you tailor your design solution to various spatial contexts.***

Interview Analysis Prompts

"Considering this document with the questions I have just uploaded, how does the interview answer them and are there additional questions and points discussed and answered?"

- ***Used to map interview responses to the research questions, highlighting new themes.***

"What are the main findings I have obtained from these interviews? What problems do VIP encounter when they travel at airports? What are some important quotes you can take from this interview?"

- ***Used to identify interview context, participant roles, and topic domains.***

"What area is the most difficult and troublesome for them to navigate to? What causes travelling in an airport to be so difficult? What do they currently do or use to overcome this? And any other difficulties?"

- ***Used to identify pain points and problem areas as well as factors that influence it.***

"What can I take from this to design something that can help improve their independent experience at airports to travel more independently?"

- ***Used to identify interview context, participant roles, and topic domains.***

"Can you provide more details for each point of the interviews?"

- ***Invoked to generate a deeper explanation of key findings, sometimes breaking down into subthemes.***

"How is assistance requested on board by VIPs to airline staff from the interviews... what are some of the limitations of assistance on board and at airports provided by the crew?"

- ***Prompt used to dissect practical staff behavior, User perception, and service gaps.***

"Can you tell me what these interviews tell me on how assistance is currently carried out for VIPs at an airport or in the plane?"

- ***Aimed at understanding the assistance process and breakdowns across the airport journey.***

Co-Design Analysis Prompts

"How do the 5 co-design sessions highlight wearables, navigation instructions, feedback types, input types, and mental mapping?"

- ***Used to assist in exploring and analyze as well***

as summarize the findings from the co-design sessions.

“What type of feedback is desired for navigating at an airport, when is it desired, and how should it preferably be conveyed based on these co-design sessions?”

- ***Understand the preferable feedback systems for VIP from the co-design participants, to carry out different actions.***

“What do the co-design sessions tell about requirements for designing a navigation system for VIP?”

- ***Highlight key requirements for feedback and navigation for the system in development from the co-design sesions.***

“Can you tell me more about how the co-design sessions explain navigation and cues for navigation, like how are directions explained?”

- ***Applied to directional guidance and behavior around spatial orientation in interviews and co-designs.***

“What do the experts mention about the mental maps, and how are they made and produced?”

- ***To dive into cognitive mapping behavior from an occupational therapist and inclusion specialist’s view.***

“What are other important notes and highlights from the interview that I can take into account when designing something to make VIP navigate airports more independently?”

- ***Used to extract design-relevant insights, often reflecting User needs or pain points.***

Analyzing Journey Map Pain Points

“What are the main pain points for VIP when travelling at Schiphol airport to depart for their plane?”

- ***Used to assist in finding relevant pain points presented to by the Users in the interviews and literary findings.***

“Can you give a pain point matrix and opportunity map for a prototype design?”

- ***Used to assist creating a ranking of the most relevant and severe pain points for chosing and determining a focus point.***

User Testing Prompts

“Since I am a designer and I want to test the vest in a simulated environment, what type of dependent variables would I like to measure if my interest is to know when independence or efficiency is desired?”

- ***To define measurable outcomes for evaluating the effectiveness of your wearable prototype in promoting independence and efficiency in navigation tasks.***

“What are some additional dependent variables I can use in a study comparing navigation with airport assistance vs. a prototype?”

- ***To assist in identifying additional dependent factors that I have not thought of***

Appendices

A1 Original Graduation Proposal
A2 Context Study
A3 Interview Notes
A4 Co-Design Notes
A5 Feedback Implementation
A6 Ideation Sketches
A7 User Test Form

A1 Original Graduation Proposal

DESIGN FOR our future

TU Delft

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME

Complete all fields and indicate which master(s) you are in

Family name: Pane
Initials: D.A.
Given name: Darius
Student number: 4879252

IDE master(s): IPD ✓ DfI SPD
2nd non-IDE master:
Individual programme *(date of approval)*:
Medisign
HPM

SUPERVISORY TEAM

Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair: Sicco Santema — dept./section: DOS
mentor: Yu (Wolf) Song — dept./section: SDE
2nd mentor:
client: TU Delft
city: Delft — country: Netherlands
optional comments:

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in **by the Chair** of the supervisory team

Sign for approval (Chair)

sicco santema
Digitaal ondertekend door sicco santema
Datum: 2024.10.29 12:57:40 +01'00'

Name: Sicco Santema — Date: 28 okt 2024 — Signature

CHECK ON STUDY PROGRESS

To be filled in **by SSC E&SA** (Shared Service Centre, Education & Student Affairs), after approval of the project brief by the chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total — EC
Of which, taking conditional requirements into account, can be part of the exam programme — EC

	YES	all 1st year master courses passed
	NO	missing 1st year courses

Comments:

Sign for approval (SSC E&SA)

Name — Date — Signature

APPROVAL OF BOARD OF EXAMINERS IDE on SUPERVISORY TEAM -> to be checked and filled in by IDE's Board of Examiners

Does the composition of the Supervisory Team comply with regulations?

YES		Supervisory Team approved
NO		Supervisory Team not approved

Comments:

Based on study progress, students is ...

	ALLOWED to start the graduation project
	NOT allowed to start the graduation project

Comments:

Sign for approval (BoEx)

Name — Date — Signature

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Name student Darius Alamsjah Pane **Student number** 4,879,252

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT

Complete all fields, keep information clear, specific and concise

Project title Making Air Travel more Inclusive for the Visually Impaired

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

The experience we have during air travel is often shaped by the experience we have of the boarding process from the gate to our seat, and that within the cabin. While significant improvements have been made to make air travel more pleasant, the user journey still lacks the necessary features to feel inclusive to certain user groups such as the disabled. These passangers often find it 15 times more difficult to travel by air compared to those without any disabilities (Airbus, 2023). With the group covering a range of disabilities, such as reduced mobility, hearing impairment, and illiterate, for this master thesis project to narrow down the scope I personally like to focus on the visually impaired due to my personal interests with this group. To narrow the scope down of this project I also aim to just focus on this one disability group, hence not visually impaired passangers that also have another disability.

The visually impaired themselves, as of March 2023, make up 295 million of the world's population (World Health Organization: WHO, 2023), and include those that have mild, moderate and severe vision impairment, blindness, and vision impairment from uncorrected prebyobia (Bärnighausen, 2021). They are different from colour blindness, and what makes them distinct is that usual aids like glasses, contact lenses, medication or surgery cannot solve their vision impairment (World Health Organization: WHO, 2023). With an aging population that has a higher likelihood to develop this disability, the group is expected to grow in the future, making it an important issue to address and solve (Dainty, 2019).

Since this would be a project that would be conducted in a wider context such as the airport and cabin, other stakeholders such as the cabin manufactueres like Airbus, as well as cabin crew and airport staff, (on Schiphol for example) have to be adressed as well. Furthermore it would also be good to contact experts in the field that currently handle and design devices for the visually impaired. In the end by understanding the issue from different stakeholder perspectives a successful prototype device can be made.

→ *space available for images / figures on next page*

introduction (continued): space for images

image / figure 1 A rough picture of the amount of disabled per group, it does not reflect the WHO figures (Airbus, 2024)

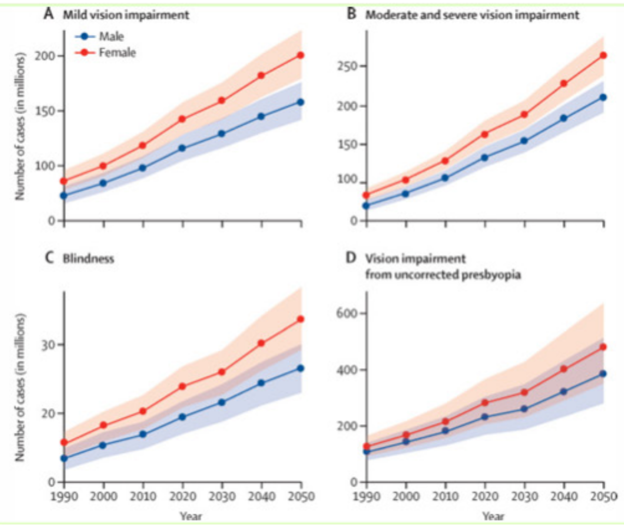


image / figure 2 Forecast of number of people affected by visual impairment (Bärnighausen, 2021)

TUDelft

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME

Complete all fields and indicate which master(s) you are in

Family name	Pane	IDE master(s)	IPD ✓ Dfl SPD
Initials	D.A.	2nd non-IDE master	
Given name	Darius	Individual programme *(date of approval)*	
Student number	4879252	Medisign	
		HPM	

SUPERVISORY TEAM

Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair	Sicco Santema	dept./section	DOS
mentor	Yu (Wolf) Song	dept./section	SDE
2nd mentor			
client:	TU Delft		
city:	Delft	country:	Netherlands
optional comments			

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in **by the Chair** of the supervisory team

Sign for approval (Chair)

sicco santema
Digitaal ondertekend door sicco santema
Datum: 2024.10.29 12:57:40 +01'00'

Name Sicco Santema Date 28 okt 2024 Signature

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	24 Oct 2024
Mid-term evaluation	20 Dec 2024
Green light meeting	21 Feb 2025
Graduation ceremony	21 Mar 2025

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

As a designer I always aim to make products that could enhance the well being of its users, and personally I always like to help people whenever and wherever I can. With this project giving me the opportunity to do just that is the reason why I chose to take on this project. Hopefully I can design something that can actually bring change to my user group 'the visually impaired' through a prototype that they can actually make use of instead of just a worked out concept. My aim to is also to create a prototype instead of just a worked out concept as I feel that this is a field where I can develop more as a designer. Often in previous projects I have contributed more in the research, conceptualization and testing phases and contribute only a bit in prototyping due to my lack of skill in it. Hence I aim to learn more in how to create tangible products through incorporating different prototyping and production methods in this projects. Lastly I personally hope to be able to become a better time organizer in this project and create a more disciplined work ethic.

A2 Context Study

Drop Off Area & Enterance

Airport Key

AMS | CGK | SIN | HKG | CBR | SYD | DPS

User Information

- DO — Dynamic Obstacle
- SO — Static Obstacle
- OBJ — Relevant Object
- NAVI — Missing Nav Info
- POI1 — Main Destination
- POI2 — Secondary Destination
- POI3 — Tertiary Destination

Obstacles

Curbs

Bollards

Luggage carts

Groups of people

Sliding doors

Revolving doors

Misaligned tactile paving

Glass walls or doors

Low signage

Street furniture (benches, bins)

Wet floors

Uneven ground or tiles

Noisy environment

Bicycles or scooters

Advertising banners or pop-ups

Interaction Points

Automatic doors

Greeters/security staff

Exterior help points

Points of Interest

Main terminal doors

Airline signage

Tactile map or guidance strip

Navigation Goals

Locate terminal entrance

Begin orientation with navigation aid

Reach Check-In Counters Safely

Check In Area

Obstacles

Retractable belt barriers

Self-check-in kiosks

People standing in queues

Luggage and trolleys

Strollers

Overhead signage

Luggage weighing machines

Promo stands or kiosks

Pillars

Cluttered paths

Slippery tiles

Temporary signage

Confusing line entries/exits

Staff with carts

Kids on the floor

Unclear counter layout

Cable covers

Low desks or benches

Reflection/glare

Noisy PA announcements

Interaction Points

Airline staff

Self-check-in touchscreens

Bag drop counters

Points of Interest

Check-in counter banks

Flight Information Display Screens (FIDS)

Airline logos and signboards

Navigation Goals

Check in for flight

Drop off luggage

Locate path to security area

Security

Obstacles

Metal detector arches

Bins and trays

Conveyor belt protrusions

People queuing closely

Screening tables

Loose belongings

Temporary floor signs

Security officer movement

Hand-held scanners

Floor bumps/mats

Narrow lanes

Cables across walkways

Wet bins

Tray return stations

Queue posts

Body scanner pads

Interaction Points

Security staff

Screening belts

Body scanner

Points of Interest

Entry and exit of screening lane

Repacking zone

Security trays

Navigation Goals

Pass through security

Retrieve belongings

Proceed to immigration or terminal area

Immigration

Obstacles

Line dividers

Stanchions

Narrow queue paths

Passport readers

Turnstiles

Light beacons

Multiple counter lanes

Unexpected barriers

Polished floors

Footprints or visual indicators

Standing groups

Counter overhangs

Interaction Points

Immigration staff

Passport scanner

Biometric readers (e-gates)

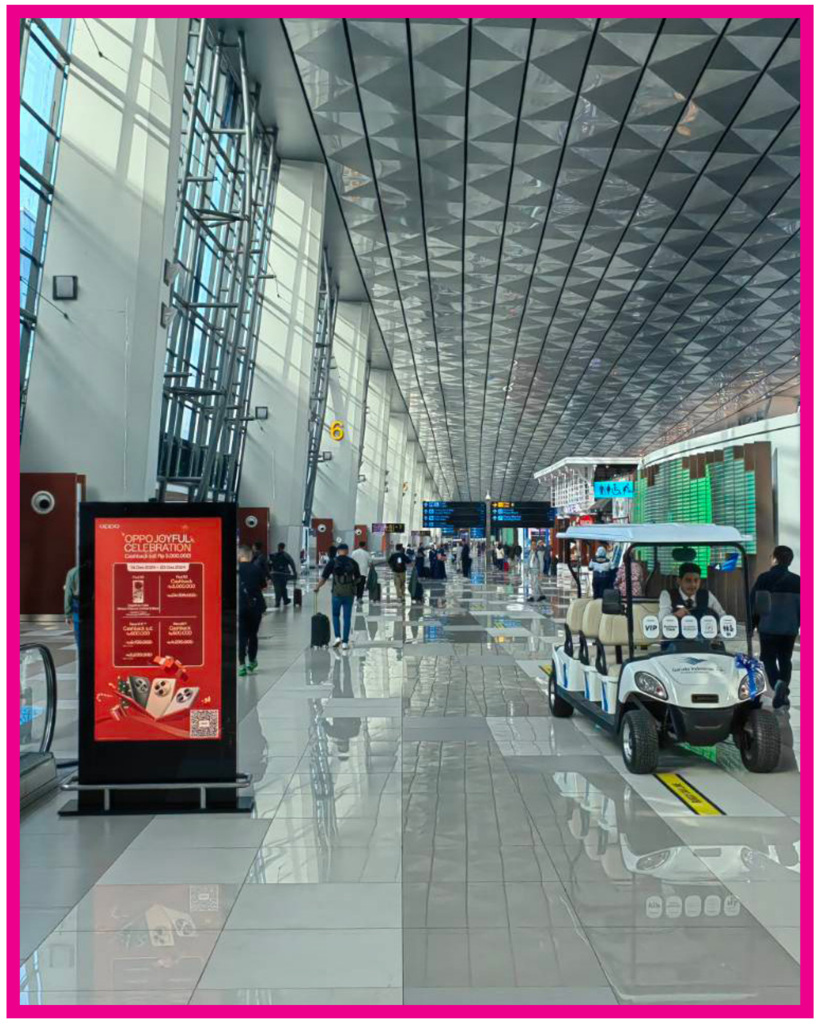
Points of Interest

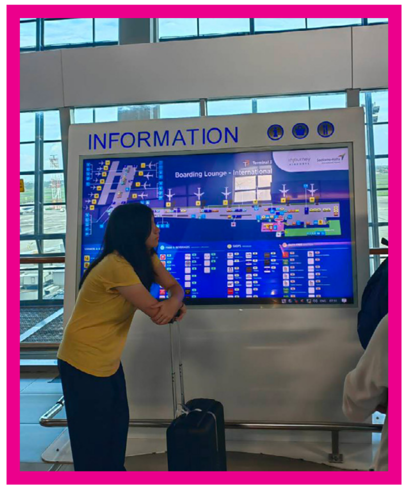
Immigration booths

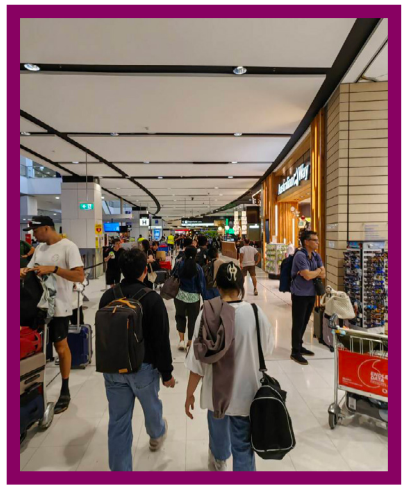
Overhead signage (gate direction)

Digital entry validation displays

Terminal Airside







Obstacles

Open seating areas

Restaurant queues

Planters

Food delivery robots or carts

Mobile kiosks

People standing with luggage

Advertising boards

Café chairs in walkways

Charging station cables

Child play zones

Cleaning carts

Service animals

Disconnected tactile paving

Lounge furniture

Overhead speakers

Reflections from glass storefronts

Sliding restroom doors

Digital wayfinding totems

Sign clutter

Uneven transitions between tiles and carpet

Interaction Points

Lounge desks

Shop entrances

Restroom entrances

Info counters

Points of Interest

Restaurants and cafés

Prayer rooms

Lounges

Toilets

Info desk or help points

Navigation Goals

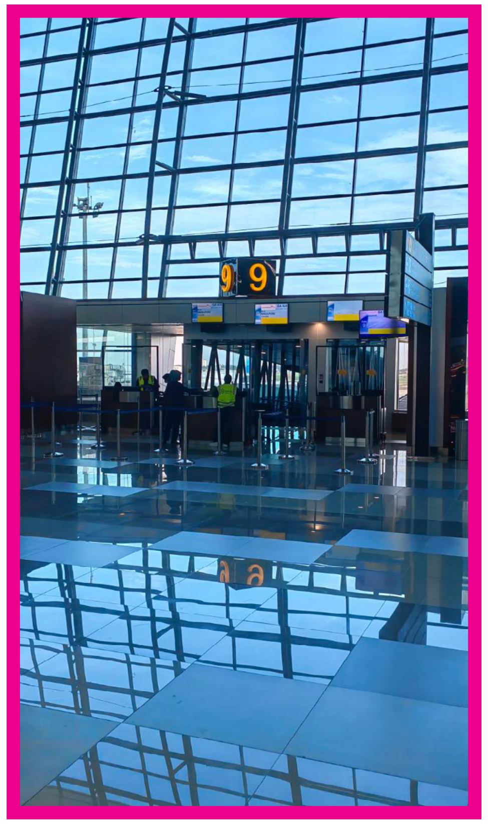
Rest or refresh

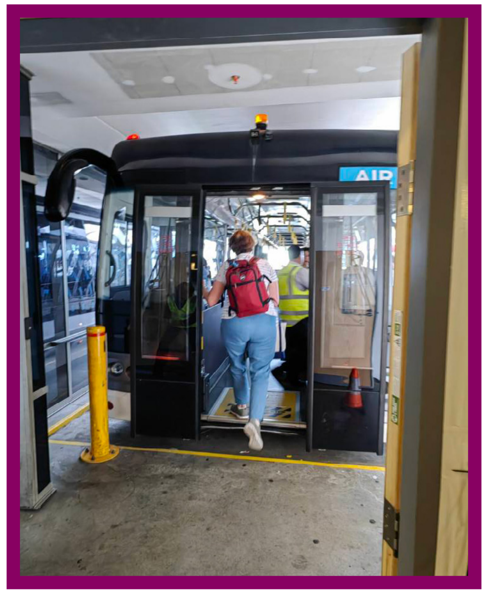
Access facilities

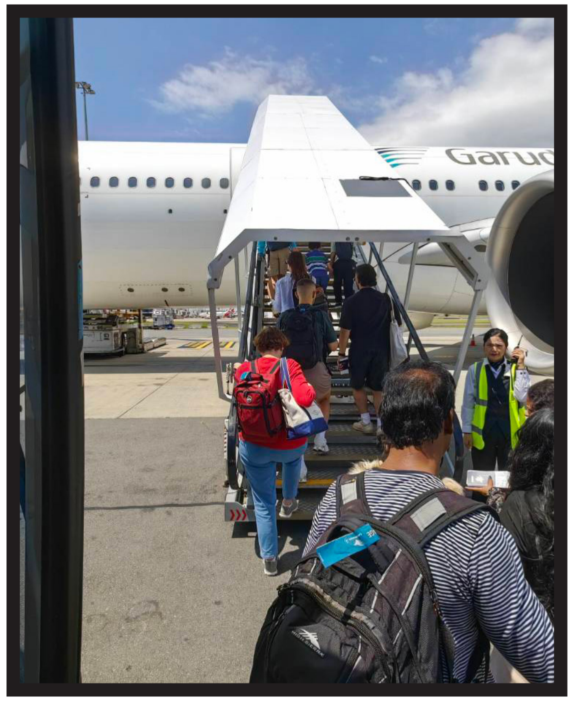
Receive reminders to return to gate

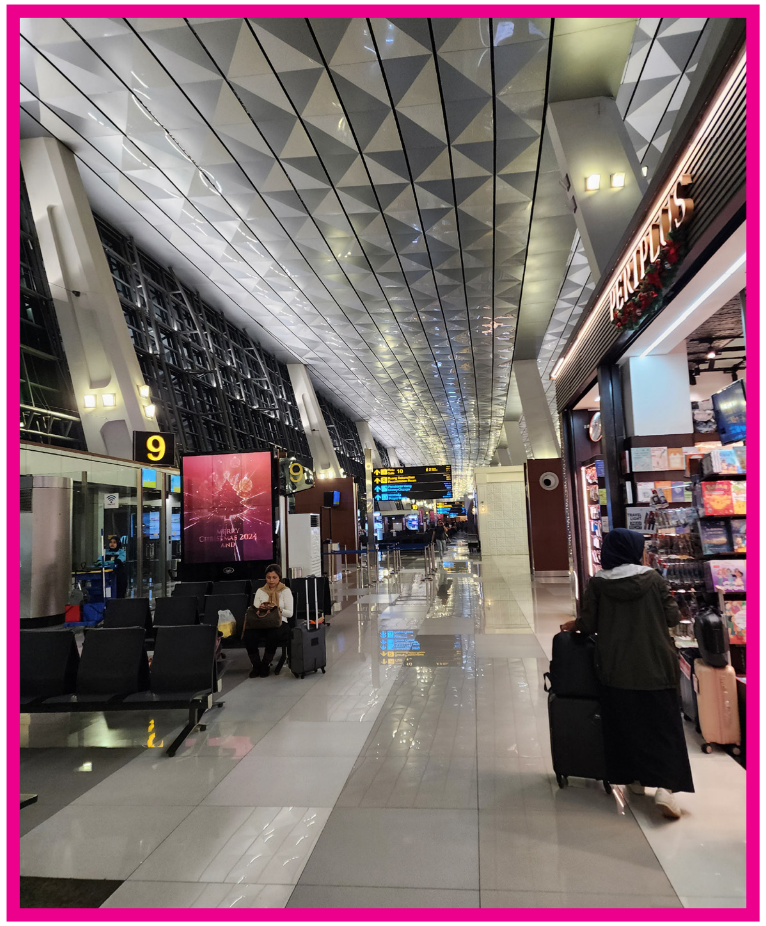
Navigate toward boarding area in time

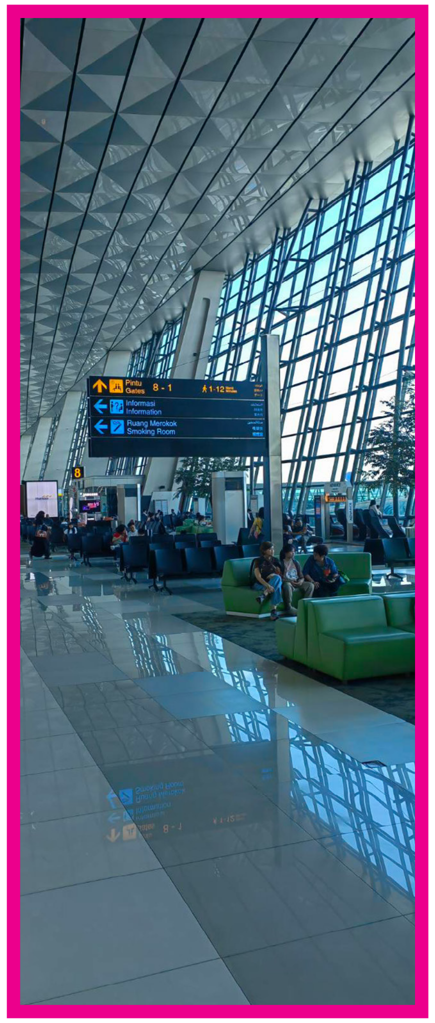
Gate Area











Obstacles

Boarding queues

Wheelchairs and strollers

Loose bags on floor

Power cords

Gate podiums

Sign stands

Carpet/metal floor changes

Gate changes on portable signage

Audio interference from announcements

People milling near gates

Tight pathways

Handrails on jet bridges

Airport trolleys

Groups waiting outside gate

Cleaning equipment

Interaction Points

Boarding pass scanner

Airline staff

Waiting seats

Accessibility desk (if present)

Points of Interest

Gate number signage

Boarding time monitor

Nearby gates (for orientation)

Navigation Goals

Arrive at correct gate

Be notified when boarding opens

Proceed independently through gate into aircraft

A3 Interview Notes

User Group (UG) Data Table									
No.	**Age**	**Gender**	**Vision Type**	**Mobility Aid**	**Travel Frequency**	**Flight Type**	**Airport Experience Type**	**Assistance Used**	**Key Insights**
UG1	54	Male	Blind	Cane	Frequent	Short + Long haul	Individual + Assistance	Airport staff	Seeks better instruction at security
UG2	48	Female	Low Vision	Cane	Occasional	Short haul	Assisted by family	Family member	Prefers verbal cues
UG3	63	Female	Fully Blind	Guide Dog	Frequent	Long haul	Minimal assistance	None	Navigates by sound and memory
UG4	43	Male	Blind	Cane	Frequent	Short haul	Assisted	Airport assistant	Needs help finding gates when they change
UG5	54	Male	Blind	Cane	Rare	Short haul	Full assistance	Airport assistant	Relies fully on guidance, prefers quiet areas
UG6	68	Male	Blind	Cane	Occasional	Short haul	Fully assisted	Airport + family	Prefers step-by-step guidance
UG7	32	Female	Blind	Cane	Moderate	Short haul	Mixed	Occasional	Wants more control, values discreet tech
UG8	71	Male	Blind	Cane	Frequent	Short + Long haul	Assisted	Airport assistance	Wants better location updates
UG9	25	Female	Low Vision	None	Occasional	Short haul	Individual with support	Family	Comfortable if path is known
UG10	33	Female	Blind	Guide Dog	Frequent	Long haul	Minimal assistance	Sometimes staff	Prefers freedom to explore
UG11	79	Male	Blind	Cane	Frequent	Short + Long haul	Individual	Rarely uses	Emphasizes mental mapping and haptic feedback
UG12	45	Male	Blind	Cane	Frequent	Short + Long haul	Independent	Airport + airline	Global traveler, expects info booths
UG13	40	Female	Blind	Cane	Rare	Short haul	Fully assisted	Family	Navigation alone is stressful
UG14	49	Female	Low Vision	Cane (occasional)	Frequent	Short haul	Individual	Rarely requests help	Finds small airports easier to navigate
UG15	57	Male	Blind	Cane	Moderate	Short haul	Assisted	Airport assistant	Prefers simple feedback & buttons

Assistance Staff (AS) Data Table						
No.	**Age**	**Gender**	**Role**	**Flight Route**	**Assistance Context**	**Key Insights**
AS1	31	Female	Cabin Crew	Domestic (Indonesia)	On-board assistance (manual)	Challenges include time pressure and ensuring dignified help for blind passengers.
AS2	22	Male	Cabin Crew	European short-haul	Boarding + seating guidance	Highlights lack of communication between ground and air crew; prefers better coordination.

Expert (EX) Data Table					
No.	**Age**	**Gender**	**Expertise Area**	**Professional Background**	**Key Insights**
EX1	45	Female	Occupational Therapy	Works with VIP	Emphasized mental mapping and task structuring; need for adaptable independence levels.
EX2	55	Female	Inclusive Design	Educator & advocate in accessibility design	Warns against overloading instructions; promotes flexible, User-personalized guidance.

User Group Interviews (UG)

1. Orientation and Wayfinding Challenges
What participants said:
Many participants described airports as "confusing", "chaotic", or "impossible to navigate alone."

UG9, who is completely blind, said:

"I see only light and dark. Without assistance or my guide dog, I cannot find my way at all."

UG8 uses a cane and emphasized:

"You just bump into things and people... there's no real walking path like in train stations."

UG2 shared:

"Even with my guide dog, I have to direct him. But how do I direct him if I don't know where we are?"

Causes:
Poor signage (often too high or small)

Inconsistent floor design (lack of tactile pathways)

Airports lack a standardized layout, making each one a new experience
Difficulty locating check-in counters, security, restrooms, gates, and assistance points.

Layouts are inconsistent, poorly marked, and overwhelming in scale.

Reliance on memory or familiar routes—often not possible at airports.

2. Most Difficult Areas to Navigate
Entrance to check-in and assistance desk:
Often unmarked or far from main entrances. Many participants didn't know where to go once they arrived at the airport.

UG1 said:

"The first hurdle is already getting to the assistance counter. You need to already know where that is."

Security checkpoints:
Unpredictable layout, many verbal instructions, pressure to move quickly.

Some were frustrated by inconsistent procedures, like being told to remove devices or repack without help.

Finding the gate:
UG4 said:

"You may get dropped off at the gate hours before the flight. If it changes, how would I know? I don't see the screen."

Toilets, seating areas, shops:
No consistent tactile or auditory signage.

UG10 pointed out:
"I can't just decide to go to the toilet or grab a snack. I need someone to take me.

3. Why Airports Are So Overwhelming
Complexity & Size
Multiple floors, unclear signage, long distances.

UG4 shared:

"I rely a lot on memory and creativity to imagine where I am. But in an airport? That's impossible."

Unpredictability
Sudden gate changes, delays, broken elevators or moving walkways—all difficult to adapt to independently.

Lack of Real Time Information
No accessible updates about gate changes, delays, or announcements, which are only on screens or inaudible in noisy terminals.

Lack of sensory feedback
Airport apps are often not screen-reader compatible. No consistent haptic or auditory wayfinding cues like there are in modern train stations.

No braille maps or indoor navigation systems.
Finding Assistance
Participants struggle to find or activate assistance services (e.g. help points are unmarked or hard to reach).

Assistance often requires pre-booking 24 hours in advance—spontaneous travel becomes difficult.
Stress and Fatigue
High mental load due to reliance on others, constant need to ask for help, and unpredictable environments.

Large spaces, noise, and time pressure (like getting through security) add to anxiety.
UG13 noted that the lack of control leads to insecurity:

"I want to feel safe and know what's going on without needing someone all the time."
4. Current Coping Strategies & Tools
Assistance Services
Most participants always book assistance, though some said the experience varies wildly between airports and countries.

UG5 emphasized the emotional cost:

"I could find my way alone. But it would take so much energy I wouldn't enjoy the trip anymore."

Several participants (e.g., UG14) use mental maps and memory to navigate familiar environments. However, this breaks down in dynamic spaces like airports.

UG14 said:
"My brain still thinks I can walk the route, but if anything changes — I get lost."
Human Assistance
Travel often done with friends, family, or airport assistance.

Spontaneous travel avoided due to heavy reliance on others.
Guide dogs
Highly valuable, but they don't "know" where to go.

UG2 and UG9 noted:

"The dog avoids obstacles, but I still need to tell him where to go."

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White canes
Used to detect obstacles, curbs, and surface changes.

Some prefer canes with rolling tips for better tactile feedback.

Smartphone + apps
Many rely on VoiceOver, Google Maps, or apps like Be My Eyes and Seeing AI.
Some participants, like Cor, tested apps like Soundscape, EasyWays, Komoot, and Seeing AI, and provided critical feedback:

UG11 said: "They give me instructions too late, or not at all indoors. I end up missing my turns."
Assistive Technologies
Some report indoor navigation apps (e.g. using beacons or 3D maps) were helpful but not widely available.
UG6 said:
"My iPhone is like my right hand. But many apps still aren't accessible."

5. Airport Assistance Insights

What Works:
Once contact is made, assistance escorts the traveler from check-in to gate.

In some airports, assistance also helps with boarding.

***Limitations**:*
Requires advance booking – spontaneous or last-minute travel is hard.

Finding the assistance team is difficult without sighted help at the entrance.

Delays in being picked up leave Users waiting or wandering alone.

Inconsistent service – depends on airport staff availability and training.

Quotes:
UG2 mentions
"You feel dependent. If they don't come, you're stuck."
UG14 says
"Even when I booked assistance, they were late or didn't show up."
Possible Improvements
Assistance On-Demand via App:
Ability to call/request help on arrival, not just in advance.
Share live location with assistance team.

Clear Tactile & Audio Guidance to Help Points:
Install tactile paving and signs from entrance/ train stations to assistance desks.

Live Flight Updates in an Accessible Format:
Customizable app or wearable device with personalized alerts (gate changes, delays).

Staff Training:
Ensure all personnel know how to interact with and guide VIPs respectfully.

Combine Human and Digital Help:
"Hybrid assistance": start with an app, switch to in-person staff when needed.

5. Most Troublesome Areas at the Airport

Drop-off area to assistance desk – often the biggest independent challenge. Challenges:

Finding the assistance point or help desk is extremely hard. Often unmarked, not near the drop-off zone, or hidden behind other structures

No clear tactile or auditory cues to indicate where to go next.

The User is often alone at this point, especially if family/friends can't escort them far.
It's the starting point, and Users are alone and disoriented.

No tactile paths, auditory signs, or clear directions.

Help poles (where available) are often unmarked, hard to find, or require knowledge that they exist.
UG12 noted:
"I often don't know where to go once the taxi drops me off."

"This is the worst part of traveling for me. Just reaching the check-in desk already takes all my energy."
UG13 further emphasized:
"I only recently learned about the help poles at the airport — I didn't even know they existed!"

Security checkpoint – fast-paced, crowded, and confusing with variable processes.
Users find it stressful, fast-paced, and inconsistent.

Layouts and instructions vary greatly, and security personnel are not always trained in helping people with visual impairments.

Sudden changes (e.g., having to unpack bags or move quickly) cause confusion.
UG9 noted: "They told me to move fast and remove items from my bag. I didn't even know where the tray was."

Finding gates – inadequate signage and hard-to-locate destinations
Often requires walking long distances.

Gates change frequently, and notifications are only on screens or inaudible.

Hard to find nearby restrooms or seating without asking for help..

UG4 mentions "If the gate changes and no one tells me, I'll miss the flight."
Airport Amenitis
These locations are rarely marked with tactile or auditory signs.

Users can't locate them without assistance and often avoid using them altogether unless escorted.

6. Additional Difficulties Reported

Language barriers: Assistance often speaks limited English or Dutch, especially abroad.

Independence is compromised: Many participants noted that they avoid traveling alone because they fear being stranded or overwhelmed.

Waiting time: are often dropped off at the gate too early with nothing to do.

Inaccessible airport apps/websites: Even booking assistance is tricky without screen reader–friendly interfaces.

7. Why Current Solutions Don't Fully Work

Navigation Apps:
GPS is not precise indoors, and apps like Google Maps or Komoot don't work well inside terminals

Voice instructions are often too vague or delayed.

Require prior knowledge of the environment.
UG11 mentions
"Navigation apps tell me to turn too early or too late. It's not reliable."

Canes and Guide Dogs:
Good for obstacle detection, but not helpful for orientation or route planning.

Dogs need User input; they can't read signs or know flight info.

Audio Cues at Airports:
Often lost in the noise or not clear enough.

Only cover some announcements, not personalized flight details.

8. Broader Accessibility Reflections

Comparison of Countries:
Some participants like Jaka and Cor noted

that airports and public transport in places like Norway or Jakarta are more inclusive than others due to better tactile paths and staff familiarity.

Inclusive Design Benefits Everyone:
Several interviewees highlighted that accessible solutions often benefit all Users, such as elderly , tourists, or people with temporary injuries.

9. Design Implications

Navigation Support Tool
Indoor wayfinding app or device that provides:
Real-time location
Step-by-step audio guidance

Enable Indoor Navigation:
Audio and haptic guidance from entrance to gate, restrooms, etc.
Real-time updates on gate changes and directions.

Provide Smart Assistance Access:
On-demand call for help via app (no need to find a help point).
Track location to let staff find and guide User.

Deliver Accessible Flight Information:
App-based real-time alerts for flights, delays, gate changes.
Custom alerts for only relevant flights (filtering option).

Support Both Tech and Low-Tech Users:
Compatible with screen readers, large font/high contrast mode.
Optional voice control and one-handed use for cane/dog Users.

Blend Human and Digital Assistance:
Hybrid support: digital until human takes over, or both in sync.
"Personal assistant" mode suggested by multiple participants.

Accessible Interface
Fully compatible with screen readers
Simple touch or voice interface
Adaptable to different vision levels (contrast modes, text size)

Proactive Information Feedback Notifications of:
Gate changes
Flight delays
Estimated walking distances/times
Location of restrooms or food courts

Expert Interviews (EX)

1. Three-Pronged Approach to Accessibility:

1.1 Individual Skill Development – Teaching blind individuals how to confidently ask for help, use spatial orientation strategies, and train with tools like tactile maps or canes .
Use tactile training tools like raised maps, real-world practice with canes, and audio pre-briefings of spaces.

Encourage mental mapping and structured exploration (e.g. learning environments in expanding circles).
EX1 "You can teach someone to prepare for their trip with a tactile map or a narrated walkthrough of the terminal."

1.2 Environmental Adaptation – Enhancing airports with tactile paths, braille and large print signs, and consistent layout features modeled after Dutch train stations .
Tactile cues like floor tiles, braille markers, and audio waypoints should guide Users.

Airports should implement station-like adaptations: numbered railings, tactile junctions, consistent signage placement.

Include braille and high-contrast signs at eye level and entrances of key areas.

EX1 said "ProRail has tactile indicators and braille on stair railings — airports could follow a similar standard."

1.3 Technology Integration – Using apps or devices for indoor navigation, with audio/haptic cues. EX1 highlights the use of cameras and AI for real-time orientation inside buildings .
Teach people how to ask for help, use space creatively, and practice route planning.
Indoor navigation systems with camera-based positioning and audio feedback.

Use AI-enhanced apps to read out signs, detect landmarks, and offer turn-by-turn guidance.

Combine GPS + real-time visual input for seamless orientation.

EX1 "With camera-based indoor mapping like NEXT/Victor's, your phone becomes your guide — it knows where you are and what you're passing."

2. User Behavior in Navigating Airports

Independent Navigation Tactics
Creating mental maps and exploring in expanding circles from a known point.

Using guide dogs or canes, often in combination with technology like voice-based apps .

Carrying visible identifiers (like white canes) to signal need for assistance without speaking .

With Assistance
Most Users are proactive in asking staff or fellow for help, especially when arriving at unknown areas.

Assistance is often sought at entrance points or checkpoints, and requires trust and energy from the User to follow a stranger through busy spaces.

Role of volunteers or trained companions (as in Indonesia) is valued, especially when consistent support is unavailable.

3. What Are Mental Maps?

Mental maps are internal representations of space built through repeated experience, spatial cues, and structured exploration. For blind individuals, these maps replace visual memory and are essential for orientation and mobility.

EX1 explains:
"People who are blind or User explore their environments step by step and build a mental picture based on direction, steps, landmarks, and what they hear or feel."

How Are Mental Maps Built?
By Repetition & Experience:
Repeatedly walking a route helps individuals memorize turns, distances, and sounds.

Tactile markers (floor textures, railings) and auditory cues (escalator sounds, announcements) help anchor points on the map.

With Structured Training:
Orientation and Mobility (O&M) specialists train individuals to create mental maps using landmark-based exploration (e.g. "turn right after 10 steps from the gate", "hear the ventilation, that's the bathroom").

Tactile models (raised maps) are sometimes used to introduce the layout of a place before visiting.
Via Technology:
Some tools (e.g., indoor mapping apps, tactile electronic devices) help preview or simulate environments to prepare mental maps before traveling.

Mental Mapping in Practice
In airports, building a mental map is especially hard due to changing gates, irregular layouts, and lack of consistent cues.

For known spaces (e.g. train stations), Users can navigate with confidence by relying on habitual routes and familiar stimuli.

EX2 notes:
"People who are experienced can even identify locations by their echo, sounds, or air flow — it becomes second nature. But in unfamiliar places, it becomes risky."

Design Implication: Support Mental Map Creation
To empower Users to build mental maps in airports, experts recommend:

Providing preview tools: tactile maps, audio walkthroughs, or virtual simulations of terminals.

Ensuring consistency in spatial design — standardized layouts, predictable signage placement, and repetitive floor textures.

Creating anchoring points with multisensory cues (sound, touch, airflow) to help Users mark locations mentally.

4. Understanding User Differences (Visual Impairment Spectrum)
Jolanda emphasizes designing for the function, not just the diagnosis. She outlines key categories of vision loss:

Types of Visual Impairments:
Totally blind – fully dependent on non-visual navigation.
Peripheral vision loss (e.g., retinitis pigmentosa) – rely on center vision and scanning.
Central vision loss (e.g., macular degeneration) – struggle with detail, even if they detect motion.

Blurriness/low sharpness – may navigate spaces but can't read signs.
Cognitive processing difficulties – Users see but can't interpret complex visuals.

Light Sensitivity:
Lighting transitions (e.g., entering dark airplane cabins) pose orientation issues.
Some need bright lighting, others need low glare.

EX1 "Lighting inconsistency alone can disorient someone who relies on residual vision."

5. Expert Opinions on Assistive Technologies
What Works:
Be My Eyes – Allows Users to receive visual descriptions from volunteers.
Aira (US-only) – Offers professional support through a call center via smartphone.
Camera-based navigation tools – Indoor mapping with camera and AI support.

These tools let the person choose when and how to get help — that control is key to independence."

What's Lacking:
No integration – Tools are fragmented; one app reads signs, another handles navigation, another offers human support.
High device cost (e.g., smart glasses costing €500+) limits accessibility.
Language and cultural mismatches – Many services aren't adapted for non-English-speaking or non-US contexts.

EX1 mentions
"Aira doesn't work in Europe because the staff doesn't understand our systems. That kills its usefulness here."

6. Key Design Principles Suggested by Experts
Build for Active Exploration
Support mental map building, give tools for pre-planning routes.

Include tactile floor plans or digital walkthroughs of terminal layouts.

Design for Sound & Touch
Leverage audio guides, haptic cues, and AI object recognition.

Make sure devices don't require use of hands constantly (Users already manage cane, bag, phone).

Support On-Demand, User-Initiated Help
Systems should allow Users to request assistance proactively, not rely solely on pre-booking or visual help desks.

Hybrid approaches (digital + human support) are ideal — smart wearables that connect with live help when needed.

7. Recommendations for Future Designs
Unified smart assistant that:
Combines navigation, object recognition, and access to remote helpers.

Works hands-free, possibly via earbuds or smart glasses.

Supports multiple languages and offline use.

Tactile + audio-based wayfinding systems in terminals.

Install audio beacons, tactile junction indicators, and low-cost floor mapping solutions.

Design with energy & dignity in mind.
Reduce the mental load of navigation.

Support the User's right to travel independently, without having to constantly explain or justify their needs.

8. International Perspective (CBM & Southeast Asia Context)
EX2 focuses on inclusivity in practice, especially in under-resourced settings. EX2 insights reveal:

Common Gaps:
Cost barriers – Smartphones and wearables are too expensive for many Users in emerging regions.

Digital literacy – Not all VIP are trained in assistive tech.

Infrastructure limitations – Tactile paths or accessible facilities often absent in rural areas or smaller airports.

Community-based Training:
Use peer training models for orientation & mobility (O&M), especially for newly blind individuals.

Train volunteers and security staff in proper guiding techniques.

EX2 mentions "Many blind Users depend on community volunteers or family to assist — proper training and affordable tech can boost independence."

Assistant Staff Interviews (AS)
1. Requesting Assistance
How it's initiated:
Assistance is typically requested in advance when booking the ticket. This data is recorded in the passenger manifest shared with both the airline and cabin crew.

At the airport, VIPs are guided by ground staff from check-in to the boarding gate. Once at the aircraft door, the cabin crew takes over.

AS1 mentions
"We get informed ahead of time via the manifest that someone with visual impairment is boarding, and what seat they are assigned to."

How Assistance Is Requested On Board

1.1 Pre-Boarding and Boarding

VIPs often pre-arrange assistance during booking, and this is noted in the crew's briefing and manifest.

At boarding, airport staff escort the passenger to the aircraft door, and inform the crew that they are handing over a User traveler.

Once on board, the passenger is guided to their seat and a brief orientation is provided (e.g. where the exits are, how to buckle seatbelt, how to locate restroom).

AS1 says:
"They tell us at the aircraft door that the person has a visual impairment, but what they need isn't always communicated. We usually just ask the person directly."

1.2. Requesting Help During the Flight

Passengers typically ask for help verbally (e.g. "Can you guide me to the toilet?").

Some will signal by pressing the call button or speak to crew directly during check-ins.

In many cases, fellow passengers also assist with small tasks (like handing waste to the cart, locating dropped items).

AS2 says:
"If someone with a visual impairment needs to go to the bathroom, they ask us or we check in every 10-15 minutes to offer help."

2. In-Flight Assistance

Onboarding Process:
The cabin crew meets the passenger at the door and guides them to their seat while explaining the layout and nearest exit.

A special Safety Instruction Card (SIC) in braille or tactile format is provided when available, especially on wide-body aircraft.

Briefing Includes:
Location of emergency exits, oxygen masks, life vests.

Explanation of aircraft layout (number of doors, distance to exits).

Seat-specific info (e.g., how far their seat is from exits, bathrooms).

Seating Rules:
Passengers with visual impairments are not allowed in emergency exit rows, but otherwise free to choose their seat.

Often seated by the window or aisle based on preference.

3. How VIPs Are Monitored

Tracking & Communication:
Seat location is logged into the crew's tablet system and mentioned during pre-flight briefings.
However, crew members can occasionally forget the passenger's exact seat, especially during busy moments, unless they recheck their devices.

AS1 "Sometimes we're so busy, we forget momentarily where the blind passenger sits. It's not intentional, but it happens."

Check-ins:
Cabin crew periodically check in with VIPs (every 10–15 minutes on some flights).

4. Type of Assistance Provided

Verbal Communication:
Clear verbal instructions are emphasized for safety, food service, and general orientation.

Crew describe what food and drinks are available, where items are placed, and offer help deploying tray tables or identifying cutlery.

Navigating to Restrooms:
Passengers may request help to walk to the restroom.

Crew often guide by voice, shoulder support, or by describing steps verbally.

Doors and locks are sometimes explained if unfamiliar.

AS2 "If someone isn't familiar with the toilet, we explain the lock position and how to flush."

5. Guide Dogs & Other Devices

Rarely encountered in Indonesia, but in the Netherlands, guide dogs are allowed in the cabin and sit by or in front of the passenger.
Most passengers bring white canes, which are stored under the seat for easy access—not in the overhead bin.
No built-in as

6. Perceptions of Assistance Quality

Positive Feedback:
Passengers often feel well-cared-for and safe, especially when staff are attentive and communicative.

Assistance is seen as reliable, especially when traveling with a companion.

Limitations Noted:
Crew may lack in-depth training on disability etiquette (e.g., sometimes talk to the travel companion rather than the person themselves).

Over-reliance on passengers being experienced flyers – first-time blind may miss important details.

No physical or digital system to easily identify the exact needs of the passenger beyond what's written in the manifest.

Opportunities for Improvement

Navigation Support
Add tactile seat numbers or braille signage in the cabin.

Develop wearables that can guide passengers independently to the bathroom or provide layout orientation.

Communication Tools
In-seat audio system that repeats safety instructions and allows custom information access (e.g., location of tray, call button).

Crew Training Enhancements
Train staff to always address the passenger directly, even if traveling with a companion.

Include simulation training for cabin crew to better understand the blind passenger's perspective.

7. Limitations of In-Flight and Airport Assistance

Information Gaps Between Airport Staff and Crew
There's no detailed handover about the passenger's specific needs (e.g. does the person

A4 Co-Design Sessions Notes

1. General Design Requirements

Support for Independent Travel

The system must enable Users to move without relying on airport staff for every step.

Should work across the full journey, including from entrance to check-in, through security, to the gate, and optionally to boarding.

"I want to do it myself, not wait around for someone to help me every time." – UG15

Adaptable to User Experience Level

Needs to support both experienced who want minimal prompts and new who need step-by-step instructions.

Option to toggle guidance intensity (e.g., detailed vs. simple instructions).

2. Wearables: Preferences and Requirements

Participants generally preferred wearables that are:

1. Lightweight and compact, avoiding bulky or heavy devices that are uncomfortable over time.
2. Unobtrusive, to not draw attention or appear overly "technical" in public.

Preferred locations for wearables include:

1. Belt or Chest area for stability and accessibility.
2. Cap for natural head movement alignment.
3. Tactile cane attachment for natural synchronization with movement.
4. Around the neck with safety features to prevent theft or obstruction.

"It should hang on my chest or belt, like something I don't have to think about." – UG10

3. Navigation Instructions and Input Types

Voice commands

Were consistently highlighted as the most natural and intuitive input method.

Participants favored systems similar to Siri or Google Assistant.

Alternatives like small tactile buttons or braille interfaces are acceptable but secondary.

Multimodal navigation

Combining spatial awareness, environmental scanning, and route guidance is preferred.

Must offer accurate spatial guidance, including:

1. Distance to destinations
2. Step-by-step directions
3. Real-time updates about gates passed and current location
4. Should clearly announce key zones (e.g. check-in, security, gate, food court) for spatial orientation

UG12 mentions "Tell me which gates I'm passing so I know how far I am from mine."

Instruction Format should include both:

1. Spatially accurate commands: e.g., "walk 20 meters forward"
2. Contextual landmarks: e.g., "you'll hear the escalator on your right"
3. Instructions must be timely and proactive, not delayed or confusing.
4. Mental Map Support
   Assist Users in building a mental model of the airport, especially through:
5. Route previews
   Landmarks (sound, texture, temperature)
   Area summaries ("This is the check-in zone with 6 counters and toilets on your left")

"If I know the layout once, I can do it again alone." – UG3

4. Feedback Types and Timing

Feedback is desired at key decision points:

1. When approaching gates, restrooms, cafes, or transfer points.
2. When deviations or obstacles are detected
3. Upon entering new zones or terminal segments.

Preferred feedback modalities:

1. Audio feedback via bone conduction headphones or earpieces is favored for hands-free use.
2. Haptic feedback is acceptable as a secondary channel but should not replace audio.
3. Avoid visual feedback unless it is combined with assistive apps for low-vision Users.
4. Unexpected situations: obstacles, crowding, missed turns.
5. Landmark confirmations: "You are near the toilets / check-in desk / security."

Example:
UG7 prefers compact wearables and feedback through earphones rather than phone speakers to avoid disturbing others.

How It Should Be Delivered:

- Audio (primary): via earpiece or bone conduction headphones for clear, private voice guidance.
- Haptic (secondary): vibrations on wrist or belt for discrete directional prompts.

"Vibration is nice if it's just 'turn left' or 'you're off track'—but don't overdo it." – UG7

Feedback and Information Delivery

Clear, concise, and not overly chatty — too much talking becomes distracting

Convey it at decision points: when turning, changing floors, or entering a new section.

On-demand information buttons or commands for environmental awareness (e.g., "What's around me?" or "Where am I?")

"Only tell me key info unless I ask for more." – UG7

5. Input & Controls

Buttons

Buttons must be distinguishable by shape or texture, ensuring easy use without looking

Users prefer simple tactile buttons, such as:

1. Navigation restart
2. Orientation (current location)
3. Option selector (e.g. between stairs, lift, escalator)

"Three buttons is manageable if they all feel different." – UG7

Preferred Interaction Methods:

Voice commands are the most intuitive ("Where is gate 23?" / "Take me to check-in").

Simple tactile buttons are accepted as backup (e.g., on the wearable itself).

Avoid complex gestures or touchscreen inputs which can conflict with using a cane or guide dog.

"I like to say what I want. Touching the screen is hard when I have a bag and cane." – UG11

6. Mental Mapping and Spatial Awareness

Participants discussed how they form mental maps:

1. Through verbal descriptions from sighted companions or airport staff.
2. By repeated visits, gradually memorizing spatial layouts.
3. Landmarks and tactile features, like texture changes or sound cues, are critical for orientation.

As UG11 explained, he relies on companions to verbally describe surroundings and establish mental anchors like cafes or billboards.

7. Additional Key Points

Autonomy vs. Assistance
Participants desire increased autonomy, preferring systems that let them bypass airport staff when they feel confident.

Real-time location awareness and obstacle detection are vital features.

Participants liked the idea of a wearable that recognizes their location automatically and provides real-time guidance, possibly integrating with airport systems.

There is skepticism toward head-worn devices that are too conspicuous or heavy.

Concerns about infrastructure dependency—participants preferred systems that don't require airport-wide installations, like beacons.

Contextual Awareness:
System should guide to and within key areas, including:

1. Help desks
2. Toilets
3. Shops or food areas
4. Rest zones
5. Should announce proximity to key areas like restaurants and allow follow-up interaction if User wants more detail

Time Awareness:
Users want to be informed about time left before gate closing and how far they are from the gate. Include automated reminders when it's time to return from breaks to avoid missing flights

"Tell me how long it will take to walk back to the gate from a shop." – Amal

User Adaptability:
System should allow:

1. Flexibility in travel choices (elevator vs escalator vs stairs)
2. Re-routing based on real-time decisions (e.g. visiting a shop before heading to the gate)

Reliable sensor-based guidance that works indoors and doesn't rely on GPS

8. Past Device Limitations (Critique of Existing Products)

U7 described the WeWalk smart cane as:

1. Too heavy
2. Uncomfortable grip
3. Unreliable touch interface
4. Poor speaker volume and limited feedback options

These critiques helped define what not to include in a new concept.

9. Conclusion for Design Implications

To design an effective navigation aid:

1. Focus on wearables that are light, intuitive, modular, and unobtrusive.
2. Use audio feedback as the primary guidancemethod, with optional haptic alerts.
3. Enable natural voice-based inputs for commands and inquiries.
4. Support on-the-go real-time navigation, with environmental scanning (e.g., Lidar or infrared).
5. Real-Time Adaptation
    - Ability to adjust routes if gates change or paths are blocked.
    - Warn Users of obstacles or congested areas in real time to prevent hitting dynamic obstacles like people.
    - *"Tell me if the gate has changed. I don't want to just wait there and miss my flight." – UG3*
6. Avoid reliance on airport infrastructure; instead use reliable sensor-based guidance that works indoors and doesn't rely on GPS Usage of:
    - SLAM (Simultaneous Localization and Mapping) without GPS is an excellent choice.

With sensors like:

- Lidar or infrared sensors
- Camera-based localization (combined with AI)

Other Important Design Insights
Privacy-conscious: system should avoid excessive talking in public or alerting others visibly.

Battery life and reliability are essential—needs to work the full duration of airport transit.

A5 Feedback Implementation

Legend

Obstacle

Orientation (Passive)

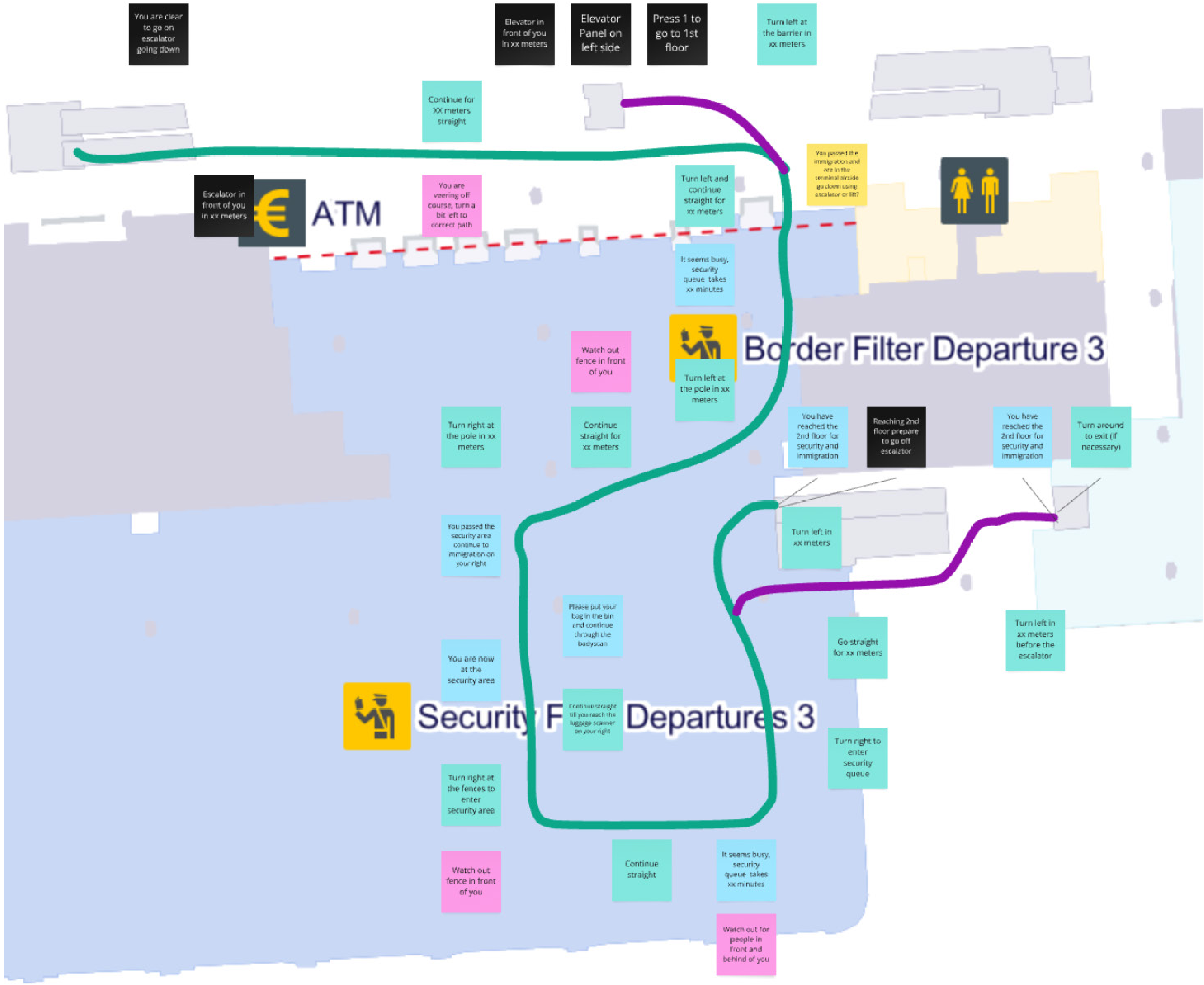
Orientation (Active)

Navigation

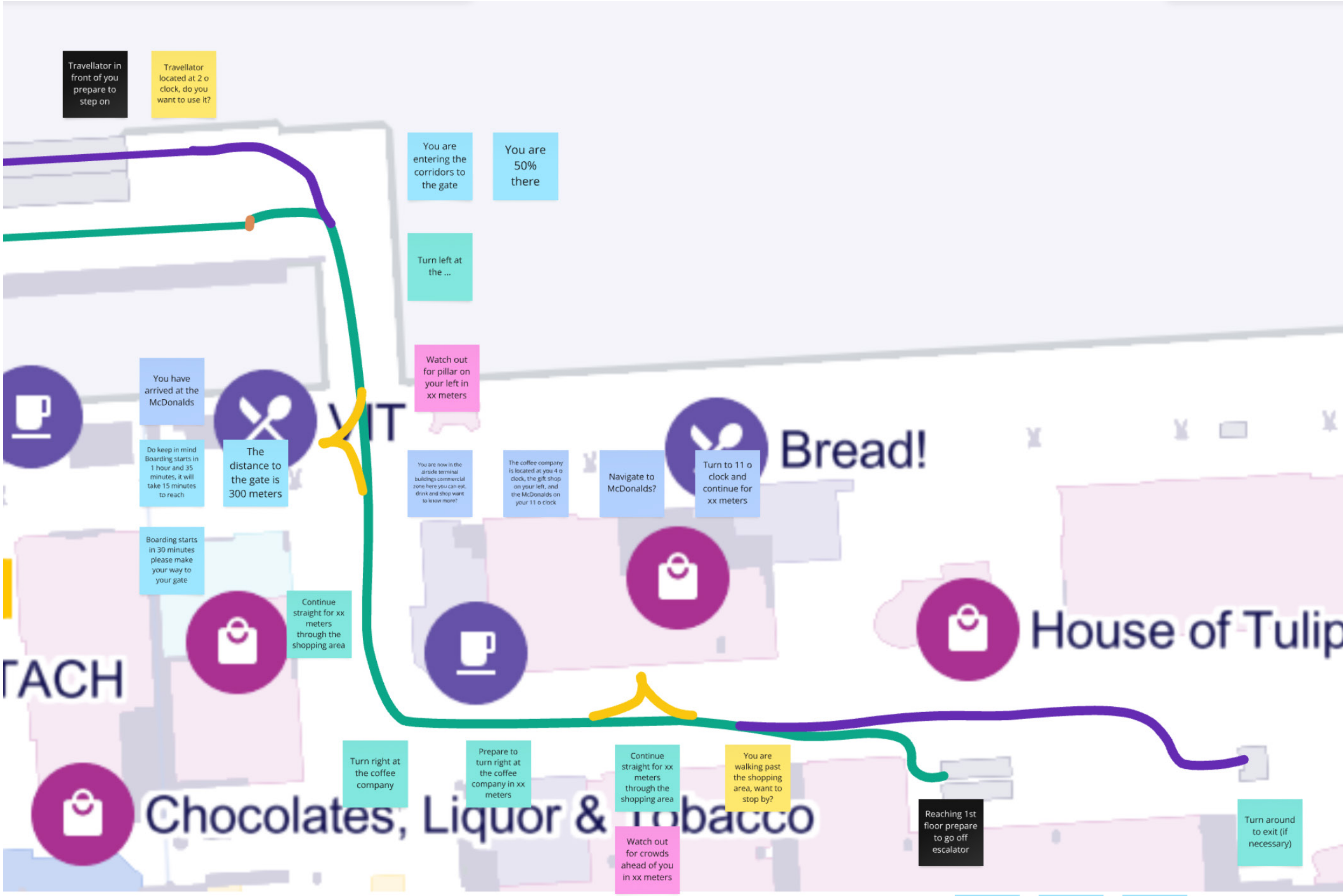
Input

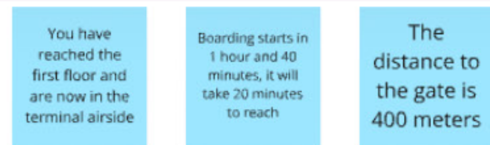
Object

Navigating from Check In Feedback



Navigating through Security and Immigration Feedback

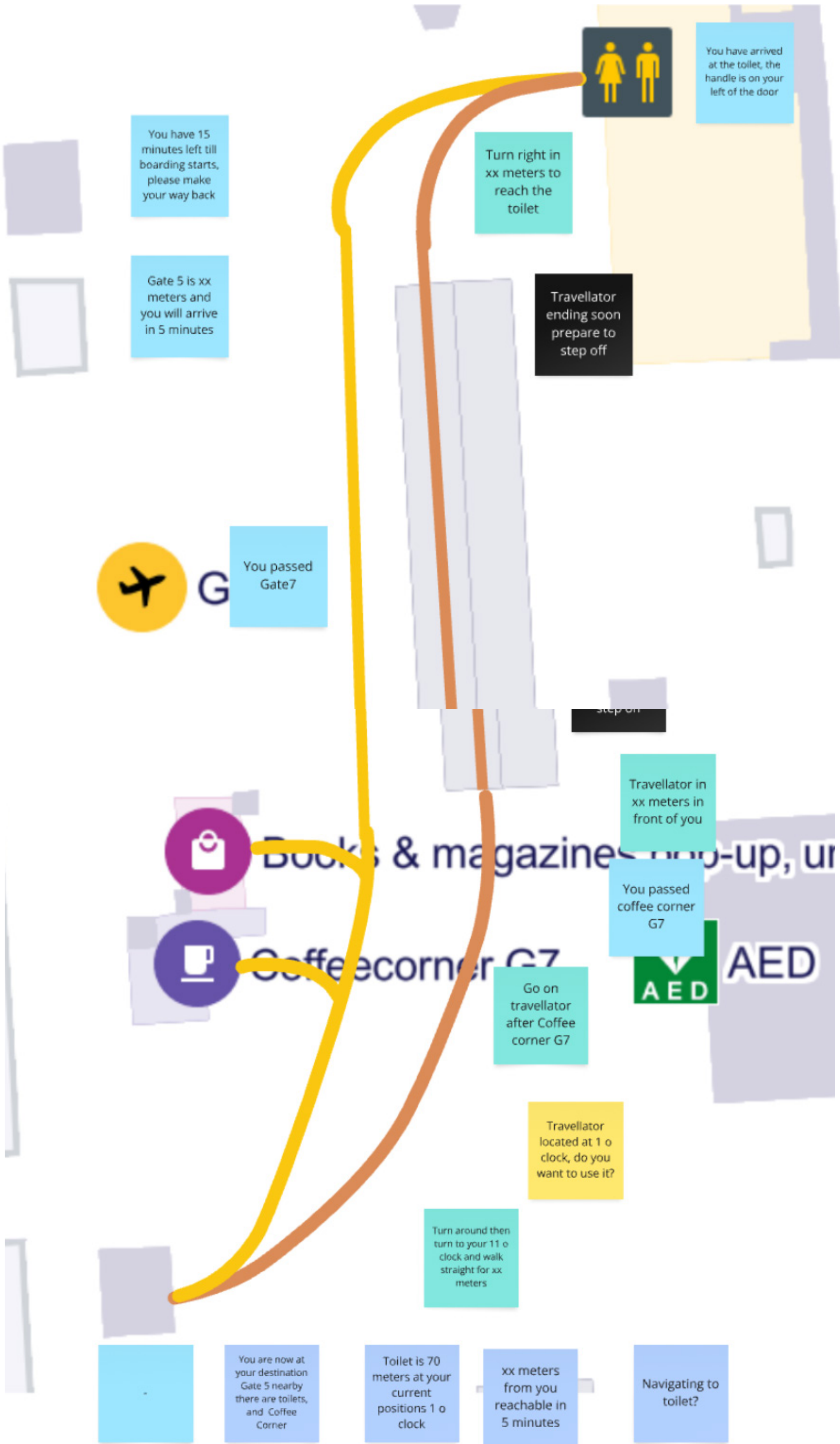




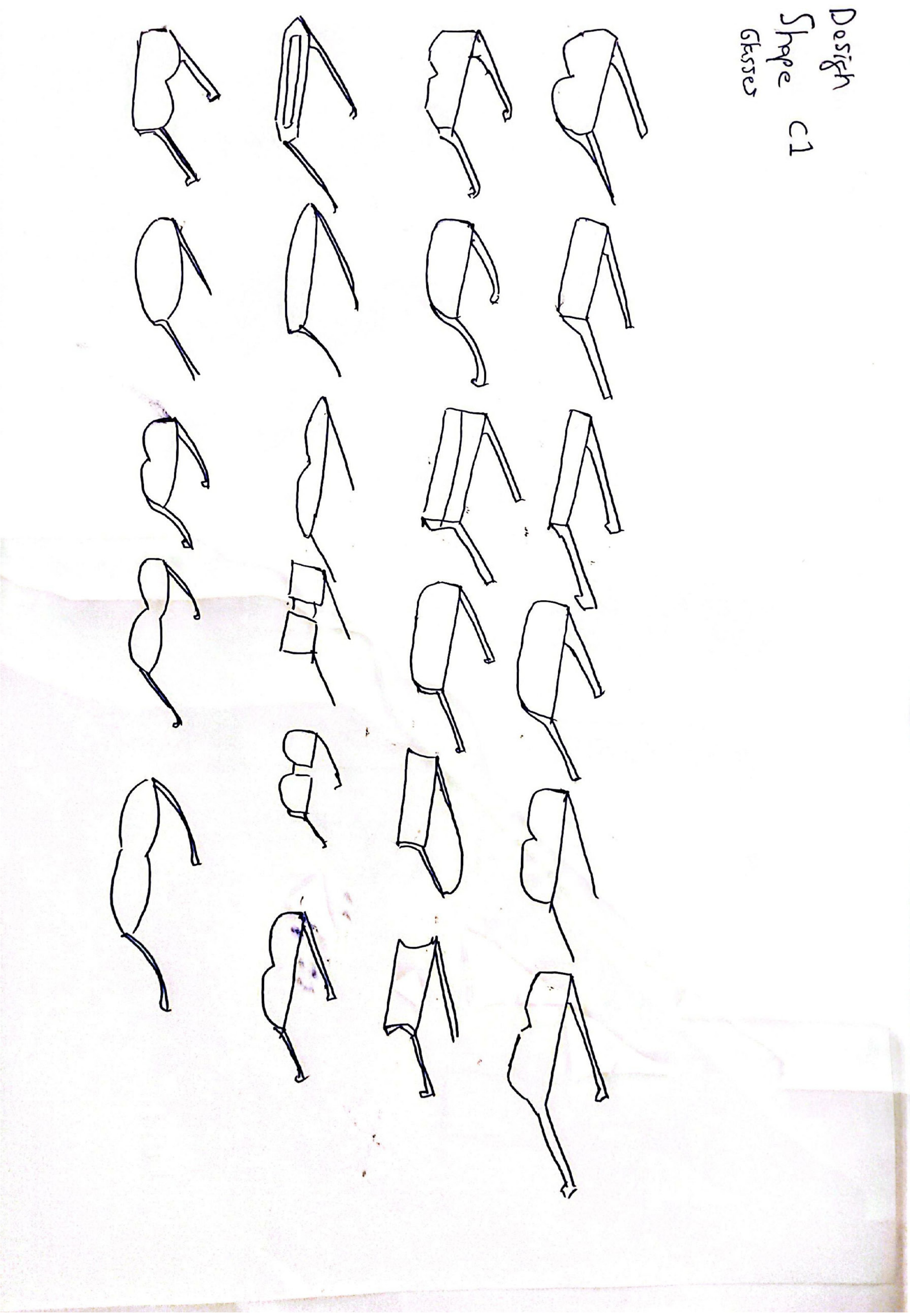
Navigating through Airside Terminal Area Feedback

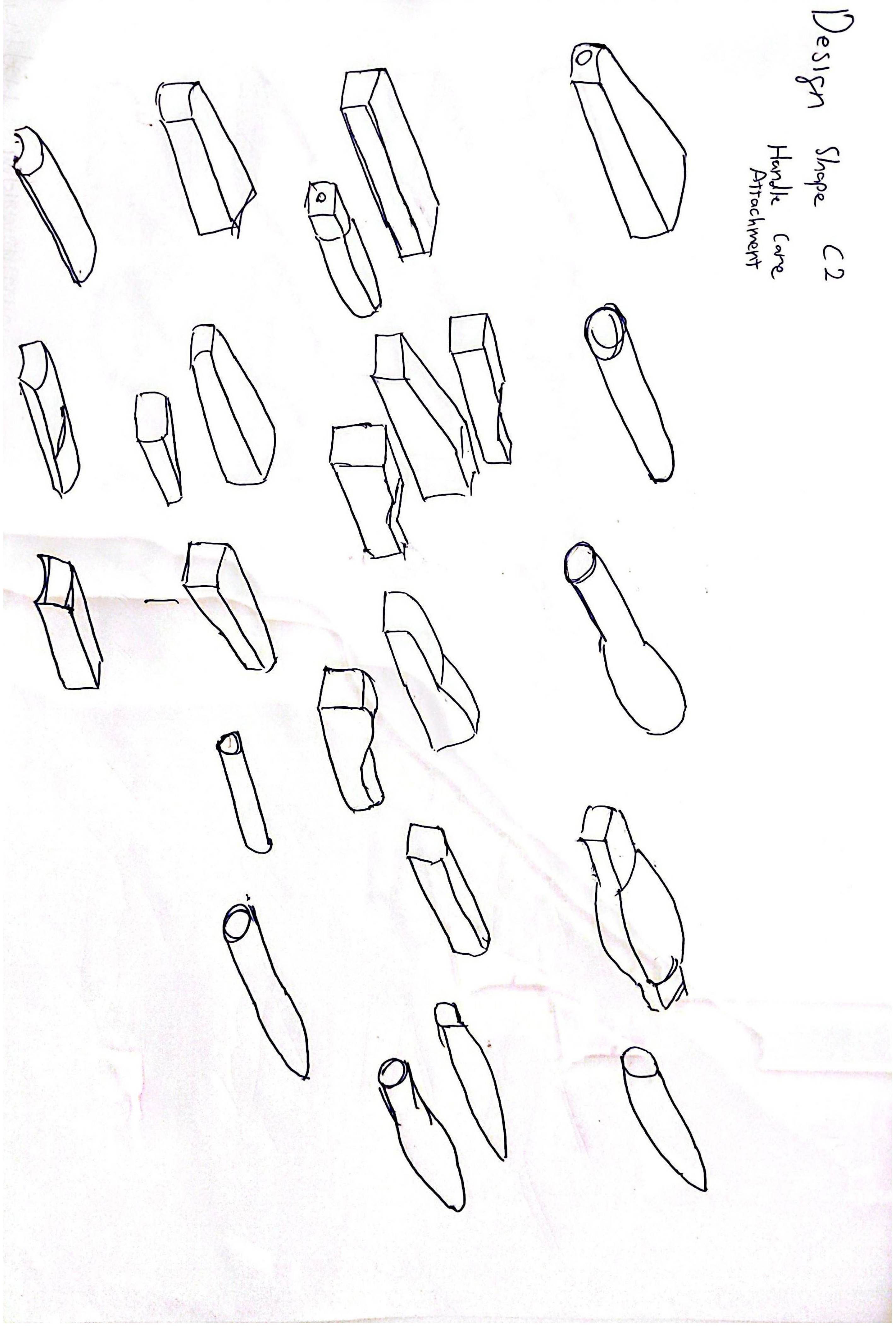
Gate Area Exploration Feedback

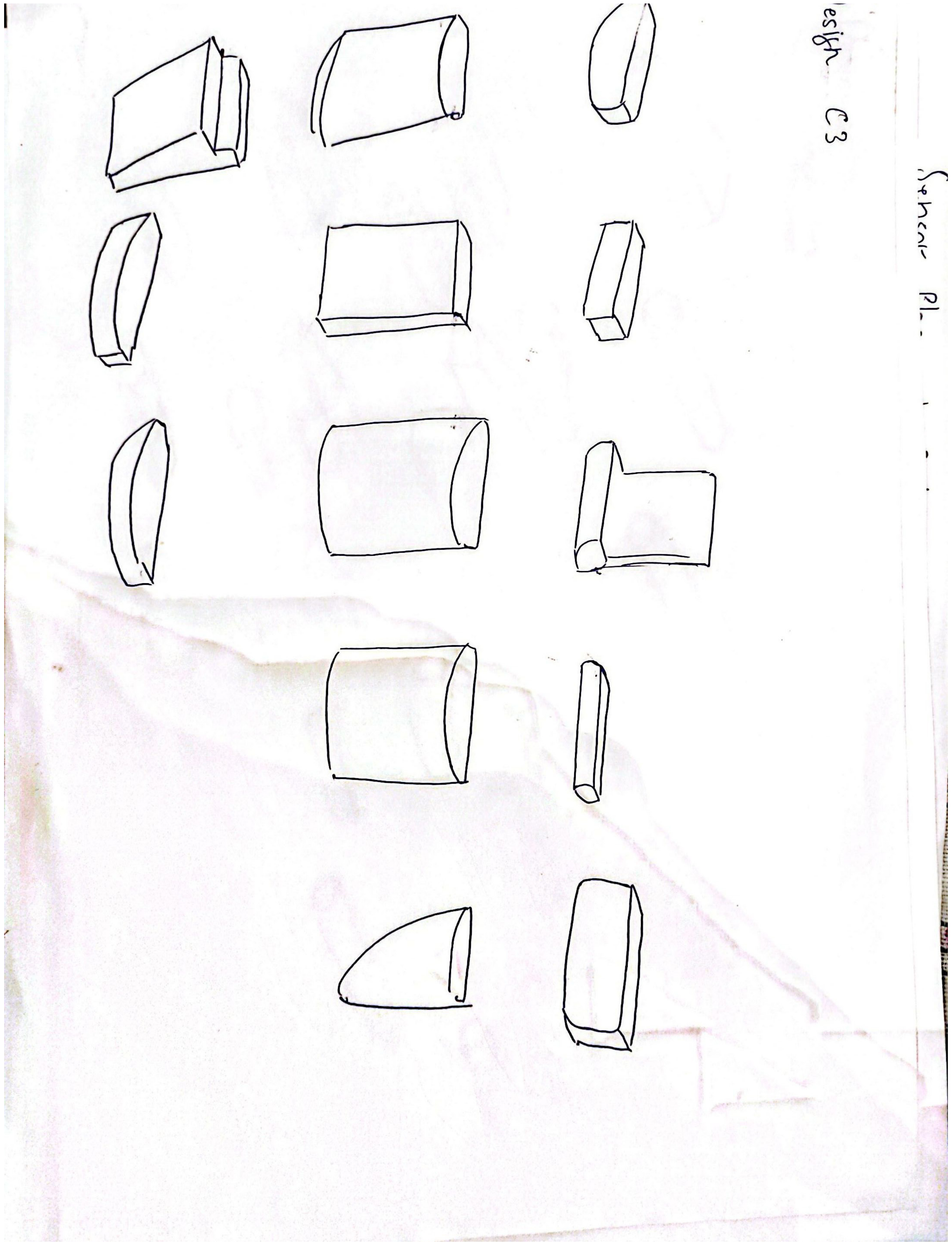
Navigating to Gate Area Feedback

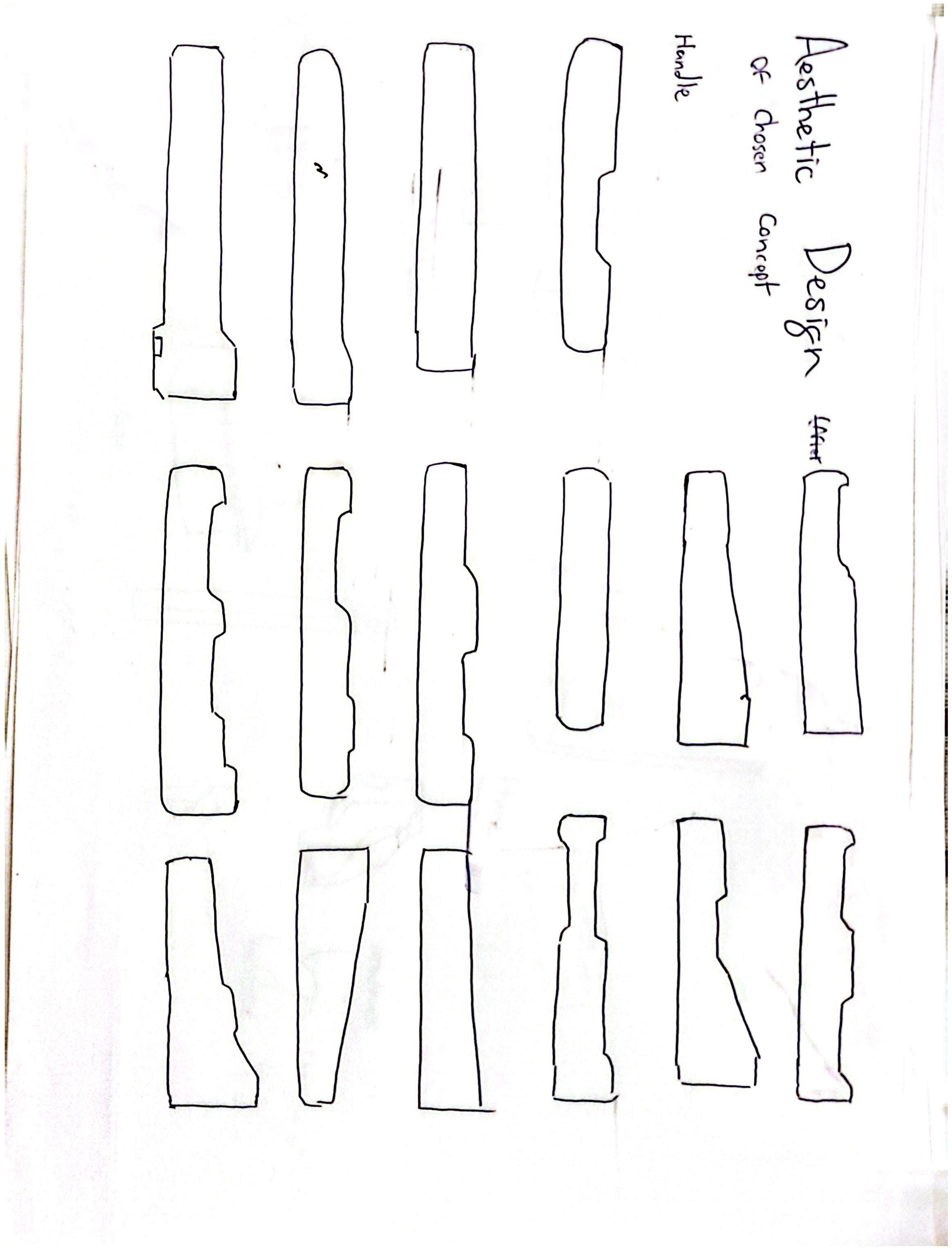


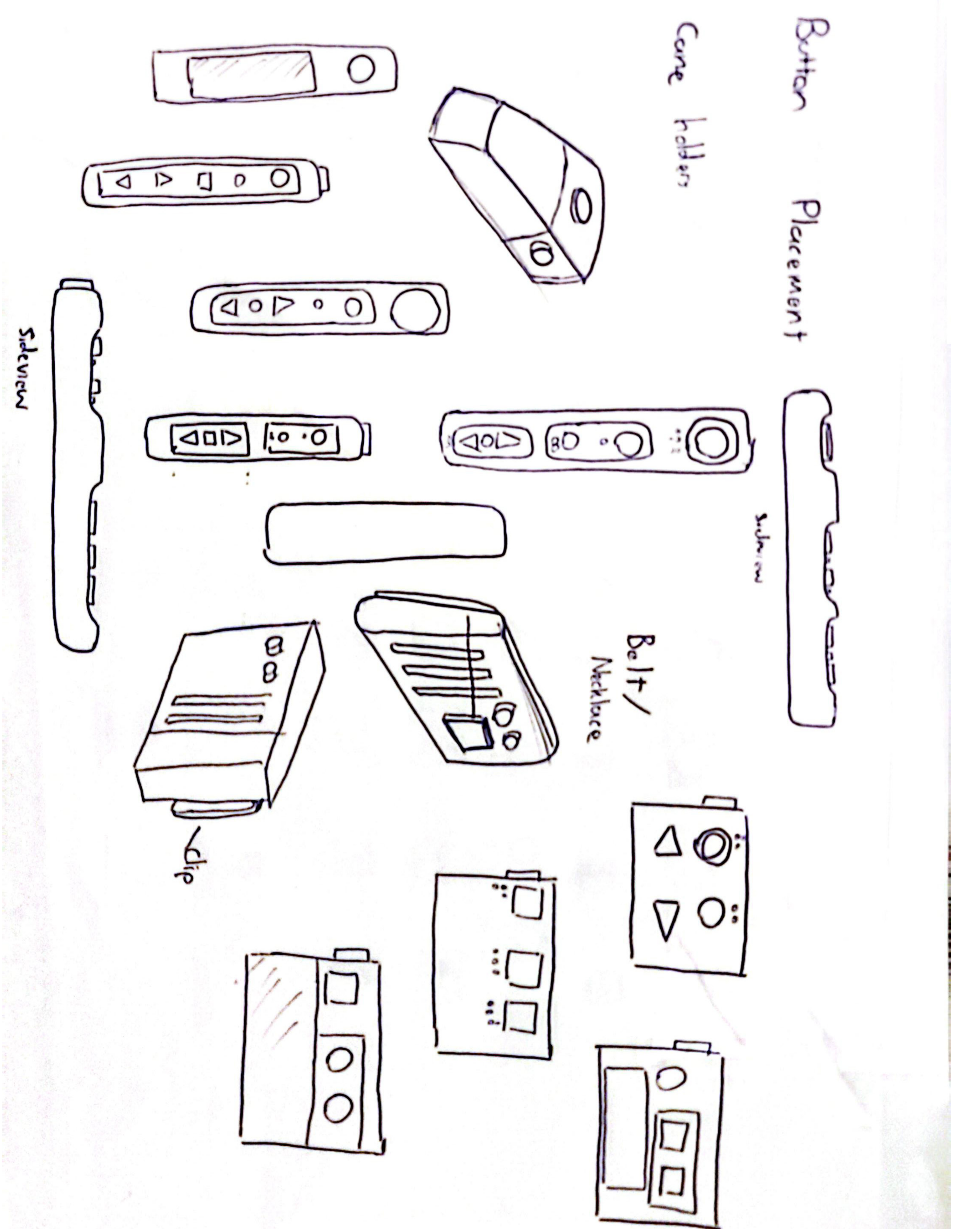
A6 Ideation Sketches

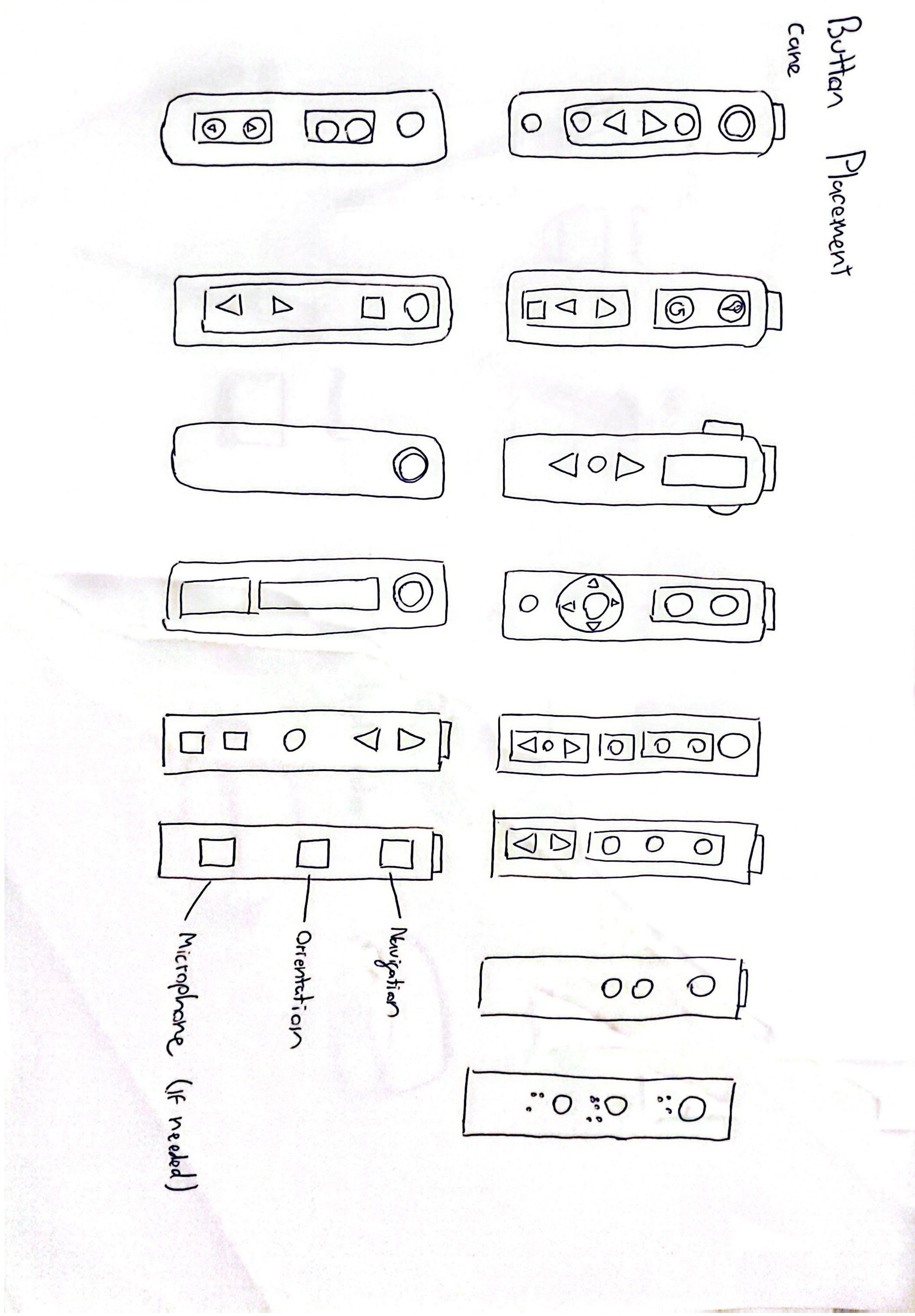





esign C3


Aesthetic Design
of chosen concept
Handle


Button Placement
Cane holders
Sideview
Sideview
Belt/ Necklace
Clip


Button Placement
Cane
Microphone (if needed)
Orientation
Navigation

A7 User Testing

Section 1 of 3

Master Thesis User Testing

Hello and welcome to my simulated user test on navigating as a visually impaired through an airport terminal from the airside building to your gate, which is gate 3 for your flight GA89 to Jakarta departing at 11 AM. In this experiment I aim to to compare navigating to the gate, between using airport assistance and the newly developed prototype vest that holds the phone to carry out navigation using VSLaM. The questionnaire exists out of 3 parts. Part 1: User Data, Part 2: Usage with Airport Assistance, Part 3: Usage with the Vest

Name *

Short answer text

Contact Details (Phone/e-mail) for additional questions if necessary *

Short answer text

Gender *

- ○ Male
- ○ Female
- ○ Other...

Age *

Short answer text

Spoken Languages *

- ☐ English
- ☐ Dutch
- ☐ Mandarin
- ☐ Hindi
- ☐ Spanish
- ☐ French
- ☐ Arabic
- ☐ Indonesian
- ☐ Other

Section 2 of 3

With Airport Assistance (Human Guidance)

Part 2: The experience on navigating along the path when guided by a human assistant

Technical Ratings

To be filled out by the Researcher (Darius) (*Enabling Independent Navigation for Visually Impaired People Through a Wearable Vision-based Feedback System*, 2017)

Time taken to reach check-in

Short answer text

Obstacles Hit

Short answer text

Corrections Made

Short answer text

Route Taken (See Strava)

Short answer text

Other Remarks

Long answer text

Airport Assistance Usage

To be filled out by the Participant Questions from (*SANTA BARBARA SENSE-OF-DIRECTION SCALE*, 2021) (*Enabling Independent Navigation for Visually Impaired People Through a Wearable Vision-based Feedback System*, 2017) and (Minge et al., 2007)

I do not feel exhausted when using the airport assistance *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

It is quickly apparent how to use airport assistance *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I consider airport assistance extremely useful *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

With the help of airport assistance I will achieve my goals independently *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Airport assistance gives me a better sense of control in the environment *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

Airport assistance makes me feel more independent *

	1	2	3	4	5	6	7	
Low	○	○	○	○	○	○	○	High

Difficulty with Mobility

To be filled out by the Participant Questions taken from (La Grow et al., 2013)

Difficulty in avoiding obstacles *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Difficulty to walk along the route *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Difficulty in knowing where I am *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Difficulty to understand instructions on what to do *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Other Remarks

Long answer text

Section 3 of 3

With Vest and Phone (Without Human Guidance)

Part 3: The experience on navigating along the path alone with the vest

Technical Ratings

To be filled out by the Researcher

Obstacles Hit

Short answer text

Corrections Made

Short answer text

Time taken to reach check-in *

Short answer text

Route Taken (See Strava)

Short answer text

Other Remarks

Long answer text

Product Usage

To be filled out by the Participant Questions from (*SANTA BARBARA SENSE-OF-DIRECTION SCALE*, 2021) (*Enabling Independent Navigation for Visually Impaired People Through a Wearable Vision-based Feedback System*, 2017)

I do not feel exhausted when using the product *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

It is quickly apparent how to use the product *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

I consider this product extremely useful *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

With the help of this product I will achieve my goals independently *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

The product gives me a better sense of control in the environment *

	1	2	3	4	5	6	7	
Strongly Disagree	○	○	○	○	○	○	○	Strongly Agree

The product makes me feel more independent *

	1	2	3	4	5	6	7	
Low	○	○	○	○	○	○	○	High

Difficulty with Mobility

To be filled out by the Participant Questions taken from (La Grow et al., 2013)

Difficulty in avoiding obstacles *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Difficulty to walk along the route *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Difficulty in knowing where I am *

	1	2	3	4	5	
Low	○	○	○	○	○	High

Difficulty to understand instructions on what to do *

	1	2	3	4	5	
Low	○	○	○	○	○	High

What can be improved? *

Long answer text

Other Remarks

Long answer text

Methodology

The User uses a low fidelity prototype and is navigated through a feedback that a researcher (Darius) says, simulating what the VSLaM system should do. The researcher also detects obstacles for the User. The entire experiment should last around 30 minutes.

Act I - Airport Assistance

1. Preparation of Experiment and Explanation
2. Navigational aid assists participant to navigate straight
3. Navigational aid assists participant to navigate by making a turn to the left
4. Navigational aid assists participant to avoid dynamic obstacles like people
5. Navigational aid assists participant to navigate straight
6. Navigational aid informs of passing assistance desk
7. Navigational aid informs of passing toilet and asks if User wants to navigate there.
8. Navigational navigates back to the route
9. Navigational aid assists participant to travel through rotating doors
10. Navigational Aid informs of gates passed
11. Navigational Aid informs of arrival at destination
12. Fill out Questionnaire
13. Repeat Steps 2 - 12 with the Airport Assistant
14. End of experiment
15. Break and Data Collection
16. Next Participant

Plan B Methodology Modifications

When Plan B is implemented all, except obstacle detection Navigational Aid tasks are informed by the Researcher through the headset who follows the participant from a distant. Stickers on the ground are placed to inform the Researcher when to give specific tasks, which otherwise the system would have done automatically.

Plan C Methodology Modifications

Similair to Plan C, but now all information will be informed manually from a distance by the researcher, inlcuding obstacle detection.