A Guiding System for the Visually Impaired in Public Transportation

A system to help blind people locate bus stops and access buses

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Project 3 Report

Preface

The project is done in two parts and the first part is Students Exchange program between Industrial Design Centre (IDC), Indian Institute of Technology Bombay, India and IAD, Technische Universität Darmstadt, Germany. This program is an attempt to promote cross cultural problem solving among participating departments of institutes of India and Germany. Students are encouraged to form two groups of 4 students (2 Indian+2 German) each and work together as a team for duration of 6 weeks in Germany followed by 6 weeks in India.

The idea behind the project was to come up with a common platform where students and institutes could exchange their design thinking and explore potential as a team. In order to achieve this objective, a common issue was identified which could be studied and researched further. The proposed solution should work in both contexts. In the present case, the issues faced by visually challenged people in public transportation system were addressed. The project was split into two parts where two students from India visited Germany and worked with the other two students. After the end of the initial period of six weeks, all four came to India to get exposure to the second context and finish the project.

The second part is a project in the same domain where the focus is on locating known and unknown spaces by community mapping and crowd sourcing. The idea was to explore new possibilities and broaden the perspectives while looking at a problem and identify cultural requirements.

Acknowledgements

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1. Introduction

Public transportation is the basic amenity that any city is supposed to have for transportation within and outside the city. That being the case, this amenity must be available to the residents irrespective of their social status, gender, physical condition, etc. It is also a basic right for every citizen to be able to navigate comfortably to places of work and so forth in the city of their residence. Busses and trains are used by a great number of people on a daily basis.

“Bus and rail networks are the lifeblood of Indian society and prime movers of the local economies” says Jamie Osborne, a Transit Planner and Accessibility Specialist with the San Francisco Municipal Transportation Agency after a travel through India [1] (Osborne, 2007).

A lot of work keeps happening in the domain of transportation to give this comfortable commute to the citizens in a country like India with such a large population. Year after year more people move to cities for opportunities and the cities have to battle with infrastructural maintenance nonetheless but we still need to buckle up to make public transportation accessible.

According to Jamie, “Through advances in technology and social discourse, we find ourselves in a world where seniors and people with disabilities have become new Indian citizens. The world is changing and transit systems especially need to demonstrate adaptability to meet the needs of this new group of users.” [1]

India has the largest blind population in the world of nearly 15 million. 1% of the population is blind. But the impairment does not restrict them from studying, having ambitions and raising a family. Sadly, many portions of the world have still not been completely made accessible. Their basic requirement is affected when the navigation is curbed. Many people prefer staying indoors than to get out there and battle everyday with transportation and infrastructure.

This project is an attempt to help the visually impaired people access public transportation with less difficulty and navigate to places of their requirement more efficiently. As part of this project, I spent the initial part of the project’s tenure in Darmstadt, Germany. This was an attempt to understand the cultural differences, infrastructural advancements, understand the attempts to provide solution and design a guiding system which would act as an assistant to the person using it whether visually impaired or the elderly.

For the project, the chosen mode of transportation is public bus since after looking at some other transportation means it seemed the bus system is pretty much the same in both Germany and India. Both countries have visions to make the countries barrier free by 2020 [2] (Johari, 2017). Though one is a developed country and one is developing pretty fast the visually impaired citizens did have their concerns about not being able to travel like their counterparts.

2. Background

Orienting oneself while navigating and accessing public transportation comes to one with practise and familiarity. Any person feels a fish out of water when in a new place, trying to figure out the direction to take. Comfort in commute comes with familiarity of a place and ease of identification. A person has many references and builds a cue for oneself while navigating. In a city like Mumbai, the speed and commotion makes it even more challenging. Take away a major cue forming sense from someone and add millions of people pouring in from all directions going to some place all the time, chaotic traffic roaring and honking from all over, hustle and bustle of the street hawkers and undulations on every surface ranging from a broken handle to a gigantic pothole made by nature or man. That is the state of a visually impaired person trying to commute in Mumbai and cities likewise.

In order to understand how the system of transportation works in germany, I got the opportunity to look at the public transportation in the city of Darmstadt and compare it with the prior experience in India. This was further informed by various papers and articles in this domain.

Darmstadt is a well developed city close to Frankfurt in the state of Hessen in Germany with a population of 1,50,000 as of 2015 [3]. They have a well connected transportation system inside the city such as busses, trams and trains. Some of the bus or tram stops have been made in a way that the platform and the bus floor match for convenient access. Due to the manageable population the drivers further help a commuter on a wheelchair or with a pram by manually extending a ramp from a dedicated section on the bus or tram.

But the city is very busy and there is a lot of commotion in many areas of the city during peak hours and the visually impaired are still facing a lot of issues.

A comparison between the cities led to the choice of busses due to the similarity in the system and the high frequency of usage. Though other means of transportation are different with respect to the infrastructure or announcement mechanism, a guiding system to help visually impaired navigate can be extended to fit any public transportation system with a little tweak.

3. Secondary Research

Not always is the system inaccessible. Sometimes there is no facility but in some cases there are some facilities but the information is not really accessible. Inclusive design must also consider conveying this information to everyone for them to make use of the facilities. Many busses have seats for disabled but ranging from crowd on bus to the person boarding not knowing leads to these people increasingly shifting towards expensive personal transport means. “Where accessible public facilities do exist they lie unused because they often exist in isolation, surrounded by hostile environments that render them inaccessible. Or no one knows they exist! Essential access information is not communicated to users.”, says Jamie and Mumbai is a great example in this regard [1]. 3% of the buses are accessible but information regarding their route is unknown. The change has to happen in the entire journey, from providing information to help them navigate.

In order to understand the state of India and Mumbai transportation sector, I went through some documents and articles. This further led to the selection of bus as the primary public transportation for making it accessible. This extends to also understanding from previous works and cases studies, how people with low vision and visual impairment carry on their day to day activities and also further the issues they face while navigating.

3.1 Current State in India

The population of our country is 1.252 billionas per the census of 2011, (India, 2007)[4]. India’s Public Transport is one of the most heavily used in the world and caters to nearly 1.1 billion people (group, 2016)[5]

Modes of transportation.

Train
Bus
Metro
Auto
Taxi
Tram (kolkata)
Waterway

India’s rail network is the 4th longest in the world, transporting 8,224 million passengers. But most popular means of transport for commute on a daily basis within the city is by bus since commuter rail services are available only in the seven metropolitan cities of Mumbai, Delhi, Chennai, Kolkata, Bengaluru, Hyderabad and Pune while bus services operate in at least 25 cities with a population of over a million.

In smaller cities intermediate modes of communication like the auto rickshaws and the tempos are used (Anindita Ghosh, 2016) [6]. A large number of Indians own and use personalized two wheelers and cars for commuting on a daily basis [6]. It takes up around 80% of the traffic on the roads of larger cities. For small distances auto rickshaws are used and the tariff changes from city to city. Taxis also are quite popular, often used by those classes of society who can afford or at times when the passengers have luggage which is not so easy while using a bus or a train.

Buses take up over 90% of public transport in Indian cities (John Puchera, 2005)[7] since it is affordable and connects many portions of the city (1, (2012))[8]. Most buses are provided by the state government based transport corporations.

Service providers

State government based transport corporations.
BRTS(Bus Rapid Transit System) : Exists in several cities (not Mumbai)
BEST (Mumbai)

3.2 Mumbai

Mumbai's population which was 12.5 million in 1991, nearly doubled to 20.5 million in 2012, [4] Indian Census, 1991; 2012) indicating the masses pouring into the City. Every day so many of them need to move around the city. The trains are extensively used for this while 60% of mumbaikars (people living in Mumbai) travel by bus (DNA India).

Modes of transportation in Mumbai

Train (Mumbai Suburban Railway) (Soans, 2014)[9]
Bus
Auto Rickshaws
Taxis
Metro (Mumbai Metro)
Ferry Services
Mono

3.3 Service Providers for Bus

BEST (Brihanmumbai Electric Supply and Transport Undertaking) has a single and double decker buses
Navi Mumbai Municipal Transport (NMMT) operates air conditioned Volvo buses in Navi Mumbai region and some regions of Mumbai
Kalyan-Dombivli Municipal Transport(KDMT) operates buses in Kalyan and Dombivli
Thane Municipal Transport (TMT) operates their buses from Thane to Mulund and Borivali.
Mira-Bhayandar Municipal Transport (MBMT) operates their buses from Mira-Bhayandar to Jogeshwari and Borivali.
Vasai-Virar Municipal Transport(VVMT) operates their buses from Vasai-Virar to Mulund, thane and Bhivandi.

On a daily basis in Mumbai there happens Transport of millions of its citizens by train, road and water. Over 88% of the commuters in Mumbai use public transport. Mumbai has the largest organised bus transport network among major Indian cities.

3.4 The scenario of Visually challenged people in India

Inaccessibility of public transportation in Indian cities for visually impaired as one of the major bottlenecks for social and economic inclusion of such population.

For a significant number of visually impaired persons especially in the developing world, public transport is, often, not a matter of choice but an absolute necessity. It is their sole medium of access to employment, community resources, medical care and recreational opportunities. As per

India’s 2011 census [4], 15 million of the world’s 37 million blind people are Indians and the impairment increases with age. Of these, only 32.8 percent are employed. The lack of means of reliable and safe transportation is clearly mentioned as one of the contributing factors.

Visually impaired represent a large proportion of the entire disabled populace. A third of blind and partially sighted people never use public transport because of the problems it poses. Survey results indicate that improving information access should relieve many of the frustrations that visually impaired people experience when having to use public transport. (IIT Delhi Study)

All the systems that have been proposed have one or more of the following limitations:

- No GPS connectivity in buses of developing countries
- Non availability of sales, marketing or servicing in developing countries
- Unaffordable cost
- Inability to board a desired bus, since multiple buses arrive and line up arbitrarily at random positions at bus stops
- Dependency on electricity or structural support that is not available at most of the bus stops
- Route number display on the front top panel of the bus, makes it difficult for a blind person to identify since there are no audio or any multisensory cues
- Dependency of a visually impaired person on fellow travellers.

3.5 Problems faced in India while navigating

In order to understand in early stages of the project what issues the visually impaired face while navigating, I referred to ‘An Observational Study on Usability Issues in Mumbai Local Trains’by Shikha Agarwal, IDC. (Christian Gold, 2013)[10]

Safety: Establish a consistent information system to present important messages and a clear line communication between commuters and railway (bus in this case) authorities to report mis-happening.

Access: Install environmental supports in compartments to help people board, balance, move, sit and stand inside the buses.

Communication:

1. Present information that is visible, easy to understand and guide people well. The information must be contextualized and presented in a consistent form for ease of understanding by everyone including occasional commuters, people who are less technology savvy and people with low vision and hearing impairments.
2. Offer language choices for independence.
3. Have markers through the bus station for people to make their way

3.6 Current state in Germany

In Germany, the public transportation plays a major role in the context of transportation of passengers. Roughly ten billion passengers use the service every year. Providing mobility to the German population is a part of the governmental basic service. It is strictly coined by the German federal state organisation. This gives a short introduction to the most important transportation systems in Germany, the legal conditions and the circumstances in the city of Darmstadt.

In Germany commonly used transportation systems in public transportation are taxis, busses, trams, underground trains, local trains and intercity trains. Inside cities taxis, busses, trams, underground trains and local trains are in use. The busses are mostly low floor busses to provide barrier free access. When using public transportation in Germany the passenger must buy a ticket at a vending machine in advance to the ride. In busses the passenger can also get a ticket from the bus driver. Normally the ticket is valid from the access to the vehicle until the final destination and can be used for the different vehicles. This means one ticket is valid for a bus, tram and train ride. Bus, tram and train stops are visually signed, so that they are recognisable as a stop. Mostly they are also barrier free, which means they are built on a higher level to provide an easy access to the vehicle and have orientation systems for blind on the ground.

The public transport in Germany is governed by the law “Gesetz zur Regionalisierung des öffentlichen Personennahverkehrs-Regionalisierungsgesetz (RegG)” at the federal level and by county laws at the state level.

Public transport in Germany is mostly a loss business, which is subsidised by government (state, county or city). Therefore, to achieve the best efficiency district councils tender the service of public transport to semi private companies.

Within the city of Darmstadt, the “HEAG Mobilo GmbH” provides the local service with busses and trams. Countrywide regional trains or Inter-City trains are provided by “Deutsche Bahn AG” or other companies. The public transport in Darmstadt is part of the transport association “Rhein-Main-Verkerhsbund (RMV)” which is an association of all public transport companies in the region of Rhein-Main and “DADINA” a local association for Darmstadt and its suburbs.

In the following table statistics about the HEAG Mobilo GmbH are summarized.

Annual passengers	45,1 million
Number of Employees	727
Number of busses	105
Length of the bus network	327 km
Number of trams	48
Length of tram network	42 km

3.7 Darmstadt

Most transportation systems in Germany are claimed to be barrier free. In the vehicle, specific seats close to the doors are reserved for disabled or elderly people. Also, busses normally have a ramp for wheelchair access. The bus, tram and train stations provide an easy access to the vehicle by being on the same level as the door of the vehicle. At the stop orientation systems for blind on the ground are implemented. Nevertheless, there are still many stops not prepared for barrier free access, since the preparation is costly.

For the usage of public transport for disabled persons in the city of Darmstadt a lot of things have been done already. There are orientation systems for blind on the ground, dynamic passenger information screens with voice output at several bus and tram stops and most busses and trams are low floor and therefore barrier free. Nevertheless, these circumstances don’t occur at all bus and tram stops. For the design and maintenance of bus stops the city of Darmstadt is responsible, whereas for the tram stops the HEAG Mobilo GmbH is responsible. There is no statistics about the existing and development of barrier free bus stops. The HEAG states that 56 of its 76 tram stops are barrier free.

4. Primary Research

During the tenure in Darmstadt we worked in a four member team. The team comprised of two German students from Industrial Engineering department from the TU Darmstadt and myself from Interaction Design and another student from Industrial design. We got help to conduct interviews in germany and for understanding of documents revealing the critical issues within the system for visually impaired people.
A three-stage process, involving as much stakeholders as possible was undertaken. First, in a brainstorming session the team itself approached and identified all relevant points of intervention and critical issues while using public transportation.
Second, including transport providers, counties and blinds using a guided telephone interview to reveal the critical issues.
Third, the confirmation of the critical issues in this context with interviews and an on-site field study.

4.1 An Ideal Bus Journey

After brainstorming, the journey that one takes from one destination to the other is considered since there are a lot of steps involved as follows:
Plan the trip (origin/ destination)
Locating origin bus stop
Locating the right bus
Access the bus
Ticketing
Finding a place to stay (sit or stand safely on the bus)
Knowing the current location/ the route of the bus
Getting down the bus
Locating destination

Each of the above steps has its own details and requisites in terms of visually impaired passengers. However, current infrastructure solves only a fraction of the issues and makes enough room for intervention at each level for making the service more accessible for the said population.

There is no such affordable and user validated system which provides the right cues from the bus, helping them in identifying his/her bus of interest before the bus approaches the bus stop. Further the process of identifying the entry door of the bus is integral part of the system. (IIT Delhi)

4.2 Experiencing darkness (Blind Museum)

In order to sympathise with the visually impaired users,the team went to DIalog Museum in Frankfurt. Guided by a blind instructor, we spent 1.5 hours in a dark room in a complete state of blindness. We had to undertake various tasks and navigate around the museum's made-up city.
The Experience gave us key insights such as

- How important the vibrations from environment is
- How the blind stick extends as a limb
- How the sense of hearing takes over with time to compensate lack of vision
- Sense of orientation
- Need of reference points
- Physical cues in the environment
- How to communicate with the environment using the haptic feedback

4.3 Interviews with the transport providers

The interview partners were Mr. Andreas Rathöfer from the council of Soest, Mr. Gerhard Renzel from DBSV (blind association), the leader of the department environment and traffic and Mr. Dirk Kornelius from HEAGmobilo, the coordinator of inDAgo project.
Based on their studies the basic problem in the process of using public transportation is the accessibility of busses, which includes finding the way to the bus stop, finding the right bus and finding the door to the bus. Especially, these problems occur when more than one bus is departing at the same time or the stop has more platforms. In these cases, existing solutions like announcements and guiding cobblestones are not reliable. Thus, the DBSV urges to improve the accessibility to busses in general, to integrate audio sounds of the vehicle/ doors to find bus/ door, a standardisation of all systems in different cities as well as the improvement of eticketing. Additionally, the issues looking up the connection, knowing where the bus departs and knowing where one is while being at the bus are mentioned as issues for blinds.

4.4 Blind Users interview, Darmstadt

1. Further an interview was conducted with 7 Blind people in order to understand
2. From when are you visually impaired x
3. Do you use a smartphone x
4. Do you use any gadgets to assist you in your daily life x
5. Are you comfortable doing everything including navigating on your own.
6. How do you navigate, can you briefly narrate a typical day
7. Have you tried navigating using voice feedback
8. Do you mind wearing a gadget that is visible to other people
9. Are you concerned about the physical appearance of the gadget
10. Try out shear, pressure and pattern
11. Would you mind wearing two
12. Will you be able to navigate if feedback is given on the neck or the temples of your forehead like this
13. Do you like to ask help from other while travelling alone?
14. Do you like wearing glasses while travelling?
15. What is the most annoying thing about public transportation?
16. How often do you use public transportation? Do you think it needs improvement?

4.5 Blind Users interview, Mumbai

An interview was conducted with residents of Mumbai and I did a cluster analysis of the information to understand cultural differences and contextual requirements.

Findings

1. Needs help to find out bus numbers and gets help from people (mostly family)
2. While on a bus route is new, asks conductor
3. Gets familiar with the new route in 3 to 4 days
4. Easy routes, user can find by himself
5. Uses maps to identify bus stop himself (creates his own hacks to use the technology)
6. When no one to identify bus number, misses the bus
7. Conductor or people who know the person help or if they know the person is blind then help is extended
8. There is a need to show people that one is blind, this coordination will help navigation

1. Design Idea : Letting the conductor or the driver know that a blind person needs to board
2. Crossing roads at intersections or while changing busses is difficult
3. Any digging or construction signs are not accessible since information is not known
4. While using talk back it is difficult to keep the phone near ears and the volume has to be low in public spaces
5. Navigation is done through audio feedback from the environment
6. Design idea : Audio feedback needs to be given along with a multisensory feedback

This further led to the focus mainly being on these specific areas which are as follows:

1. **Locating origin bus stop/ platform**
2. **Locating the right bus**
3. **Accessing the bus**

The above mentioned problems are prevalent in both the countries and many blind users of public transportation face issues which restrict their navigation in general

5. System Overview

Based on the secondary and primary research, and the main problem areas further identified as existing in both the countries. It was clear that a system level intervention was required and for the same mainly 3 systems were identified in the overall journey as,

1. User System
2. Platform System
3. Bus System

All of these need to communicate with each other and the user needs to get input from these contextually in order for him or her to navigate.

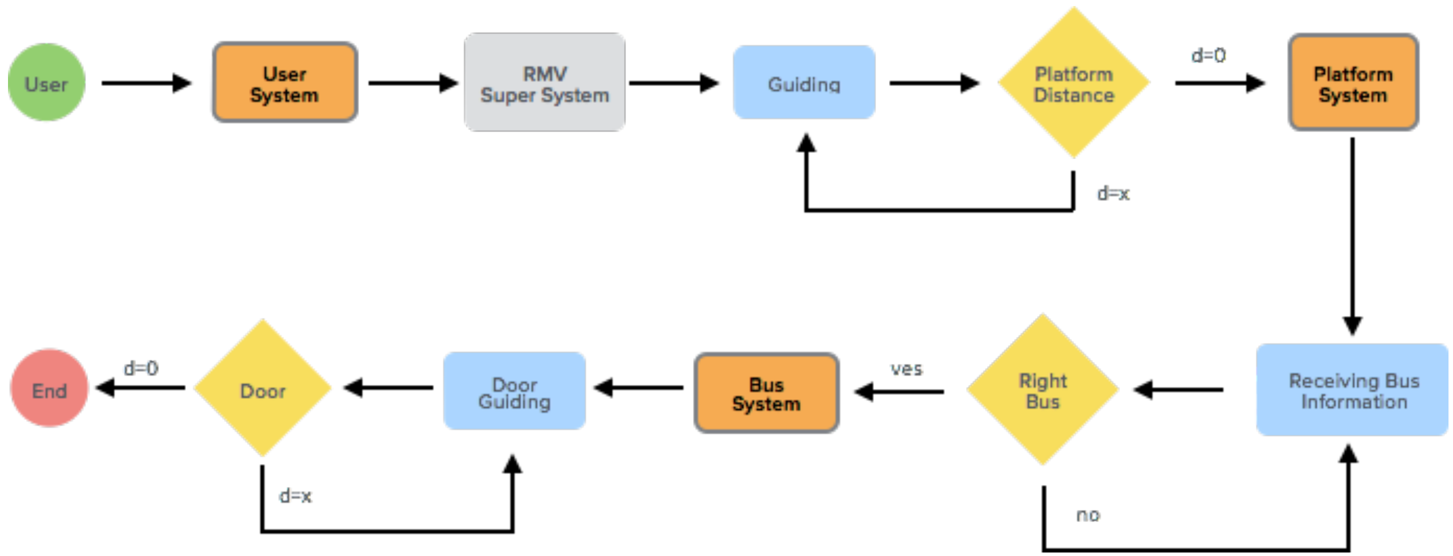

Figure 1

System overview with a Scenario.

In order to explain the system overview, we have made a persona.

User Characteristics:
-Paul Kooper
-Totally blind
-Usually uses public transportation on his own
-Orients with audio and tactile stimulus
-Uses smartphone and blind stick

Figure 2

Paul kooper has these targets on a daily basis:
-Find the stop and the bus safely
-Convenient ride
-Fast orientation
-Be independent

So when Paul leaves from his home to work he goes to a bus stop. The bus stop is in a busy junction of the city. Many buses leave from the same bus stop every day. So it becomes difficult for him to locate his bus stop. The idea is that the bus stand will interact with the device that Paul is using and give him cues.

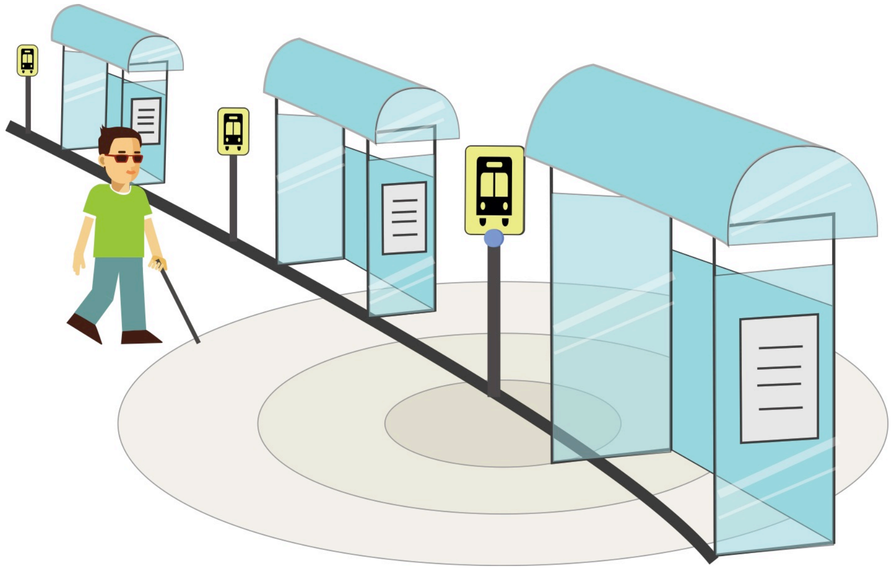

Figure 3

There is a beacon the bus stop and when Paul comes in it's range, He gets signals from the bus stop and navigation feedback on the device on his hand which helps him orient himself in both known and unknown space easily since the signal is pretty accurate even for close proximity navigation. When close within a radius of one meter. Paul can just use his blind stick to confirm if he is standing at the right spot, which will be confirmed by the device, he is wearing.

When Paul reaches the right bus stop, he waits for the bus of his requirement to come. But when many buses come and leave the bus stop, it becomes difficult for Paul to determine his bus by himself.

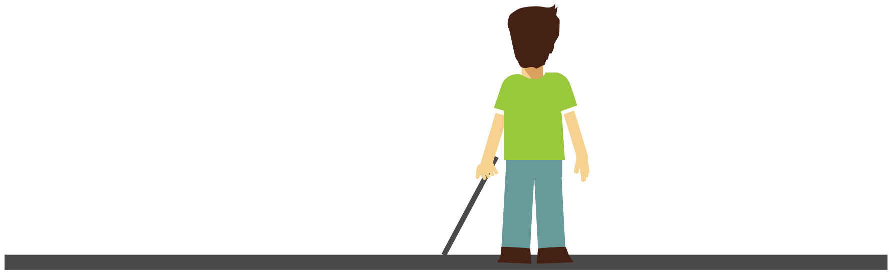

Figure 4

When people are there, he talks to them and inquires about the approaching bus and they also help him board it. But Paul likes to be independent.

So the idea is to inform Paul about the arrival of his bus in advance and prepare him. The device on Paul's hands will give him feedback when the right bus arrives too, thus eliminating the error of choosing the wrong bus.

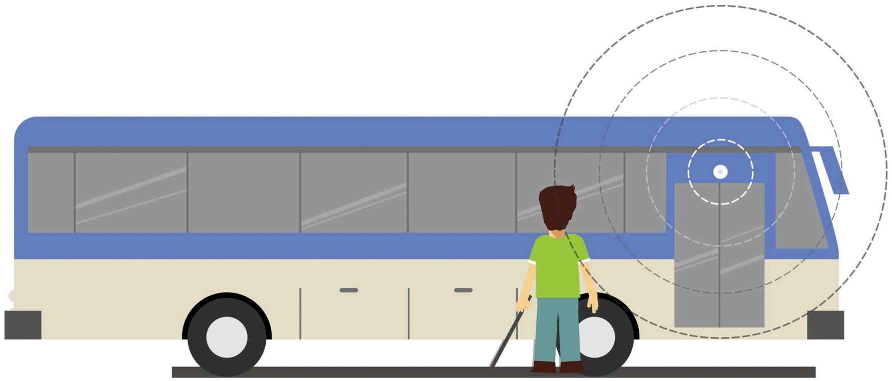

Figure 5

Then when the right bus arrives, there is issue of finding the door, which also needs to be eliminated. The bus always does not halt at the same location or the precise location meant for it. When that happens, even a person with sight finds it difficult to access the bus before it departs. So, in a chaotic junction where Paul is standing, the door also needs to interact with Paul. He gets directional feedback to the door and this helps him access the bus by himself.

6. User Context

Based on the ideation and user interviews a table with user context was created as follows. This is a consolidation of the user and the stake holders along with the environment that could have possible impact on the user.

User and other stakeholder	blind or visually impaired person	-female and male person from the age of 7 (german regulation) -blind or visually impaired -unconfident in unknown territory -often recognizable as blind -commonly on their own -using public transport multiple times per day -collecting information in advance to the ride -sensitive for barriers -use smartphone mainly -orientation with audio and tactile stimulus	
		System	**Hardware**
Targets and work tasks	User targets	-find the stop and bus safely -convenient ride -fast orientation -bus identification -get on the bus safely -be independent	-useful -comfortable -keeping liberty of action -no disturbance of action -durable -inconspicuous -well designed
	System targets	-safe navigation of the user to the entrance	-allow user interaction

		-reliabilty -standardisation -integration and extension of existing systems	-giving safety to the user -easy removable and put on
	Work tasks	-Interaction with the user -Bus stop and bus identification -distance calculation -guiding to platform, bus and door	-support system -calculate necessary processes
System environment	technical environment	-electricity on the bus (partly at the bus stop) -standard hardware on the bus is the ibis-wagenbus (VDV 300) and CANopen DIN EN 13149, slow transmission; GPS-, Bluetooth interface -BLIS Dresdner Verkehrsbetriebe AG -TRIAS new interface for standard realtime information VDV301, ip based -visual, auditive and haptical notification at the bus (partly at the bus stop) -Smartphone available for interaction over: radio-waves, bluetooth, infrared, wifi, GPS -boarding aid (low floor busses etc.) -internet access -cell tower	-smartphone -other aid technology
	physical environment	-barriers -different weather conditions (-20 to 40 degrees, rain etc.) -noises -vibration -illumination -passenger flow (crowd)	-clothes -blind stick -jewelry -(blind dog)
	social environment	-mostly on their own -hectic -availability of contact persons -bus driver & conductor -passenger	

	cultural environment	-acceptance -language	
Equipment	User	-blind stick -blind sign -smartphone -blind dog	

6.2 Requirements

The following table is regarding the requirements for the development of the idea into a prototype. The requirement of the hardware, software, interactions, system and the legal norms are considerend in this table.

Dimension	Nb.	Subdimension	Type	Description	Source
System behaviour	1	independent, convenient and safe navigation	I	The user wants to travel independently and fast to find the bus stop and right bus	
	2	High location accuracy	I	Accuracy of the location should be designed for blinds (< 1m)	m4guide AP110
	3	Signal range	I	20m, because ranges >20m can be covered by GPS	example luisenplatz
	4	Signal strength	W	resilient transmission and stability (e.g. other passengers vehicles)	
User hardware	5	Light, handy and portable	I	The user hardware is used and carried by the user in public. Therefore, is should be handy and light.	m4guide AP110
	6	Comfortable	W	The user will not use the system if it constrains the comfort in using public transportation	m4guide AP110
	7	Unobtrusive to wear	W	The user does not want to stand out as blind	m4guide AP110
	8	Easy to attach/ remove	W	The user hardware should be easily removable and attachable, but meet the requirement of steadiness	
	9	Affordability	W	The price of the hardware that is used by the blind passenger must be affordable for people from India and Germany.	
	10	Reliablility	I	The hardware is used in traffic situation where an increased risk of incidents with other traffic participants exists. Therefore, the system and the battery lifetime must be	m4guide AP110

				reliable.	
	11	Not hand wearable	W	The hardware should not be worn in the hands of the user due to theft and safety in case of slump	m4guide AP110
	12	One hardware	W	Due to comfort and price issues the should only be one hardware	m4guide AP110
	13	Resilient	I	Touchable for tactile feedback	
	14	Low risk of loss and theft	I	The product should have a low risk of loss and theft	
Interaction Requirements	15	Two-Sense-Principle	I	The barrier-free usage of public transportation requires that people with sensorial restrictions can receive information. Therefore, always two senses should be addressed simultaneously.	DIN 18040-3:2014-12
	16	Consistent design of guiding systems	W	The design of the system should be consistent to existing solutions that blind passengers know the meaning of the stimulus.	Interview DBSV, DIN 18040-3:2014-12
	17	Visual, Audio and Tactile feedback	I	Seeing, Hearing and Feeling is for a safe navigation inalienable.	DIN 18040-3:2014-12
	18	Visual Feedback	W	Good Contrast (K>0,8 - Luminance - DIN 39975), legible writing, bold letter	DIN 18040-3:2014-12; DIN 32975
	19	Audio Feedback	I	High relation between useful signal and disturbance noise	DIN 18040-3:2014-12
	20	Voice interaction	I	Voice entry and voice output, high volume	m4guide AP110
	21	Tactile Feedback	I	The signal must be recognisable. Sensation with fingers, hands, guiding stick, feet, minimum 2mm height	DIN 18040-3:2014-12
	22	Vibration	I	Vibration feedback is demanded by blind people	m4guide AP110
	23	Continuous feedback	W	Geiger counter for continuous feedback is the recommended solution	m4guide AP110

	24	Self-description	W	The user hardware is easy to understand and enables an easy and intuitive input of information.	DIN EN ISO 9241.10
	25	Expectation-compliant	W	System reacts as the user would expect.	DIN EN ISO 9241.10
	26	Individualisation	W	Changing between input and output signals and the user interface.	DIN EN ISO 9241.10, m4guide AP110
	27	Fault-tolerance	W	Autocorrect and avoidance of mistakes	DIN EN ISO 9241.10
	28	Controlability	W	Several function: Back, Repeat, Delete, enough break between commands	DIN EN ISO 9241.10
	29	Appropriate for tasks	W	Just provide the user with the necessary information (e.g. default values or often used funtions)	DIN EN ISO 9241.10
	30	Faciliation of Learning	W	User improves usage speed while using the system	DIN EN ISO 9241.10
	31	Minimal disturbance of passengers or environment	W	The system shouldn't disturb other passengers or the other environment.	Interview m4guide
	32	Minimal interference on other senses and signals	W	The user shouldn't be disturbed in his important senses (e.g. no additional tactile feedback on the stick)	
	33	status feedback	W	The system should give feedback that it works and in case of an error it should give a warning.	
Offered Information	34	Location of the platform and the bus stop	I	Warning in advance and when the user finally arrives at the platform	DIN 18040-3:2014-12; VDV
	35	Busnumber of the vehicles departing from the platform	I	Busnumber of all approaching and departing vehicles from the platform	m4guide AP820
	36	Delay	W	Warning when the selected bus is delayed	m4guide AP820
	37	Information for change of busses	W	Getting necessary information about changes of busses	m4guide AP820

	38	Location of the bus door	I	Guiding the way from the platform to the bus door	Interview DBSV
	39	Information about the distance	I		m4guide AP110
System Architecture	40	Integrability into existing infrastructure	I	The system for the bus and platfrom must be integrateable in the vehicle or the platform, especially existing technology.	
	41	Combability with Interfaces	I	The system requires the compability with existing systems (like RMV, TRIAS) ,especially concerning the interfaces between them	
	42	Interaction with Stakeholders	W	The interaction between the user and the busdriver or conductor may improve the comfort of usage	m4guide
	43	Evaluability of the system	W	The system and its impact should be evaluable.	
	44	Modularity	W	The system exist out of different modules. Functions can be activated or deacivated on demand	
Miscellaneous	45	Legal Conformity	I	The system and the usage must comply with relevant legal issues.	Personenbeförderungsgesetz BO-Kraft; Straßenverkehrsordnung; ISO 612-1978; TÜV
	46	Impairment on health	I	The user must not be impaired on health or lead in dangerous situations.	
	47	Data Security	I	The data and the privacy of the system user must be secure.	GG, Bundesdatenschutzgesetz
	48	Acceptance	W	Acceptance of the product by the society and the individual user, especially concerning the German and Indian market as well as the target groups.	
	49	Cost Effectiveness	W	The system should be produced sustainable and market profitable.	

7. Ideation

7.1 Wearable

Based on the system overview, an initial idea was to create a wearable as the system that the user has on him or her. For the ideation many factors were considered and compared. The place to wear and the feedback that the device has to give to the person wearing are a few of the considerations made. The following sections have these considerations in tabular format for convenient comparison

Table for categorisation for development of Idea

Technology	**Feedback Mechanism**	**Sensor**	**Place to wear**	**Gadget/Existing Examples**	**Wearables**	**Possible solutions**
Bluetooth	Voice, Noise	Visual	Hand	Smartphone	Wrist band/Watch	Blind Stick with navigaton
Wifi	Visual	**Auditory**	Wrist	Smartwatch	Shoes/Vibratng Soles	Guiding Dog/Bot
GPS	Touch/Tactile	Vestibular	Head	Fitness bands	Glasses	Segway
Infrared	-Vibration	Gustatory	Arms and Hands	New Gadgets	Collar(neck)	Google glass sorts
Radiowaves	-Thermal	Olfactory	Neck	blind stick	Glove	Wearable dress
	-Shear motion	**Somatoviszeral (tactile)**	Leg/Feet		Clothes	
	-Texture/Pattern	Motoric (kinesthic)	Ears			
	-Puncture		Body (others)			

Pros and cons of different feedback

Feedback	Pros	Cons
Voice, Noise	-demanded by DBSV -much information within short time -feeling of interaction with a person -blinds are used to it -sense enhances when blind (echolocation improves)	-problem of understandability -disturbance of other important information (e.g. missing of car sounds) -cannot replace vision
Visual	-much information within short time -seeing of items -depth of focus	-some might not see at all
Touch/Tactile in general	-tactile spatial acuity enhances when becoming blind	-difficult interaction design (blind has to learn)
-Vibration	-demanded by DBSV -blinds are used to it	-disturbance of other important information (e.g. missing of feedback of blind stick)
-Thermal	-no disturbance of other feedback	-needs time to recognize, high contrasts needed -not much information can be transferred
-Shear motion	-clever for showing directions	-not approved yet (product has to be developed)
-Texture/Pattern	-commonly used by blind	-needs time to be readed, realized
-Puncture	-independent of other feedback mechansim	-pain

Types of Receptors on Skin

Meissner Corpuscle - Stroking, fluttering
Pacinian Corpuscle - Vibration
Merkel Disc - Pressure, texture
Ruffini Ending - Skin stretch
Hair tylotrich, Hair guard - Stroking, fluttering
Hair-down - Light stroking

Pressure on skin
Pressure and skin stretch take longer to return to rest state, which means the impact is felt longer. They return to rest state as long as it does not cause any pain.

Pressure can be felt in 3 dimensions
>as a point of pressure (where force of a mass on the body is focused at one point, such as a digging corner of a solid form),
>as a line or band of pressure (a digging edge or belt),
>as a planar pressure (such as a circumferential compressive garment like a girdle, or as force spread over a contoured surface).

Texture is an array of pressure and the dynamic feedback is texture

Comparison of places to wear

Hand			
Wrist	>Comfortable >But when folded slightly, the feedback accuracy is lost >Easy to operate (even while moving) >For sighted it is comfortable to use the display at a distance that is convinient >Traditionally used to wrist watches so it is easy to adapt	>Sweat >for voice feedback need additional device	(Frank, 2015)[11]
Head	>Increases proximity to ear and eyes - helps to combine senses >Step by step navigation with confirmation		[11]
Ears (heads + ears like head mounted display)	>Very less disturbance as this body part is like a tunnel >Best for feedbacks thta involve sound >Can also keep hands free >Can answer calls >can shake head to answer a call and just talk >For giving multiple feedback (auditory, vibration etc.) this reduces the number of wearables >The device remains hidden >Works for step by step navigation	>Invasive >Less comfortable to wear for a long time >The moisture from the ear canal spoils the electronics (needs great care while manufacturing for long run)	(Know, 2006) [12] [11]

Pros and Cons of different places if wearable

	Pros	Cons	Types
Head	The proximity to our eyes makes glasses the most natural device for tasks that require our sense of sight.		>Head up display (google glasses) >Display with sound (VR devices)
Ear	>discreet so remains unnoticed >continuous instructions	>The smaller the device the smaller is the battery and this reduces its lifetime	>BTE Hearing Aids; These devices are worn with the hearing aid on top of and behind the ear. All of the parts are in the case at the back of the ear and they are joined to the ear canal with a sound tube and a custom mold or tip. >ITE Hearing Aids: These are custom made devices, all of the electronics sit in a device that fits in your ear, they come in many sizes including CIC (completely in Canal) and IIC (Invisible in Canal). >RIC RITE Hearing Aids: These devices are similar in concept to BTE hearing aids, with the exception that the receiver (the speaker) has been removed from the case that sits at the back of the ear. It is fitted in your ear canal or ear and connected to the case of the hearing aid with a thin wire.
Wrist bands / watches	>Disappears in a while (forget that one is wearing it)	>certain material and weight can cause sweat rash or muscle fatigue	

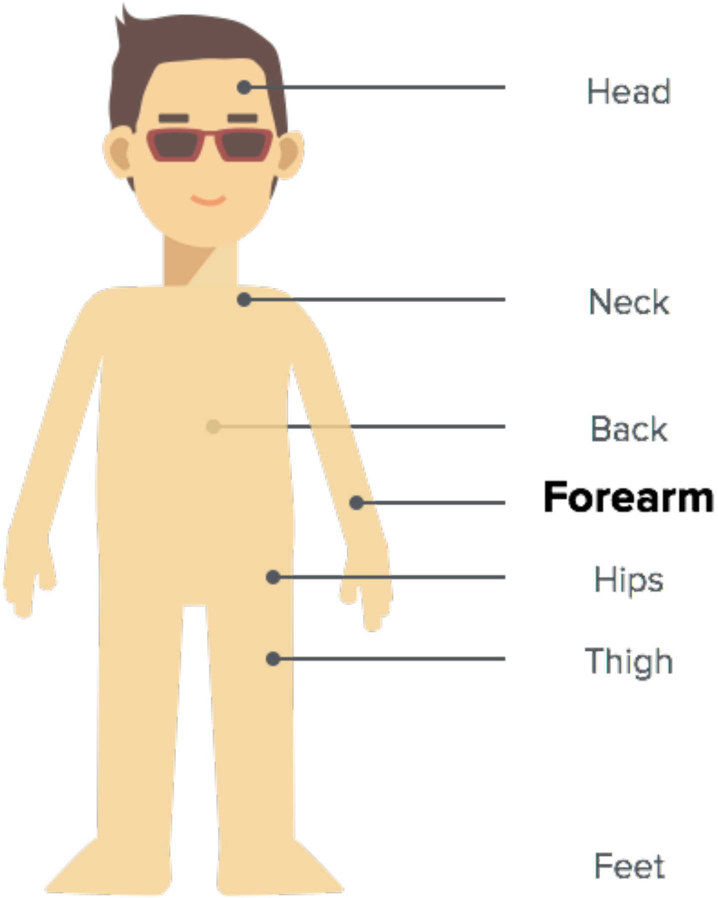

Figure 6

For the placement of the device, a placement study was done. As identified in this research (Design for Wearability; Francine Gemperle, et al. (1998)), by Carnegie Mellon University, we identified these places on the human body were a wearable is convenient when a person is in motion. Since the person needs to wear it while walking, all the body fluidity has to be considered and the areas identified are shown in figure 4.

Based on considerations of ease of device operation while in motion outdoors, the shortlisted areas where neck, hips and forearm. For the conclusion of the placement position, we asked them about their convenience in the interview conducted with 7 blind users.

Most people felt forearm as the most convenient with the feedback being vibration supported with audio feedback. Thus we proceeded forward with an armband for the wearable with vibration and auditory feedback.

Prototype

After the required placement and feedback study, it was decided to generate ideations for placing the device on forearm and build prototype accordingly. The theoretical framework of the device is given in the following image. As noticeable, the entire system is driven by a smart phone which acts as a processor. The smart phone takes information of the door location of the bus from the beacon fitted on the door top, and transfers it to the device. The wearable device then converts the information into a more legible and understandable manner and gives it to the user in form of auditory and tactile feedback.

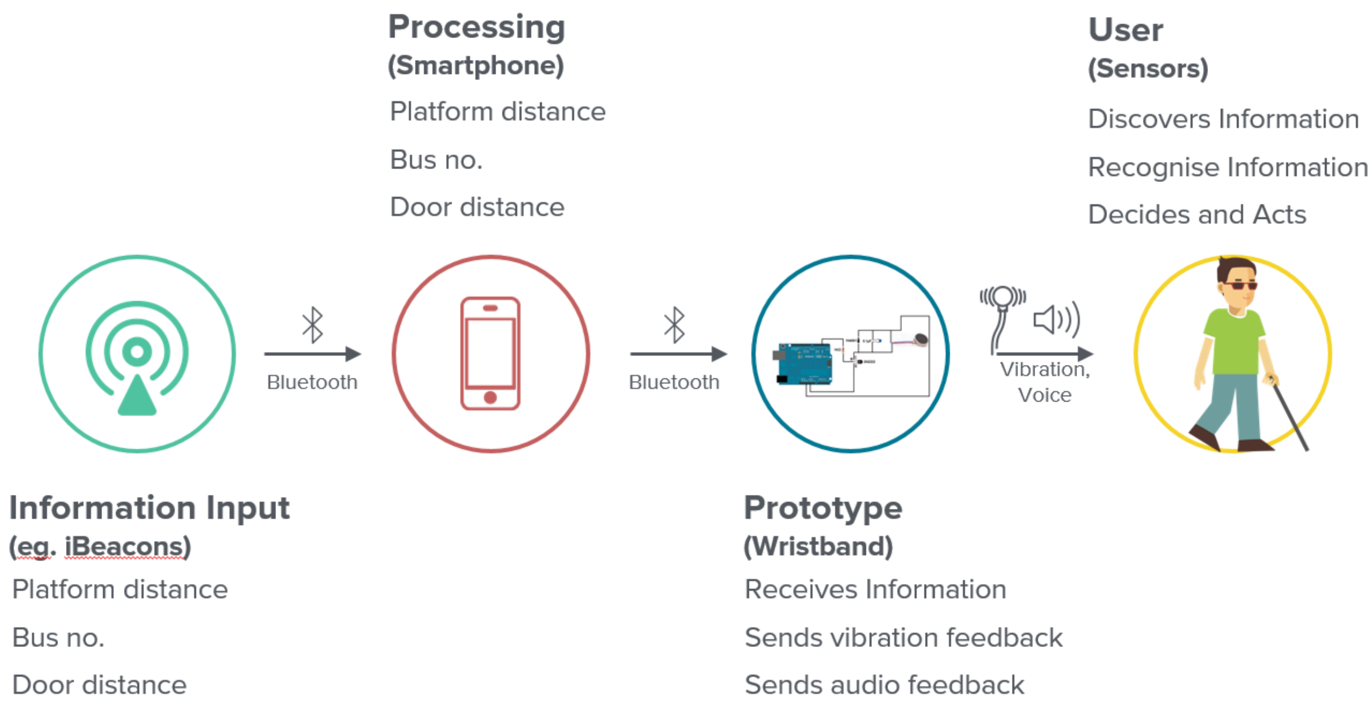

Figure 7

Prototype sketches

The various ideations for the arm band or the vibratory feedback device were also generated, the following image shows a few of them. The ideations generated were majorly focussed on understanding the aesthetics, usability and wearability of the device, based on the current trends in wearable technology. The shown sketches below are only schematic and conjectural, however, the final outcome at the end of the design process might be completely different in aesthetics but conceptually similar to these.

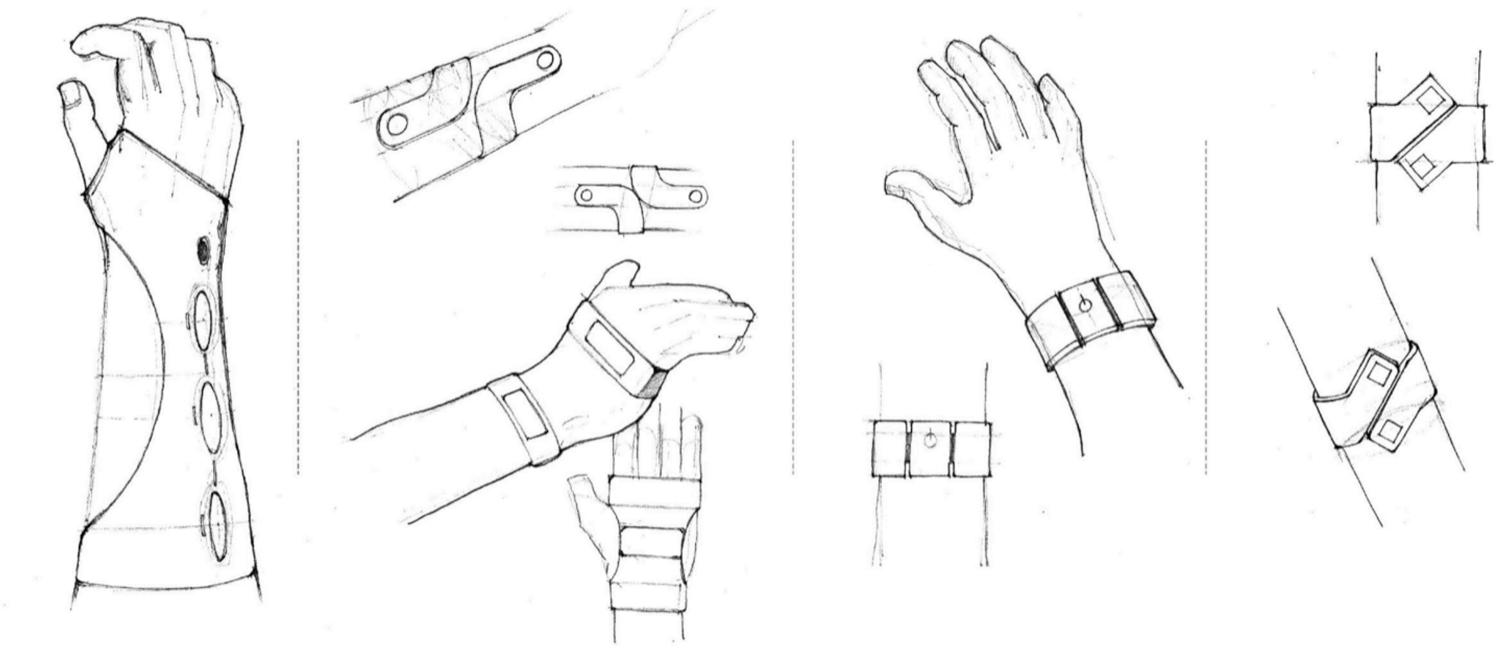

Figure 8

8. Evaluation

The first prototype was made by buiding a simple glove which gave feedback in the form of vibration on inner forearm above wrist. The wearable is in the form of a glove for ease of wering during testing to keep the vibrator fastenend in place. The feedback was generated by a wired controlled that we built using gates to give 5 types of vibration combinations.

The test was to figure out if vibration as a feedback will work and how would a person be able to use it with his/her blind stick. The experiment was controlled and performed in a safe place for this intial test. Each perticipant had to start from an unknown point and walk using the cues given in the form of vibrartion and locate an object (in this case a bag).

Figure 9

The Feedback was in rhe form of a Geiger counter where the intensity of vibration increases based on the proximity. There were 3 stages in the geiger counter and for 10 meters, 5 meters and 1 meters. Whenever the participant felt that they were lost, they could recalibrate the device and the device would help them orient back by continously vibrating, when the participant faced the right directions. After a first few attempts, voice feeback was also added to the device.

A total of 10 participants volunteered to try the device, out of which 7 were male and 3 female. They were given training to understand the vibration feedback. Then while each participant used the device to locate the object various observations were made. Each session was followed by a brief interview. The interview was constructed to focus on improving the idea hence, comfort, ease of navigation, pattern recogniton, vibration results of the evaluation is in figure 10.

Remarks by user

- Better feedback for wrong direction would help
- Feedback when moving away from target is important
- Calibrate when stick in right direction and give a feedback
- Voice feedback is hisghly recommended
- Audio feedback in the form of certain alerts would help orient.
- Calibration vibration and the rest of the feedback vibration coincide.The first vibration need not be so intense.
- The device felt like a co passenger but auditory signal was difficult to understand in crowded area.
- There could be different vibration for right and left

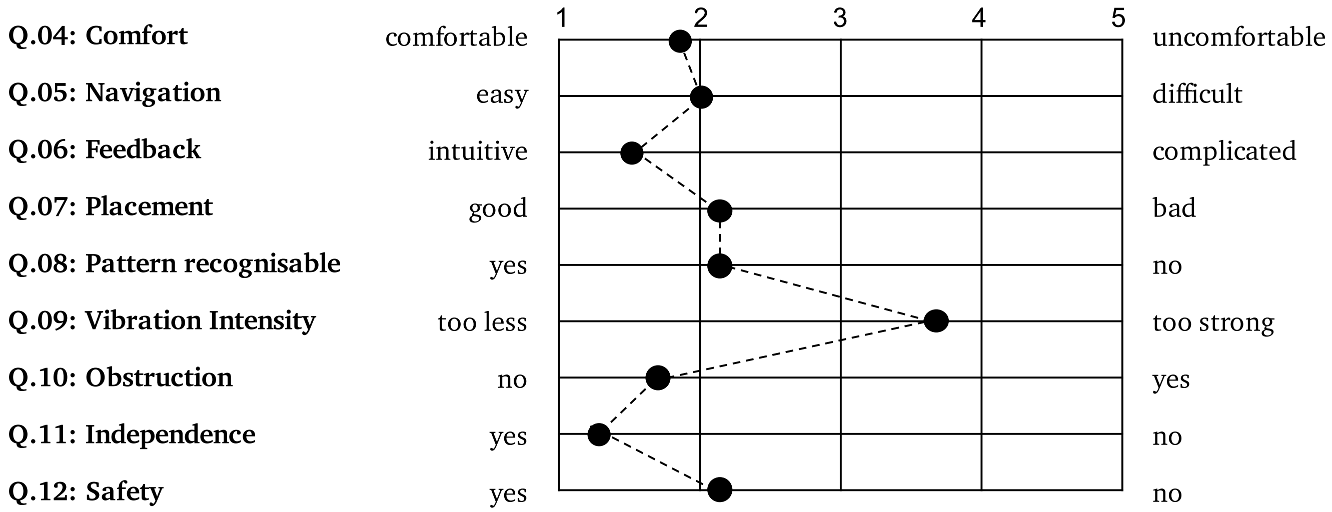

Figure 10

The average of the quantitaive data from the likert scale has been plotted to understand the general reception of this wearable. The wizard of oz test helped us understand that a device on the forearm will not hinder a person's regular actions but they need a considerable amount of pattern contrast to be able to understand any change while using it out there in the world where there are many natural vibrations and noise from the environment itself.

Part 2

9. Experimental analysis of different navigation systems

The most common application that people use today on a day to day basis for anavigation is map. The principle behind most of the common maps is crowd sourcing and this method has succesfullly contributed to making of maps with rich information and also keeping the maps updated. India has a large population and crowd sourcing works well to generate date and convert it into useful information for everyone.

Using this same structute, the idea is to create 'community maps' for visually impaired where the main contributors of the maps are people with vision impairment and followed by immediate friends and family as a starting point to collect data. Maps when used in accessibility mode gives directions and updates current locations (user positions) in areas with good satellite signal but this fails in urban areas. It becomes difficult to rely heavily on a system that updates with respect to the currentl position specially when one major feedback reveiving sensory is not in use.

So in this case additional information about the physical details of references and landmarks along with other sesnsory based information could be highly useful which when structured and timed properly can assist them better. But again most of the aids are made by sighted people in good intention to help visually impaired people navigate but is it actually asisting them or is it detrimental needs to be investigated. Some description of routes by sighted people makes it difficult for a visually impaired person to use for navigation [16] (Nicholas A, 2005). Further to see if the descriptions by visually impaired people assisted others in navigation an interview was conducted in the early stages before designing the experiment.

Along with this sensorial information that is given as descriptions, if this information is provided at the right time during the embarkment of a journey, a visually impaired person might be able to orient onself better in environmant and use his/her own judgement assisted by this information to further navigate. This does not make a person highly dependant on the aids. One way of doing this is by using spacial cues in the form of Binaural audios as done by ARGUS project where cues are available in 3D space in the form of stereo audio for predetermined routes. [14] (Spiller, 2014)

While navigating to unfamiliar places there is an anxiety which can be reduced by providing the information during the planning phase[15] and most Visually impaired people plan their journey before starting, which was gathered in my observations and interviews as an intersting finding. Thus the informatrion must not only be available while navigating with respect to the location as it makes one reliable and not survey the environment [15] (Thora Tenbrink, 2013). 3D sound of the environment can be available during planning istelf, similarly sensorial descriptions along with routes taken by other visually impaired travellers here can be effectively used to assist other people.

9.1 Egocentic vs Allocentric Spactial Processing

An important aspect to be considered for autonomous navigation by the blind is deciding between routes and survey while giving them directions. The current way any of the sound cues given to predeter mined routes either by ARGUS or to the cyclist will create a natural tendency to make the visually impaired egocentric. 'If egocentric representation of space is the perspective that blind adopt by default it does not mean that they will not be able to adopt to allocentric representations'[15].

Egocentric representations is mainly routes which are sequentially one after the other and then when one f the turns is missed the whole route is sort of jumbled up and the person is lost. When all paths in a city are known and the system baased on gps is quickly able to re-route if deviation detected is allocentric but not in its true sense I feel since the machine here is empowered but not the human using it. If the device or the system fails, the person is stranded.

The true essence of allocentric spcial processing is letting the person be empowered and be able to develop a sense of survey. By giving details about the environment that they have to navigate in, the loss of one cue allows them to quickly form another based on their knowledge about the environment.

9.2 Binaural Audio

‘The word binaural means “both or two ears”. Human audition is in most of the cases binaural and this term is used to refer anything concerning two ears. To understand what binaural hearing is, it is necessary to understand how our ears differently perceive sounds. The sound waves with their directionality and their amplitude make our ear/brain system locate sounds using our two ears.

Duplex theory describes sound reaching the two ears as Interaural Time Differences (ITD) and Interaural Level Differences (ILD). While ITD represents, in terms of time, the path difference from the sound source to each ear, the ILD is produced due to shadowing of the head’, [14] (Spiller, 2014)

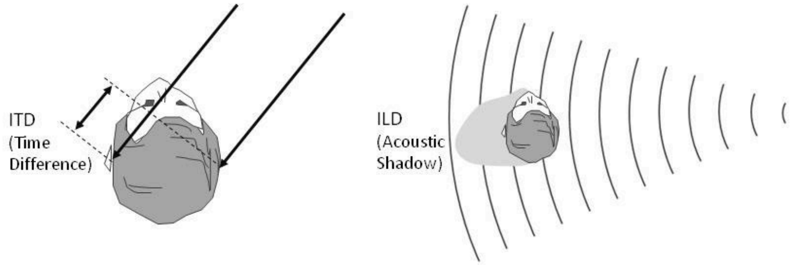

Figure 11 : ITD and ILD. Interaural Time and Level differences [14]

This allows a person to perceive the direction with the depth and the experiment will use this to see how a participant is able to adjust and orient in an environment given he/she is trained with the 3D spatial sound of the environment.

9.3 Goals

This project aims at comparing traditional maps made by sighted people with talk back with istructions combined with sound of specific landmarks and 3D binaural environment audio to see which one has less cognitive load on a user and allows navigation with less error deviations. The idea is to observe whether these methods can create an allocentric spatial perspective in the users and with time the unavailability of any cues should also not be a problem since the information is embeded in their memory.

‘An allocentric representation of space would allow one to mentzally explore the environment, as opposed to physically explore it, and would consequently allow for reorganization of itineraries such as alternative routes or shortcuts’ [15].

10 Related Work

A good number of projects, experiments and products have been developed by using talkback and haptic feedback for GPS based navigation [17] (James R. Marston, 2006) but a discussion on why it is difficult for a visually impaired person to navigate like a sighted person so this can be used by other designers and developers of a product has been done [13] (Michele A. Williams, 2014) since most of the current maps or aids are developed by sighted well wishing people who might have not considered about the whole new world the mental model they have [16].

Further using GPS for the location and ginging directional cues using sound in the form of 3D and binaural audio are around the corner over the last few years [18] (Matthijs Zwinderman, 2011), where the 3D sound cue is given for cyclists while riding to reduce cognitive load of reading boards. In [19] (Lee Tae Hoon, 2015), the authors have conducted experiments to conclude the best resolutions required for a binaural audio recognition when it is rendered in stereo back to the listeners and they have localize the source of the sound. They claim that navigation is a continuous localisation task and that binaural audio is immersive enough for navigation. Binaural provides 360º immersion when reproduced and the resolution in the axiz of a person's nose is highest.

11 User Studies

The user research was conducted in three stages. The first being interviews with visually impaired partivipants which happened both in India and Germany as mention in section 4.5 of part 1. This was followed by focus group observation with interviews. For this part the visually impaired participants were observed after consent while travelling using bus or train, while walking to the bus station and other landmarks. Based on this and secondary research as mention the previous sections, experiments were structered and finally a third round of evaluation happened in multiple environments using different selected methods (describe later). For the experiments, one of the methods was to observe and analyse how visually impaired navigated with instructions from other visually impaired people. For this part, after slecting the location, a few(mention how may later) contributors were chosen to navigate and describe the paths to be used for the latter part of the experiment.

The focus group observation had 9 participants out of which 4 were working and 5 were students. It had 5 male and 4 female participants. 4 of these participants while accessing bus or trains. I travelled with 2 participants in bus and with one in a share cab. They were asked to take the common mode of transportation they take after work and were just accompanied. All the participants participated in a discussion later.

Key Findings

- Locating a Bus stop (place) is the most difficult thing, when on their own.
- Details about shops around them helps to confirm.
- People make friends with cobbler, vadapav wala to get help.
- They understand only cues like 'walk straight till the sugarcane juice stall, then turn left'. Not when in terms of meters or step count.
- The visually impaired have a mental map of places in their memory
- Their cues help other visually impaired easily understand the route to navigate autonomously.

Classes of contextual information used by visually impaired participants

Visually impaired participants described their bus stations and the routed they take to them using informtation which is understood by other visually participants. This information is difficult to use for navigation by the sughted counterparts just like the vice versa exists [16].

Class of contextual Informantion	Example	% used by Visual Impaired
Directional	Left/right, north/south	75
Structural	Road, monument, building	75
Environmental	Lake, tree	37.5
Textual-structural	Cheda bookshop, Laxmi restaurant	25
Textual-area/street	JVLR, Rajiv Chowk	12.5
Numerical 1	First, second	62.5
Numerical 2	100 m. 45º	12.5
Descriptive	Steep, tall, red	25
Temporal/distance	Walk until you reach...or just before you get to...	100
Sensory	Sound of cars passing or smelling a bakery	87.5
Motion	Bus passing, doors opening	50
Social contact	Asking people for help	100
Small Shops	Tea stall, Cobbler	75

Based on how their reserachers classified the information, I also have classified my interview with the participants so as to understand their language while describing the path they take on a daily basis to other visually impaired participants.

12 Design Idea (clean up after experiment)

There is a idea for substituting the results of the experiment conducted and creating a sstem. The objective for the same are as follows

- A navigation product or a layer on Google maps as a filter for accessibility, which guides visually impaired with instructions and 3D sound along tracks and also help them plan before hand
- To make this system a crowdsourcing platform that both sighted and visually impaired people can access to benefit or contribute just how the maps now have grown in developed and developing countries.
- Provide updated data through from people who have taken the path or came to know through someone to help them decide new routes
- Based on predefined information provide them new routes and alternatives to take and also provide visually impaired friendly landmarks

Conclusion (have to update)

Designing for visually impaired is one such field of design which has been a point of discussion for decades and still the solutions are debateable. This doesn't mean that the solutions are ineffective but that it's such a critical and special human condition that it's not easy to predict the success or acceptance of any product. And hence, this makes it more interesting to work on such projects. The unique finding during the project was that these two contrasting cultures of India and Germany still face difficulties in finding solutions for such population similarly which made the problem even more challenging. The common issues faced by visually impaired people both in India and Germany were well understood and brainstorming and detailed discussions were carried out in order to come up with something which would be suitable for both the contexts holistically and can adapt to both the systems.

Till this stage, conceptually the device has been designed and discussed with visually impaired people in Darmstadt. The response to the device has been quite positive and motivating. Thus, the further step would be to actually build a prototype or proof of concept and try it in a real life situation, with actual users. This part of the project would be done in India where the other two German students would come to India and work upon building the prototype with the Indian students. The prototype then would be evaluated by conducting evaluation exercises and inferences would be drawn. Furthermore, improvements would be made to the device and then it would be tested again. This cycle of evaluation, rebuilding and testing would be done multiple times (preferably three, while looking at the time constraint) in order to ensure the robustness in the device. And once the evaluations are done, it is expected the device would be able to work conceptually in a real life scenario, in both the contexts.

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Appendix

User studies with visually impaired users from Darmstadt

Question:	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6	Person 7
Gender	female	male	male	female	male	female	male
Age	30	45	30	48	51	56	64
What is the percentage of your visibility?	3%	0%	2%	0%	0%	1%	100%
For how long were you visually impaired?	24	45	30	48	33	19	0
What your preferred sense to replace visual sense with?	Hearing	Hearing and touch	Hearing and touch	Hearing	Hearing and touch	Hearing and Smelling	Hearing and touch
Do you use a blind stick?	Sometimes	Always	Sometimes	Always	Always	Sometimes	Always
Do you use a smartphone?	Yes	No	Yes	Yes	No	yes	yes
Which operating system do you use?	IOS	IOS	IOS	IOS	Android	IOS	0
Do you use earphones while travelling?	No	No	No	No	No	No	No
Do you use any gadgets to assist you in your daily life?	Yes	No	Yes	Yes	No	Yes	0
How do you usually navigate?	Independently	Independently	Independently	Independently	Independently	Blinddog	0
How do you navigate,	Smartphone,	Smartphone,	Smartphone,	Smartphone,	Smartphone,	Blinddog	0

when you leave the house?	preparation, asking people	preparation, asking people	preparation, asking people	preparation, asking people	preparation, asking people		
Have you tried navigating using talkback?	Yes	No	Yes	Yes	Yes	0	0
Would you like to wear a device which can guide you?	0	No	Yes	Yes	Yes	Yes	0
How do you prefer the device to give you feedback?	0	Vibration	Vibration	Audio and Vibration	Audio	Vibration	Has to be tested
1) Forearm, vibration	0	yes	yes	yes	no	yes	yes
2) Guiding stick, Vibration	0	yes	no	yes	no	no	no
3) Hips, Vibration	0	no	yes	no	yes	no	yes
4) Neck, Pressure, Speaker	0	no	no	no	yes	yes	yes
5) Smartphone applied to guiding stick, Vibration, Speaker	0	no	yes	yes	no	no	no
Contact:	Patty (Blind museum)	Klaus Meyer	Erdin Ciplak	Brigitte Buchsein	Karl Matthias Shäfer	Miss Roth	Michael Damm
		BSBH	Blindlife	BSBH	BSBH	p61@live.de	
		6915059672	Facebook	06171/91144	1602624886	15755093061	61544903