BUS IDENTIFICATION SYSTEM FOR THE VISUALLY IMPAIRED:
EVALUATION AND LEARNING FROM PILOT TRIALS ON PUBLIC BUSES IN DELHI


Assistive Technologies group, Indian Institute of Technology, Delhi, Hauz Khas, New Delhi, India.
assistech.iitd@gmail.com

Abstract
Many studies have established the need and utility of accessible urban transport system for visually impaired persons. However, most public transportation systems, especially in the developing countries, are not accessible and this is often listed as one of the major bottlenecks for social and economic inclusion of visually impaired. OnBoard, the bus identification and homing system has been developed to address these needs. A radio-frequency based, completely user-triggered system helps the user first to identify the route number and then enables the user to board the bus using the auditory cues from the entrance of the bus. This study discusses a quantitative evaluation of real-life field testing that helps assess the effectiveness in enabling independent boarding of public buses. Further, it also describes specific requirements that got identified during the trial phase. We have also discussed the design improvements which enable the installation of the bus module in varying buses of different service providers. Objective of our study has been to generate empirical evidence that would facilitate the move towards incorporation of such a system in public buses globally. The positive feedback received confirms that the system enables independent access to the visually impaired without compromising on their safety.

Keywords: accessible urban transport, visually impaired persons, bus identification, homing system, independent boarding

1. Introduction
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 [1], 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.

In U.K, a survey of 800 people by RNIB showed that about 40% of visually impaired people relied on others to drive them around. Crudden et al. [2] identified the lack of transport system as the second greatest barrier (negative employer being the first). A study by Golledge et al. [3] identified perpetual dependence on sighted assistance for external travel a leading cause of frustration for a large number of visually impaired people. An unfriendly public transport system that is not adapted for their special needs reduces their options forcing them to settle for less-productive local employment opportunities. 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.

We hereby present the results of a study conducted during the completely supervised trials in public buses of Delhi. This has involved a) setting up a successful collaboration with DIMTS, an organization involved in operation of a large number of buses in the city, b) Installation of the system on public buses and the corresponding design improvement done to make the system robust, c) completely supervised pilot trials and d) validation of the system in form of user feedback. This is a step towards enabling us to conduct completely unsupervised trials on a larger scale.
2. Literature review

In the past there have been similar research efforts to develop embedded devices to alleviate problems. The Talking Signs identification system [4] consists of infrared (IR) transmitters incorporated in the destination panels of buses that transmit route information. Since, an IR beam is highly directional, the visually impaired user must point the handheld receiver towards the transmitter on the bus which is difficult since the precise bus location is unknown.

In the PAVIP Public Traffic system [5], RFID transponder tags are placed on bus stops that transmit information about the route numbers of buses approaching. However, the system does not give the user an active choice to select between multiple buses that may be present at the bus stop and the problem of boarding the bus remains unresolved. Step-Hear [6], a RF based system comprises of a transmitter and a small activator. The system does not provide any means for the user to choose between different transmitters and does not handle the case of multiple activators and transmitters within range of each other.

Broadcasting bus [7] is a GPS based system announcing the bus number upon arrival at the bus terminal. A pilot survey showed that the smart bus stops are not adequate when equipped only with the voice reporting system because voice information is difficult to decipher when many buses simultaneously arrive at the same terminal.

A study carried out at university college of Ireland, explored issues concerning access to public transport for people with sight loss [8]. The study conveyed that providing audible announcement at different stages of boarding, actually improves their access to public transport. But, this research does not focus on how a visually impaired could independently identify and board his/her desired bus of interest. Moreover, there was no such mechanism that could guide a VI person in identifying the entrance door of the public transport especially when buses stop in a wide range at a bus stop.

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

1. No GPS connectivity in buses of developing countries
2. Non availability of sales, marketing or servicing in developing countries
3. Unaffordable cost
4. Inability to board a desired bus, since multiple buses arrive and line up arbitrarily at random positions at bus stops
5. Dependence on electricity or structural support that is not available at most of the bus stops
6. 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 cues
7. Dependency of a visually impaired person on fellow travellers.

To the best of our knowledge, there is no such affordable and user validated system which provides the auditory 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. This system is so designed to address the above limitations in addition to meeting the specific requirement of public bus service providers. Study of challenges faced by visually impaired in accessing public buses and design and user testing of an affordable bus identification system had already been addressed. The initial prototype and design was discussed in an earlier publication [8]. Technical design and small scale testing was reported in [9]. Systematic exploration of the bus-seeking behaviour of visually impaired was well documented in [10]. However, a real-life field trial followed by a systematic evaluation was yet to be studied. This paper represents our system’s success in performing completely supervised user trials and evaluation of the findings from limited scale pilot trials in public buses of Delhi, India.
3. System design & subsequent modifications for installation

The following sections introduce the bus identification system and the various design modifications from previous version for on-field installation.

3.1 System description

The system comprises of two modules: (i) User Module and (ii) Bus module. Once the user hears a bus approaching the bus stop, he presses the Query Button on the User Module, transmitting a RF signal to all buses in the vicinity. Each bus responds to the User Module by transmitting its route number. All numbers received are sequentially read out by the user module. User may proceed to select the desired route number by pressing the Selection Button which triggers a voice output from a speaker located at the entry of the selected bus. This acts as an auditory cue and assists in moving towards the entry door of the bus. The system allows for flexibility to customize operation according to user specific bus usage patterns, saving time and effort. Using an auditory interface, the user can store the route numbers of commonly boarded buses (called a restricted set) in the user module. This allows the user to concentrate only on relevant bus numbers.

- Auto-Query mode (optional): The device automatically scans for buses at regular intervals and notifies the user. This eliminates the user’s need to continuously press the query button.

- Pre-selection mode/Restricted set: In case the user is interested in boarding one particular bus, he or she can store its route number in advance and use the selection button to check if the desired bus is present at the bus stop. This allows the user to skip the query phase and immediately check for the desired bus.

A number feeding unit was developed to program / change the route number of a particular bus module (with a unique id) as and when required. This operation can be done remotely within a range of 30m without the necessity of having a physical wired connection.

3.2 Design improvements and modifications for installation

In this section, we detail the modifications that reduced the maintenance cost, improved the system efficiency and made it more robust. The goal of the modifications was to maximize usability with minimal changes to the permanent infrastructure of buses and bus agency support structure. The bus module required design modifications and customizations in order to allow installation in varying buses being used by different organizations we have dealt with. In this phase of trials we ensured no modifications to the existing bus infrastructure was required. The overall design of the bus module is divided into two parts: (i) Speaker and Antenna module installed on the railings of the bus, and (ii) Under-the-Seat Module comprising of the battery, amplifier and control circuits. The long wire antenna connectors enable installation of the antenna at a suitable place (top of the speaker box) for better communication.
Figure 2- System installation showing (a) outside long-distance view of the mounted module (b) Close-up of the mounted module (c) Inside view of the mounted /clamped speaker module (d) Battery module kept beneath the seat.

For easy maintenance and timely indication of system failures, a LED grid has been incorporated to indicate successful charging in progress, sufficient battery power and a healthy functional system. The environmental noise is observed to be very high in some cities compared to others. Thus, there was a need to keep the volume of the loudspeakers adjustable. A variable potentiometer has been provided so that the sound level can be adjusted manually. Our previous version of the bus module weighed almost 8 kg, thereby, making the deployment of the system difficult, leading to difficulty in maintenance. The current speaker module which hangs on the window railings only weighs 2 kg and the under-the-seat module weighs 3.5 kg. Further, the modules are much more robust considering that they are fabricated on a single printed circuit board, while the various circuits have been embedded.

The charging mechanism in the previous version of bus module comprised of a transformer and a rectifier, which made the system bulkier. In the new bus module, the charging port has been integrated along with the other circuitry and is shifted to the exterior of the box. This has eliminated the need of the transformer and the rectifier, thereby easing the charging. Additionally, a relay has been added to bring down the power usage when the device is in sleep mode. The improvement has brought down the charging requirement from 1 day to 7 days.
4. Study design & field trials
The field trials were conducted on five public buses running on a major route in Delhi. Twelve users cumulatively attempted 100 boardings over the three months from July to September 2014. In this study, we have recorded, analyzed and presented the observations of thirty boardings.

4.1 User enrolment
Twelve visually impaired users were enrolled in the trials from three blind schools and associations in New Delhi. There were 9 male and 3 female users from an age group of 19-45 years with prior bus boarding experience. Table I illustrates the composition of users according to age. Owing to work and other commitments, most users were only available part-time during the trial period.

Table I-User enrolment data

<table>
<thead>
<tr>
<th>S.No</th>
<th>Organizations involved</th>
<th>Number of participants</th>
<th>male</th>
<th>female</th>
<th>Age band(in years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Saksham Trust</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>19-35</td>
</tr>
<tr>
<td>2</td>
<td>National Association for blind (NAB)</td>
<td>8</td>
<td>7</td>
<td>1</td>
<td>22-45</td>
</tr>
<tr>
<td>3</td>
<td>Center for Blind women</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>19-26</td>
</tr>
</tbody>
</table>

Figure 4- Population distributions according to, from left-(a) age (b) years of bus use independently.

4.2 Collaboration with public bus operator
We have collaborated with the Delhi Integrated Multi Model Transit System Ltd. (DIMTS), an organization that operates a large number of buses in Delhi. They gave us access to buses on a major route in Delhi, thereby enabling us to conduct field trials in a real-life scenario for the first time. The
system was installed on five public buses on a major route no. 507. These stops are at least separated by 600m and appear in the map below.

![Map of bus route and stops](image)

Figure 5- The route of bus no. 507 and the stops where the trials were conducted are highlighted.

4.3 Understanding current bus access behaviour
Semi-structured questionnaire-based interviews enquired about the present dependence on public buses and interaction with fellow commuters at the bus stop. It focussed on the problems which they face and features they would like to be incorporated in an assistive device. Interviews lasted 30 minutes and centred on extent of use, preferred time of day, need for help from a sighted guide for bus boarding and any pre-planning required. Further they were asked about how they seek assistance from fellow sighted travellers at the bus stop which helps them to identify and board buses. They were asked to recount instances when they are successful in obtaining help as well as when they were refused help, misguided, harassed or ridiculed. The interviews were conducted with 12 visually impaired users who took part in the training.

4.4 Training and introduction to the system
Proper hands-on training session followed the questionnaire-based interview mentioned above. The entire training program was divided into six simple activities for easy learning and understanding by the user. The activities are listed in table 2. Each of the activities is planned for a step-by-step introduction to the system, understanding the benefits and usage of the device.
Table II-Training activity description.

<table>
<thead>
<tr>
<th>Activity No.</th>
<th>Title</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>An overview</td>
<td>Familiarize trainee with the OnBoard device and its functionality</td>
</tr>
<tr>
<td>2</td>
<td>Holding the user module</td>
<td>Learn the correct techniques for holding the user module</td>
</tr>
<tr>
<td>3</td>
<td>User module buttons</td>
<td>Locate and identify the use of different buttons and switches</td>
</tr>
<tr>
<td>4</td>
<td>User module battery charging</td>
<td>Learn how to charge the user module</td>
</tr>
<tr>
<td>5</td>
<td>Customized modes of operation</td>
<td>Learn different modes of operation like auto-query and default mode</td>
</tr>
<tr>
<td>6</td>
<td>Real time usage of the module</td>
<td>Operating the module in a natural controlled environment</td>
</tr>
</tbody>
</table>

The sessions were mostly interactive providing ample opportunities to the users to clear their doubts by seeking clarifications from the trainers. The training also included practical sessions where users were initially guided in use of the device in controlled environments and later moving into open unfamiliar environments. On-Board device comes with a user manual and a trainer’s handbook facilitating the user in properly using the module.

4.5 Observation of user interaction on public bus stops while boarding buses
Two sighted buddies accompanied every user to bus stop and recorded the parameters while user tried to board the bus. They were required to ensure safety as well as record observations on the user’s boarding experience. Apart from establishing the functionality of the device, the study also focuses on the conduct of drivers, conductors and fellow co-travelers at the bus stop and the success rate of boarding with the system. Users were called for the trials based on their availability and during this time slot, those buses with system installed were tracked via GPS. Based on this information, users accompanied by sighted buddies were stationed at the bus stops across the route. Kindly note that the buddies only played a co-ordination role and were instructed not to interfere with the user while operating the system.

---

1 In Delhi most buses have GPS installed though this is not common across the country
4.6 Outcome variables
For on-field observations, we recorded data in the form of functional parameters which are of use to determine the effectiveness of the system.

a) **The approximate distance when bus is queried successfully** indicates the distance between user and bus when the user module first speaks out the number of the bus. This provides information of when the user is notified of the incoming bus and his preparedness to board.

b) **Approximate Distance of user from Bus when it stops** gives the measure of the distance the user has to navigate between the place where he is standing and the front door of the bus which he has to board. It is also indicative of the real life conditions in India as the buses do not stop at the designated place owing to road conditions/traffic.

c) **Number of Queries done / help sought** is a measure of the number of times user needs to press query, (and he hears “no buses”) before the speaker reads out the numbers of the buses. This gives us an estimate of the user’s ability to sense an approaching bus. A higher value would indicate that the user is not able to distinguish the distinct sounds of the engine of the bus as it enters the bus stop.

d) **Successful Number of Queries (Failure when "no buses")** gives indication of the working of the query system and to determine whether the bus numbers of nearby buses are received and sequentially spoken out by the user module.

e) **Number of Selections Done (Number of times the user needs the audio cues)**-After identification and selection of a desired bus, the bus loud speaker calls out the bus number. The user has to navigate the distance between him and the bus and if required can trigger the sound multiple times.
f) Successful Boarding (Yes / No); If No, Reason for failure to board—This gives the success rate of boarding after a series of trials and helps us understand any difficulties the user is facing in accessing the system in real life settings.

A post-trial feedback session was undertaken to validate whether the system actually helped the users eliminate their problems of boarding a desired bus. The feedback received from the users on using the system in identifying their desired bus and its entry door through audio cues was immensely valuable.

5. Results

5.1 Current bus access behavior

The questionnaire analysis and the observation yielded overwhelming evidence that visually impaired people face major difficulties in accessing buses and heavily rely on sighted assistance, which is often unreliable. Boarding buses independently impacts their safety as they have to rely on engine sound or touch the bus body to reach the bus door. During the study, users mentioned that seeking help sometimes leads to misbehavior and misguidance and impacts personal interactions.

Table III - Histogram showing the different aspects hampering the user’s access to public transport and the number of users.

<table>
<thead>
<tr>
<th>problems users face in accessing public transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>hesitant in asking for help</td>
</tr>
<tr>
<td>problem in identification of bus number</td>
</tr>
<tr>
<td>people respond irritantly/argue</td>
</tr>
<tr>
<td>use of white cane in locating door</td>
</tr>
<tr>
<td>problem in moving towards bus door</td>
</tr>
<tr>
<td>boarded a wrong bus/missed buses frequently</td>
</tr>
<tr>
<td>person forgets to inform/confusing remarks</td>
</tr>
<tr>
<td>problem in case of multiple buses</td>
</tr>
<tr>
<td>had injury while boarding?</td>
</tr>
<tr>
<td>reach late to destination</td>
</tr>
<tr>
<td>high level of anxiety</td>
</tr>
</tbody>
</table>

5.2 Key Usage Scenarios Observed

The following are some key notable features of the system that were identified in the field trials.

a) Multiple users- As the bus module responds to more than one user module via RF communication, more than one user can board the bus simultaneously.
b) **Identifying the entry of the bus** - As the speaker is located at the entry of the bus, users are able to navigate towards the bus door without having to trail the bus body with hand/white cane.

![Figure 8 - Identifying entry of the bus door. (Left)- User, after activation of speaker, starts to move towards the door. (Right)- User successfully reaches the door before co-passengers huddle around the entrance.](image)

c) **Re-orientation of path to traverse** - In case the bus has moved some distance owing to traffic congestions etc. the user can trigger the speaker output from the bus multiple times and hence orient himself towards its entry. This eliminates the need of relying on sighted assistance.
d) **Multiple bus scenario**- Visually impaired users are able to identify an incoming bus by the characteristic engine sound. In case multiple buses enter the depot, identifying their bus of interest is a problem owing to the dynamic nature of the traffic and commuters congestion. The OnBoard bus identification system helps the user to keep track of the location of the bus by triggering voice output from the bus speaker.

Figure 10-Multiple bus scenario. From left- (a) User has queried the bus and moves towards another bus in front of him. (b) He re-orientates himself after listening to the speaker sound from the bus, (c) On his way to board the bus; the user was trailing the bus body for some distance.

e) **Bus stopping far from stop**- In some public buses in Delhi we found that drivers do not bother to stop the bus at the designated place. This leads to the need for more distance to be travelled by the user, thus leading to a higher probability of missing the bus. As the speakers output is audible from a distance of 30m, the bus identification system assists in navigation towards the bus. This output further informs the driver and conductor that a person with special needs wants to board their bus.

Figure 11-Bus stopping at large distance. From left-(a) User successfully queries but the bus passes by the bus stop, (b) User has activated the speaker of the bus and starts moving towards the entrance, (c) Successfully boards the bus.
f) **User alerted in advance**- As this system is completely user triggered, it enables the user to query the bus well in advance of the bus stopping at the bus stop. Thus, while being seated at the bus stop, the user can be alerted about the approaching bus.

![User alerted](image)

Figure 12- User alerted .From left- (a) User seated at the bus stop rises after hearing the desired route number from his user module, (b) User selects and hears the output from speaker of the bus, (c) User successfully boards.

5.3 Measure of system effectiveness in improving bus boarding

a) **Range of operation**

Although the RF communication range between the user and bus module during testing was determined to be 30m, in real life condition this is considerably reduced owing to metallic barriers etc. hindering the performance of the antenna. Moreover the user realizes the bus entering the bus stop at a distance less than this threshold value. Hence in most cases the query is not done till when the bus is at a distance of 10m. Practically a distance of more than five meters gives sufficient time for the user to board after taking into account the average duration of bus stopping at the bus stop. In our study, in a total of 73.3% cases the user was able to query the bus successfully at a distance greater than 5m.

![Approximate distance](chart1)

Approximate distance when bus is queried successfully

![Distance from the user](chart2)

Distance from the user when the bus stops

Figure 13-Successful query distance

Figure 14-Distance when bus stops.

b) **Distance of user from the bus when it stops**

This statistic shows that 67% of times the bus stops at a distance greater than 3m. Thus it confirms the requirement for suitable navigation guidance for the user to identify the entrance door.
c) Number of queries done
In order to query the bus in timely fashion it is essential for a user to sense the bus while it enters the stop. As shown in the graph below, in 66% of the cases the user has to do 1-2 queries expecting a bus in the stop when the desired bus was at a far-off distance. This shows that the user is able to sense a bus entering the bay area of the bus stop.

![Figure 15: No. of queries done](#)
![Figure 16: No. of selections done](#)


\[
\begin{align*}
\text{Queries done} & \quad \text{Selections done} \\
\text{No. of queries} & \quad \text{No. of times} \\
0 & \quad 0 \\
1 & \quad 0 \\
2 & \quad 1 \\
3 & \quad 2 \\
4 & \quad 3 \\
5 & \quad 2 \\
6 & \quad 1 \\
7 & \quad 0 \\
8 & \quad 0 \\
9 & \quad 0 \\
10 & \quad 0 \\
11 & \quad 0 \\
12 & \quad 0 \\
13 & \quad 0 \\
14 & \quad 0 \\
15 & \quad 0 \\
16 & \quad 0 \\
17 & \quad 0 \\
18 & \quad 0 \\
19 & \quad 0 \\
20 & \quad 0 \\
\end{align*}
\]

\[
\begin{align*}
\text{Frequency} & \quad \text{Frequency} \\
0 & \quad 2 \\
1 & \quad 1 \\
2 & \quad 0 \\
3 & \quad 2 \\
4 & \quad 1 \\
5 & \quad 0 \\
6 & \quad 0 \\
7 & \quad 0 \\
8 & \quad 0 \\
9 & \quad 0 \\
10 & \quad 0 \\
11 & \quad 0 \\
12 & \quad 0 \\
13 & \quad 0 \\
14 & \quad 0 \\
15 & \quad 0 \\
16 & \quad 0 \\
17 & \quad 0 \\
18 & \quad 0 \\
19 & \quad 0 \\
20 & \quad 0 \\
\end{align*}
\]

\[\text{Figure 15- No. of queries done} \quad \text{Figure 16-No. of selections done}\]

d) Number of selections after locking the preference of bus
In order to navigate safely to the bus door, the user may need to hear audio cues repeatedly from the bus as he might be disoriented or the bus may have moved some distance since it was last queried. In 3 cases the user was able to board the bus without triggering the speaker output more than once. This shows that the speaker functions as a guidepost and the user can navigate his way to the bus door by triggering select multiple times. In 37% of cases, selections were done twice before boarding. An interesting case was of partial visual impairment, where the device was required in order to identify a route number but not for navigating towards the bus entry.

e) Successful boarding
During the trials, a total of 12 users cumulatively attempted 100 boardings. Of these 94 were successful and six were not. On each occasion the users were successful in correctly identifying the desired bus. In spite of identifying the buses correctly, on six occasions the user could not successfully board. The major reasons identified for the misses are:

a) The buses not stopping at the specified location, b) Buses entering the stop simultaneously one behind the other, c) the driver not stopping at all or stopping for a very short duration.

![Figure 17: Successful boardings of individual users](#)
5.4 Testimonials

Mr. Sanjay says “I have been using the bus ID system from the last two months on the 507 route and find it immensely helpful. Once after college I was approaching the bus stop and heard a bus go past me. I wanted to know which bus it was and pressed the query button on my device. It responded giving me feedback and I was able to activate its speaker, thus being able to board the bus. The long range of communication between the remote and the bus is very helpful in preparing to board the bus once I identify it. Few of my friends also have been trying out the system and we are absolutely thrilled. We hope the system will be implemented on public buses throughout Delhi in the coming years.”

Ms. Babita has this to share “This system is a very important tool in identifying buses in places where there is no one around the bus-stop whom we can ask. We have to wait for someone to approach and this system being an accessible independent system is very helpful. In the trials I was fairly successful though a few times it so happened that the module was not functioning even though I got input from the hand-held module. In future I expect that the system would not have these system level failures.”

Mr. Leon says “The system is extremely helpful for us in gaining independent access to public buses in Delhi. Further the device which is designed to fit in my hands is also very ergonomic and easy to use. The speaker’s clarity is good and I was able to activate the speaker from a distance. Ideally I want the user module integrated with mobile thus eliminating the need to carry a separate device. I am looking forward to see the next phase of the project and would like to be actively involved in the project.”

Mr. Samuel has given the following inputs: a) the system has been very helpful in determining the bus position which was a huge challenge. The reason this is more complicated is because the buses do not stop at specific location. In case of high traffic-density areas like metro stations, the location of the bus stops itself becomes challenging and leads to more confusion. (“metro bus stops mein bohat confusion hota hain”). He is also able to access the bus number of the particular bus which he is interested to board and thereby he does not need to ask other commuters which can lead to confusion. The speaker’s location at the front of the bus allows him access to the front door but sometimes he needs to board from the back door too—with the present system he is able to identify the bus which is making him more confident in boarding buses.

Mr. Feroz gave us feedback about the systems utility in identifying the route number which becomes a huge challenge in cases where there are few people at the bus stop. He also shared the difficulty in locating the entry of the bus and the hazards in trailing the bus body with white cane. “As the speaker is strategically located near the entry of the bus I am confident about the direction in which I am moving, though I might still take help from commuters to keep a safe distance from obstacles and avoid collisions. Though the voice output from the speaker is good, the voice cracked sometimes and this led to confusion sometimes. The user module can be made smaller so that it can fit in one’s pocket effortlessly.”

Mr. Sukhdev informs about the difficulty in accessing bus numbers in a crowded bus stop.“asking commuters is sometimes not comfortable and it often leads to conversations about the work we do, in which we are not interested.” Even if the bus is identified correctly they have to rely on assistance for guiding through the traffic and this leads to confusion. “If there is delay in approaching the bus, it sometimes leaves from the bus stop. The OnBoard system is very useful in accessing the buses and identifying the location. The speaker is very audible and it leads to the bus door. During the trials I had observed that the connection between the modules was not established and hope that the success rate will be more in subsequent phases.”

---

2The names have been changed to keep the users anonymous
6. Limitations

a) System limitations
Any research study of this nature, covering a wide spectrum can only be representative, leaving scope for further investigation. It is our responsibility to share with our readers, the major constraints under which the present investigations have been conducted. As presented in our previous research, the system functioned very well during lab and field testing on university buses. There were no issues regarding system failure both electronically or mechanically. But deploying the system on public buses of Delhi, revealed some of the manufacturing defects pertaining to robustness. Due to high noise levels at a few bus stops convinced us of the need for better amplification audio which has now been incorporated. The user module has a projecting antenna which was deemed inconvenient to some users.

b) Study limitations
The following limitations pertaining to the field trials have been observed which need to be catered to.

i) During peak hours, a heavy rush was observed which made it difficult for users to de-board from the front gate of the bus. Frequent collisions were observed near the front door.

ii) Due to time pressures of private bus operators, bus drivers were frequently observed not stopping the bus at the designated bus bay. This leads to other vehicles overtaking the bus from the wrong side which hampers user movement as well as safety.

![Figure 18](image)

Figure 18-Main hindrances for easy access. Figure showing from left (a) User colliding with commuter due to heavy rush. (b and c) Traffic obstructing path of user for boarding the bus.

7. Conclusion
The work presented is an essential building block for our next goal of conducting completely unsupervised trials involving more buses and users. As part of our first attempt at conducting completely supervised trials on city buses, the results have been satisfactory for both developers as well as the consumers. A success rate of 94 boardings out of 100, when seen in conjunction with the reasons for failures is encouraging and validates the effectiveness of bus identification and homing system in making public transport accessible to visually impaired people. Further, we would like to share with our readers that the work provided the essential footing for us to successfully collaborate with BEST, a public bus operator in Mumbai who has permitted us to conduct larger scale unsupervised trials in their city buses.

8. Acknowledgement
We are thankful to the users who spared their precious time in validating the system installed on the public buses and in responding to our questionnaires, a contribution which resulted in the collection of valuable information. DIMTS, the Delhi Integrated Multi-Modal Transit system support by providing us access to the buses under their coordination is gratefully acknowledged. We are also thankful to the Assistech team for providing valuable support and resources without which the project may not have been possible.
9. References


