USER TRIGGERED BUS IDENTIFICATION AND HOMING SYSTEM:
MAKING PUBLIC TRANSPORT ACCESSIBLE FOR THE VISUALLY CHALLENGED

Mehra Dheeraj[1], **Singh** Vaibhav[1], **Paul** Rohan[1*], **Garg** Ankush[1],
Agarwal Chinmay[1], **Sharma** Vasu Dev[1], **Dhakar** Sanjay[1], **Arora** Pawan[1],
Balakrishnan M[†], **Paul** Kolin[1], **Rao** P.V.M[1], **Manocha** Dipendra[2]

[1]Assistive Technologies Group
Department of Computer Science and Engineering,
Indian Institute of Technology (IIT), Delhi,
Block II-A, Hauz Khas,
New Delhi - 110016
India

[2]Managing Founder Trustee
Saksham,
Dakshineshwar Building, Hailey Road,
New Delhi - 110001
India

[*] **Corresponding Author:**
Rohan Paul, Email: rohan.cosmos@gmail.com

[†] **Project Director:**
Prof. M. Balakrishnan, Email: mbala@cse.iitd.ac.in

[‡] **Additional information on authors:**
Dheeraj Mehra, Vaibhav Singh, Rohan Paul and Ankush Garg are co-inventors of the system; Chinmay Agarwal and Sanjay Dhakar contributed to the electrical design; Pawan Arora contributed to the mechanical design and Vasu Dev Sharma contributed to the controlled trials during their bachelors and masters research at the Indian Institute of Technology (IIT) Delhi. They are presently at Citigroup Ltd. (India), Netapp Pvt. Ltd. (India), University of Oxford (UK), University of California (USA), Ecole Centrale des Nantes (France), IIT Delhi, University of Arizona (USA), IIT Delhi and IIT Delhi, respectively. Since graduation, they have been associated with this project in voluntary and individual capacity.

SUMMARY

The bus transport system is seldom tuned to the special needs of the visually challenged. Identification of buses arriving at bus stops is difficult because route numbers are only displayed on the number plate. Moreover, a number of buses arrive together and line up arbitrarily at bus stops. Even after identification, it is difficult to navigate towards the bus and board it as the physical location is unknown.

Approach

- Use of wireless radio-frequency technology to identify route number of buses present and approaching a bus stop. Assisting the users navigate towards the bus by providing auditory cues emanating from the entry of the bus.
- Installation of the system on university buses and conducting field experiments with potential users under normal traffic conditions.

System Design

The system comprises of three modules: (i) *User Module*, (ii) *Bus Module,* placed in each bus and (iii) *Programming unit*, to change route numbers at the depot. Once the user hears a bus approaching the bus stop, he or she presses the *Query Button* on the User Module, transmitting a RF signal to all buses in the vicinity. Each bus responds by transmitting its route number. All numbers received are sequentially read out by the user module. The user selects the desired route number by pressing the *Selection Button* which triggers a voice output at the entry of the selected bus. This acts as an auditory cue and assists in moving towards the gate of the bus. The system allows 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 by filtering out the undesired ones while querying. The modes of operation available are:

- ***Auto-Query mode (****optionally with a restricted set****):*** The device automatically scans for buses and notifies the user.
- ***Pre-selection mode***: 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.

Experimentation

In order to evaluate real life applicability, system prototypes were installed on two university buses and tested with four visually challenged bus commuters at bus stops in New Delhi under normal traffic conditions. The success rate in boarding desired buses was observed to increase as the experiment progressed. Additionally, trials were conducted within campus with twenty users. Localization studies helped us verify the high responsiveness of visually impaired to auditory cues.

Conclusions

Reliable access to bus transport system is essential for enhancing socio-economic opportunities for the visually challenged. The system is entirely user-controlled (without any driver involvement) and ameliorates the anxiety of boarding the right bus. The system is language-independent, requires minimal modifications in the bus and would also benefit senior citizens and individuals with low vision. Projected cost of the user/bus module is **under 25 USD** each.

PURPOSE OF THE STUDY

For nearly all of the 45 million blind people and 314 million visually impaired people worldwide, public transport is the only viable mobility option. **Eighty Seven percent** of the world's visually challenged live in **low-income countries** where a majority of them are poor and cannot afford private transport on a daily basis [1]. The problem is often compounded by the fact that they are forced to be dependent on sighted assistance for mobility. Using public transport which is not friendly often compels them to compromise their productivity as they tend to opt for local employment opportunities [2].

A barrier-free transport system is a precursor for providing the visually challenged **equal opportunities for education and work.** Accessing the public transport system is difficult for the visually challenged as it is seldom tuned to their special needs of orientation guidance and timely route information through a perceptible medium. In many contexts, especially, crowded public transport systems in India and other developing countries, accessing public transport is difficult for the visually challenged due to the following reasons:

- In public buses, the route number is displayed on the front top panel of the bus. While a blind person can hear a bus approaching the bus stop, he or she **does not know its number** and is unable to board the bus.

- Occasionally, a visually challenged person relies on a fellow traveler to identify the bus. This creates **dependence** on others and is difficult during non-office hours and at less-frequently used bus stops where the person might be **alone**. Sometimes, the conductor calls out the route number. But, this is **unreliable** and gives little time for boarding the bus.

- It is commonly observed that a number of buses arrive together and line up arbitrarily at the bus stop. Thus, even after identification the user **cannot navigate** towards the bus since he or she is unsure about its physical location.

- In **developing countries**, a majority of the bus stops consist of a single shed with no power supply. In some cases a bus stop may not be a structure at all, but a place next to an important building or a landmark. Hence, placing an **announcement device at the bus stop is not feasible**. Even if the device is battery powered; battery replacement and safety against theft are a challenge.

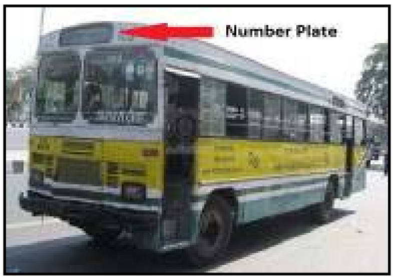

Figure 1: Problem in accessing public transport: The user at a bus stop (left) can hear buses arriving (right) but cannot read the route number displayed on the number plate and is unsure of the bus entry.

In the past there have been ***similar research efforts*** to develop embedded systems to alleviate similar problems, as identified above. The Talking Signs identification system [3] 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 challenged 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 [4], RFID transponder tags are placed on bus stops that transmit information about the route numbers of buses that ply through the bus stop. The user pre-selects the bus number of interest and is given a cue when the bus arrives. 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 problem of boarding the bus remains unresolved. Further, the system is expensive and unaffordable for a large number of users in less developed and developing countries.

Step-Hear [5], a RF based system comprises of a transmitter and a small activator. Installed at strategic locations, the base sends out continuous signals. When the activator, held by the user, is within range of the base, it vibrates and beeps. Pressing a button on the activator triggers a pre-recorded voice message from the base. However, the system does not provide any means to the user to choose between different transmitters and does not handle the case of multiple activators and transmitters within range of each other.

All systems currently available possess one or more of the following limitations: (i) unaffordable cost (ii) non availability of sales, marketing or servicing in developing countries (iii) unsuitability for complex unstructured traffic and bus stop conditions in developing countries where multiple buses arrive and line up arbitrarily at random positions (iv) dependence on electricity or structural support available on bus stops.

To the best of our knowledge, there are no systems functional in developing countries, which constitute 90% of the visually impaired population in the world. The project aims at developing an **affordable** system for developing countries with the following specific objectives:

- To design and implement an affordable user enabled system to obtain the route number of buses approaching a bus stop.
- To assist the user in boarding the desired buses by enabling him navigate towards the entry.
- To install the system on university buses and conduct field experiments with potential users under normal traffic conditions.

MATERIALS AND METHODS

We developed a novel, radio-frequency based, user controlled, bus identification and homing system for the visually impaired that assists in identifying route numbers and boarding the desired bus. Preliminary design ideas were presented by the authors in [6]. The system design process was user centric. A sustained interaction mechanism was established with a **focus group** of 20 visually challenged bus commuters aged 24-52 with varying degrees of blindness at the National Association for the Blind, Delhi. The feedback from the focus group was incorporated at each stage of the project starting from problem formulation, conceptual demonstration to prototype evaluation stages. Next, we present the salient features of the system.

1. System Description

The system comprises of three modules: (i) *User Module*: A handheld device carried by the user, (ii) *Bus Module*: A module placed in each bus and (iii) *Route Number Programming unit:* A device used by an authorized person to program route numbers for each bus module. There are two stages of operation: (i) *Query stage* and (ii) *Selection and Tracking stage*.

1.1 Stages of Operation

1.1.1 Query Stage

Once the user hears a bus approaching the bus stop, he presses the **Query Button** in the user module which transmits a radio frequency (RF) signal to all buses in the vicinity. This activates the bus module placed in each bus which respond by transmitting their route numbers. All the route numbers received by the user module are spoken out to the user through a small speaker in the handheld unit (Figure 2). As an example, assume that buses 501 and 620 are at a bus stop. Once the user queries, he will hear the following **Voice Output**: | *five* | *zero* | *one* | ***(gap)*** *six* | *two* | *zero* | ***(gap)*** (Symbol '|' indicates that the numbers are read out sequentially).

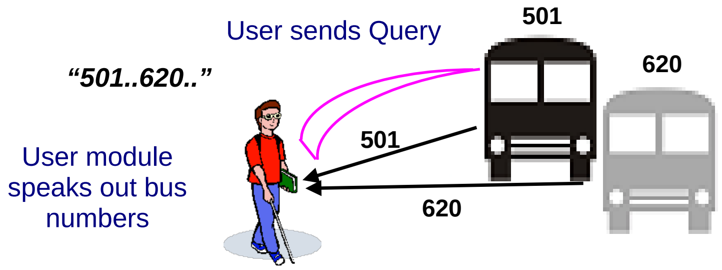

Figure 2: User queries for route numbers. User module reads out the received numbers.

1.1.2 Selection and Tracking Stage

If the user is interested in boarding the bus whose number is being read out, he presses the **Select Button**, in the interval after that number has been read out. e.g., If the user wants to board bus number 501, he presses the button after (| five | zero | one |) has been read out.

Voice Output: | *five* | *zero* | *one* | ***(button pressed)*** | *six* | *two* | *zero* | ***(gap)***

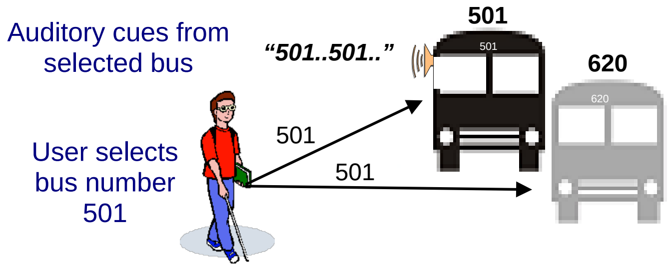

Figure 3: User selects desired bus to trigger an auditory cue from its entry

The user module transmits the selected number to all the buses leading to voice output from the entry of the selected bus. This acts as an auditory cue, and assists the visually challenged person to move towards the entry of the bus. The remaining buses that haven't been selected, do not respond (Figure 3). Once the user selects a particular bus, a small bulb starts flickering in the driver's control panel (like a car indicator). This indicates the presence of a person with special needs at the bus stop. Thus, the driver can wait for a slightly longer duration to allow the user to board the bus safely. The arrival of a bus is followed by movement of people towards the entry. Hence, after moving a short distance the user might require the cue again. In such a case, the user can repeatedly press the selection button to activate voice output of the route number at the entry of the selected bus.

1.1.3 Multiple Bus Route Options

Consider the following scenario at a bus stop. Three buses, with route numbers 501, 620 and 344, line up at the bus stop in quick succession. The user can reach the destination via two buses 501 and 620, but would prefer to use bus 620 over bus 501 as it takes lesser time. The user module would operate in the following manner. In the query stage, the user module would receive and speak out three route numbers: 501, 620, and 344. The user would press the Select button twice, after number 501 and then after 620 has been read out. **Voice Output: |** five **|** zero **|** one **|** ***(button pressed)* |** six **|** two **|** zero **|** ***(button pressed)* |** three **|** four **|** four **|** ***(gap)***

The device considers the last selection as the preferred bus for boarding and transmits route number 620 instead of 501. Consequently, bus number 620 would produce the auditory cue.

1.2. Programming Bus Route Number

In the Bus Transport System, each bus is assigned a route number at the depot. Multiple buses can be assigned the same route number and the same bus can have different route numbers on different days. The route number programming unit is a wireless, portable, battery operated unit that allows an authorized person to program bus route numbers from the control unit without physically boarding the bus.

1.3. Customized Modes of Operation

The current version of user module can be operated in three modes described below. Once a mode is activated the device continues to operate in that mode even after a restart and until the user manually deactivates the mode. While waiting for a bus the user might not be interested in knowing the route numbers of all the buses arriving at the bus stop. A **restricted set** of route numbers the user might be interested in is maintained for this purpose. This allows the device to filter out all the irrelevant route numbers thereby reducing the user's effort and saving time. This feature is particularly useful at the busy bus stops where a lot of buses ply.

Default mode: In this mode the user has to manually press the query button each time he or she hears a bus arriving at the bus stop. Subsequently, the route numbers for all the buses in the vicinity would be read out to the user. Alternatively, the restricted set of route numbers can be activated which would filter out all the irrelevant route numbers.

Auto Query mode: In this mode the device automatically queries every two seconds for any buses approaching the bus stop, thereby reducing the user's effort. In case no buses are detected for two minutes the user is informed of no buses being present. This acts as an assurance to the user that the device is functioning properly and also reminds the user about switching off the device when not in use. Activation of the restricted set is optional in this mode.

Pre-Selection mode: In case the user is certain of boarding a particular bus, he or she can store its route number in advance and can 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 thereby saving both time and effort. The **pre-selected number** can be stored on an offline basis while the user is at home or at the place of work.

The default mode is really simple to use for any user. A user can make use of the advanced modes after adequate training with the user module.

1.4 Mode Selection

The modes of operation mentioned in the previous section can be activated via the special switches allocated for this purpose on the handheld device (Figure 4). When the user switches the device on, the last selected mode is conveyed to the user through an audio output. The user might choose to change the mode if he wishes.

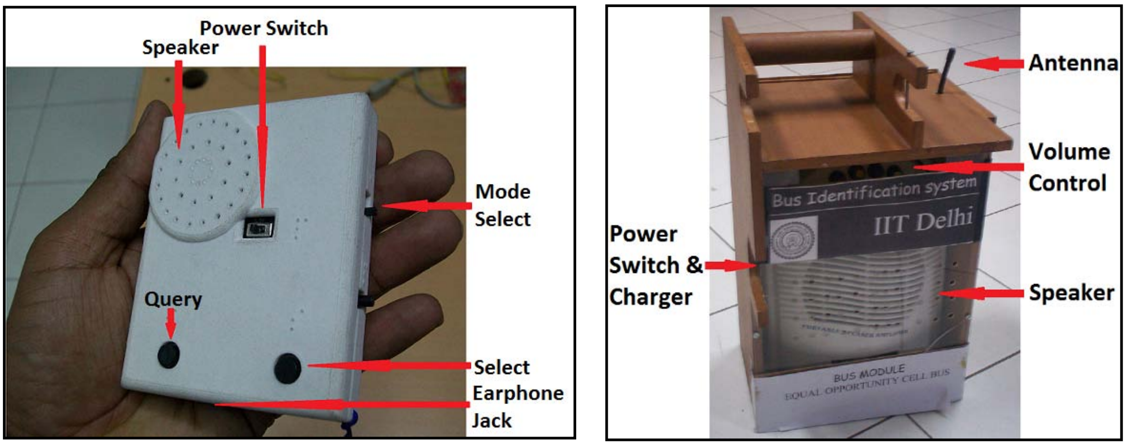

Figure 4: (Left) Hand held user module. Speaker, Headphone jack, Query and select buttons, switches for power and mode select are indicated. (Right) Bus Module with speaker, antenna, volume control and power switch indicated.

1.5 Programming of the Restricted Set and Pre-selected Number

After entering the programming mode by **simultaneously pressing the query and select buttons,** an easy to use audio based interface provides step-by-step instructions to add or delete route numbers from the restricted set or to edit the pre-selected route number.

RESULTS

To test the efficacy and utility of the system in real life scenarios, field experiments were conducted with twenty visually challenged bus commuters. The following three categories of experiments were conducted:

- Assessment of sound based localization ability of visually impaired
- Experiments within the university campus
- Experiments on a busy route outside the campus

The study design of the experiments followed by the outcomes is discussed next.

1. Volunteer enrolment and Questionnaire based Survey

Twenty visually challenged bus commuters comprising 15 males and 5 females, aged 24-52 and associated with three different associations for the blind were enrolled for the field experiments.

The first two days of the trials involved a questionnaire based survey aimed at understanding the current scenario regarding bus transportation for the visually impaired. The results highlighted the high anxiety level among most bus commuters, their apprehensions in seeking help from fellow travelers and the non-availability of any other effective mobility aids.

User	Age	Education	Experience in bus usage (yrs)	Proficiency in computer and mobile phone usage
A	35	Post-Graduate	13	Low
B	30	Graduate	10	Medium
C	27	School	16	High
D	24	Graduate	9	High

Table 1 : Background of participants in the study

The questionnaire helped us in ascertaining the experience of the focus group in boarding public buses, their proficiency in using electronic devices like mobile phones, laptops, etc and their willingness in being a part of the trials in real life scenarios outside campus. These inputs helped us identify four visually challenged bus commuters in the 24-35 age group and varied educational backgrounds for the trials under normal traffic conditions at bus stops outside the campus.

2. User Training

On days 3 & 4 the system was introduced for the first time to the users. After a brief discussion about functionality, the users were asked to fill a short questionnaire to help us **gauge their expectations** from such a device. Subsequently, all intricate details about the usage & functionality were explained. The detailed device specifications like shape, dimension, volume, audibility, battery type, battery usage & price estimate were also discussed during the training session. This stage was undertaken in a **game-like setting.** Three bus modules were placed at different locations thereby representing three different buses. The user was randomly oriented as if on a bus stop and was told a route number which he or she was to board. To make it interesting, obstacles were placed in the user's path. Only one of the bus modules had the route number desired by the user & the modules were randomly activated (at times simultaneously). The aim of the user was to move towards the bus module with his desired route number in as less time as possible. Since the speaker would ultimately be mounted very close to the gate of the bus the users were made familiar with the relative position of the speaker & the entry gate. The above steps were repeated until the user was comfortable with device usage.

3. User Experiments

The bus modules were installed in two university buses with the external speakers mounted on the window railings adjacent to the front door and the communication modules placed near the driver's control panel (Figure 5).

Figure 5: (Left) Bus module installed near driver's controls. (Right) Visually impaired person uses the user module to identify desired bus by triggering auditory cues at the entry of the bus. The person boards the bus independently without any external sighted assistance.

3.1 Sound based Localization experiment

A high responsiveness to direction of sound helps the visually impaired in navigating towards the bus and boarding it, once the route number has been identified. The user can repeatedly trigger the sound output in order to locate the entry point of the bus. Thus, the efficacy of the system is highly dependent on the ability of a visually impaired in ascertaining the direction of origination of sound by listening to it.

In order to test this hypothesis, users with complete visual impairment were randomly positioned around a stationary bus. The users were aware of the relative position of the speaker with respect to the bus's entry but had no prior knowledge about the location of the bus. The aim of each user was to reach the entry of the bus making use of the auditory cues triggered by pressing the selection button.

During the experiment which went on for 2 days, users showed high responsiveness to auditory cues and were successfully able to reach the entry of the bus in all cases.

3.2 Experiments within the campus

For three days, experiments were conducted inside the campus, with all twenty users trying to board the bus three times at the institute bus stop (Figure 6).

Figure 6: Image sequence illustrating a user independently identifying and boarding the bus at the IIT Campus bus stop. The user required only 4 auditory cues and 50 seconds to reach the bus entrance. Note: the bus stop is only a landmark and not a fixed structure. Hence, the bus stops at variable distances near the landmark.

3.3 Experiments on a busy route outside the campus

A three km long route with four bus stops was identified on a busy road in Delhi for field experiments with four users. A user positioned at each bus stop was asked to board one of the two buses which traversed the route three times (Figure 7). Drivers were instructed to stop for a realistic time period at each bus stop, but they could wait slightly longer incase their bus was selected by the user.

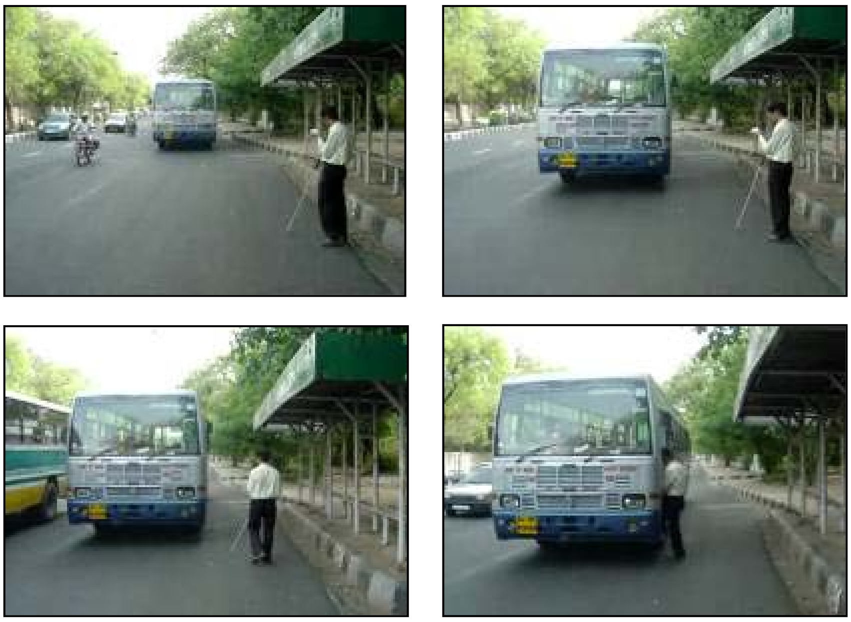

Figure 7: Image sequence showing a visually challenged person successfully identifying and boarding the bus at Mehrauli Road bus stop with no external sighted assistance. Trials were carried out on a busy route with high traffic noise.

The initial distance between user and bus, the time taken to board the bus and the number of times select button was pressed for an auditory cue were recorded. The fellow travelers and bus drivers were interviewed to study the potential impact of system deployment on them. The results have been discussed in the section on outcomes.

4. Outcomes

Table 2 shows the observations recorded for the trials with four users at the city bus stops outside the college campus. Users were able to board the bus successfully 6 out of 9 times without any sighted assistance. Figure 7 shows the image sequence of the experiment. When the user hears the buses arriving at the bus stop, he or she presses the query button. The user module speaks out bus numbers: **|** *zero* **|** *seven* **|** *one* **|** *eight* **|** *and* **|** *one* **|** *five* **|** *two* **|** *seven* **|**. User selects bus number 0718 and navigates towards the bus by triggering auditory cues.

User	**Success**			**Time**			**Distance**			**Select Count**		
	1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
A	No	No	No	-	-	32	-	-	10	-	-	4
B	No	Yes	Yes	-	17	17	-	3	4	-	2	4
C	Yes	Yes	Yes	17	29	26	7	6	8	5	4	5
D	Yes	Yes	Yes	20	18	15	5	7	8	5	3	4

Table 2: Summary of three observations each for users A, B, C and D

On three occasions users were unable to board the bus. In each case, the user successfully queried for route numbers but pressed the select button incorrectly and selected the wrong bus number. As the experiment progressed, users grew in confidence and used the system more effectively.

During the study, users showed high responsiveness to auditory cues and were able to ascertain the direction of the sound source. They periodically triggered the auditory cue after walking for 2-3m. On an average, four auditory cues were required by the users. The average time taken, 21 sec was greater than the average stoppage time of the bus, 13.5 sec. The considerable variation in the total time required to board the bus can be attributed to the variability in the distance to the bus and the number of obstacles like people, uneven steps, moving cycles etc. in the path. Hence, it is necessary to instruct the driver to wait for a slightly longer duration to allow the visually challenged person to board safely. Users with high proficiency in operating devices like computers and mobile phones, irrespective of educational background, performed better in learning and using the system. The results of the study are indicative but need empirical correlations. However, as the sample size was small due to limited number of prototypes, the results of this study are only indicative and need a larger trial to be conclusive.

The fellow travelers were interviewed to study if the system deployment and voice output were annoying in any sense. The feedback was positive. One of the interviews highlighted the increase in awareness among fellow passengers about the presence of a visually impaired at the bus stop who might otherwise have gone unnoticed. The feedback from the driver was positive as the system requires minimal infrastructure change and direct involvement of the driver.

DISCUSSION

Reliable access to the bus transport system is a key challenge for enhancing mobility and socio-economic opportunities for the visually challenged persons, particularly in developing countries. The user-triggered bus identification and homing system is an entirely user-controlled system that requires no driver involvement. It is aimed at providing independence to the user and reduces anxiety and uncertainty in boarding the right bus. It may also benefit the senior citizens and individuals with low vision.

The installation of the system requires minimal modifications in the bus. The system design is highly modular and language independent thereby allowing usage in any language or dialect. The user module can potentially be integrated into a mobile phone. The system described for the bus transport system is generic and can be used for trams, trains, metro rail etc. where multiple route vehicles are boarded from the same location. It can also be adapted for a building navigation system for the visually challenged wherein identification modules can be placed at important landmarks like fire-exits, staircases etc. that transmit auditory cues once selected by the user.

The projected cost of the user and bus modules is under 25 USD which should place it within affordable range for users in developing countries. The cost would decline substantially once these devices are mass produced. The system reduces dependence on sighted assistance and thereby empowers the visually challenged.

CONCLUSION

Reliable access to bus transport system is essential for enhancing socio-economic opportunities for the visually challenged. The system is entirely user-controlled (without any driver involvement) and ameliorates the anxiety of boarding the right bus. The system is language-independent, requires minimal modifications in the bus and would also benefit senior citizens and individuals with low vision. Projected cost of the user/bus module is **under 25 USD** each.

REFERENCES

[1] World Health Organization 2009. Fact Sheet No. 282: Visual impairment and blindness. [Online] http://www.who.int/mediacentre/factsheets/fs282/en/ [May 2009].

[2] B. Olufemi Odufuwa, Towards Sustainable Public Transport for Disabled People in Nigerian Cities,Stud. Home Comm. Sci.,1(2): 93-101 (2007).

[3] Bones Inc. Personal Assistant for Visually Impaired People. [Online] http://www.bones.ch/pages/eng/pavip/pavip.html [January 2008]

[4] Talking Signs Inc. 2000. Talking Signs Locations in San Francisco. [Online] http://www.ski.org/Rehab/WCrandall/introts.html [June 2007].

[5] Step Hear, Guiding your way. [Online] http://www.step-hear.com/ [February 2010]

[6] Paul R., Garg A., Singh V., Mehra D., Balakrishnan M., Paul K., Manocha D.. Smart Cane for the Visually Impaired: Technological Solutions for Detecting Knee-above Obstacles and Accessing Public Buses, Proc. of 11th International conference on Mobility and Transport for Elderly and Disabled Persons (TRANSED 2007), Montreal, Canada, June 2007.

ACKNOWLEDGEMENTS

The authors are grateful to Ms. Jeena Jacob, Ms. Vinitha Varghese, Ms. Saranya Saji, Ms. Anita Roy, Ms. Regeena Peter, Ms. Aswathy Augus who assisted in the conducting user survey. We also thank Mr. Yogesh Taneja, Ms. Rammi K. Seth and Mr. Som Dutt Sharma for their support in coordinating user trials.