

# Enhancing Public Transit Accessibility for the Visually Impaired Using IoT and Open Data Infrastructures

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## ABSTRACT

In urban areas, public transit plays a significant role by offering mobility, but visually impaired passengers are faced with challenges due to poor access to transit information such as timetables and real-time service status. In this paper, we propose a public transit information system for the visually impaired integrating the concepts of IoT and Open Data infrastructures. We developed *TalkingTransit (TT)* – a location-aware system that enables users to obtain real-time service status and timetables of public transit in Tokyo that has more than 1200 stations and 1500 bus stops. Unlike existing systems, our system can be used from off-the-shelf smartphones without requiring any dedicated hardware. It also provides in-station information using Bluetooth low energy (BLE) technology to help users identify a right platform or exit. The system was iteratively co-designed with blind users to develop interfaces specialized for their needs. A user study shows that our interaction design was well accepted and provided improved access to massive public transit information.

## Categories and Subject Descriptors

H.5.2 [Information Interfaces and Presentation]: User Interfaces – *Input devices and strategies, User-centered design.*  
K.4.2 [Computers and Society]: Social Issues – *Assistive technologies for person with disabilities.*

## General Terms

Design, Experimentation, Human Factor

## Keywords

Accessibility, smartphone, visual impairments, public transit, location-based services, IoT, Open Data.

## 1. INTRODUCTION

Modern cities are equipped with public transit systems including underground and surface train, and bus networks. People of all walks of life – commuters, students, senior citizens, and people with special needs – greatly depend on public transit for their mobility needs. Particularly, people with visual impairments, most

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of whom are unable to drive, highly rely on buses or trains for getting to work, school, shopping and other facilities. However, they face many challenges when using public transit due to poor access to information such as timetables, line numbers of arriving vehicles, location of facilities at station – which are mostly provided in visual formats (signs, prints, digital displays, etc.) [11, 14]. Unexpected situations involving real-time changes like delays and suspension of services can cause additional difficulties. Taking into account the fact that there are more than 285 million visually impaired people and rate of vision loss will double along with aging population by 2030 [1], providing accessible transit services is crucial to inclusive cities.

The recent trend of making proprietary data increasingly publicly available by major organizations, coupled with the governmental commitment to open data at national and international levels including the G8 forum<sup>1</sup>, has greatly expanded the possibilities for creating value-added IT services. When the notions of open data and Internet-of-Things (IoT) are integrated, and hardware and software enablers of IoT are properly used to access, process and retrieve open data, useful and cost-effective applications can be developed thanks to today's prevalence of smartphone usage, and fast and reliable network connectivity [15]. Over the past decade, in our ongoing efforts to apply Internet of Things (IoT) technologies into practice, we have been developing location-based services including barrier-free information by deploying sensors both for positioning (NFC, RFID, BLE, etc.) and environmental sensing (temperature, humidity, etc.) in urban space, and conducting large-scale field tests [3, 10, 16]. More recently, we have been promoting building Open Data infrastructures in Japan [12], and as a part of this initiative, we have developed *OpenData API* for efficiently retrieving massive transit information in the Tokyo metropolitan area. From our experience of working with both of these emerging concepts, we recognized the potential of developing innovative applications by combining open data and IoT, which motivated us to develop *TalkingTransit* – a smartphone-based location-aware system for the visually impaired.

By using IoT and Open Data infrastructures, TT enables users to obtain (1) real-time service status and schedules using smartphones and (2) detailed in-station information via BLE technology. TT offers a set of intuitive interfaces iteratively co-designed with blind users, which allows them to access mass transit information in Tokyo, one of the most complex public transit systems in the world. Existing push-based systems [8, 14, 19] notifying users of arriving vehicles often use smartphone's GPS to trace a bus, and/or custom hardware (e.g., tactile bracelet), but may not be useful for checking timetables or service status in

<sup>1</sup> <https://www.gov.uk/government/publications/open-data-charter>

advance. Some pull-based systems [2, 6, 11] allowing users to retrieve transit information adopt a Braille display or keyboard for easy interaction, but these are expensive and cumbersome. Unlike the existing systems, TT doesn't require any dedicated hardware and can access real-time information anytime, anywhere by using open data infrastructure. We also conducted a users study with 11 visually impaired users comparing the existing approaches using Apple's VoiceOver<sup>2</sup> to our approach showing that our interaction design gave a better user experience by allowing users to find desired information quickly and easily. Using OpenData API, TT can access massive information made open by 11 railway operators including East Japan Railway and private railways; 2 subway operators (75 lines and 1270 stations in total) and Toei Bus (132 routes and 1585 stops). Information retrieved by OpenData API include real-time service status, current positions of vehicles, timetables, and in-station information from in-situ BLE markers and sensors (temperature, humidity, pollen, etc.).

The rest of this paper is organized as follows. In Section 2, we explore assistive systems in public transit. In Section 3, we describe the design and implementation of TT in detail. Section 4 presents a user study to verify the usability of our system and its results. In Section 5, we discuss our findings. Finally, section 6 concludes this paper.

## 2. RELATED WORK

In this section, we investigate assistive systems in public transit: the technologies they use to obtain transit information, their interaction techniques and functionalities.

Many systems have focused on getting the current position of vehicles. Jacob et al. [8] used smartphone's GPS to determine current location of the bus and compared to each stop's position data for letting the user know when to get off. *Ariadna* [14] puts a device on the bus, which continuously transmits its GPS position to the central server using General Packet Radio Service protocol. The server then sends bus arrival notifications to mobile phones owned by visually impaired users waiting at the stop using the same protocol. Zhou et al. [19] installed Mobi+ cards, a dedicated embedded system which consists of GPS, a RFID reader, a speaker, etc. both on the bus and at stops. When a blind rider with a RFID tag showing his visual impairments comes to the bus stop, the Mobi+ card recognizes him and provides sound alarm of upcoming buses. Although these systems are helpful while waiting or riding a bus, it may not be useful when the user wants to know vehicle schedule or real-time service status in advance for pre-trip plan. Furthermore, they need special equipment or cause battery draining by continuous use of smartphone's sensors. Our system uses Open Data so that we can provide rich transit information anytime and anywhere without any dedicated hardware. Some research efforts have been investing the use of crowdsourcing in collecting contextual information around bus stops. GoBraille [2] offers crowdsourced information about landmarks of bus stops (e.g., whether the stop has a shelter or a bench), which is entered by visually impaired riders waiting for a bus. Hara et al. [5] proposed a custom tool to gather landmarks around bus stops that help the user identify bus stops by using Amazon's Mechanical Turk<sup>3</sup> and Google Street View. Although the concerns about using crowdsourcing such as getting incorrect

and outdated information have been reported [2], it could be a feasible approach to collect information that needed by a special user group.

Stopman [17] uses speech recognition to interact with a user. The user can get arrival time of the next bus by telling a bus stop name. However, it may give a bad user experience in a noisy place and some users might feel uncomfortable with performing speech input in front of public. Audio-haptic transit map presenting train routes of the New York City subway was provided for visually impaired riders [13]. Raised-lines and small depressions indicate train lines and stations respectively. The riders can get relevant audio information by dropping a special pen into each depression. Brunet et al. [4] designed vibrotactile patterns informing events (e.g., arrival of vehicles, accidents, Points of Interests, etc.) for a custom-made tactile wrist bracelet. HapticTransit [8] generates a tactile feedback to notify the arrival at their destination using a smartphone. There are several systems adopt Braille display to deliver the transit information [2, 6]. Public Transport Explorer [11] uses a Bluetooth keyboard for allowing the user to interact with smartphones. However, these interaction techniques require additional equipments which could be costly and cumbersome to carry. Our system provides simple yet effective gesture-based user interfaces co-designed with visually impaired people, and does not require any dedicated hardware.

## 3. DESIGN AND IMPLEMENTATION OF TalkingTransit SYSTEM

TalkingTransit is a location-aware system running on smartphones that allows visually impaired users to obtain transit information including vehicle schedule, and service status which gives real-time updates on delays, service changes and suspensions of trains in Tokyo.

### 3.1 System Overview

Through iterative design process with blind users, which is described in the next subsection, the current version of TT includes 4 main functionalities:

- **Timetable search:** Users can get the arrival times for the next vehicle, as well as a full timetable by using one of the two search modes according to their usage scenarios. *GPS-based search* allows users to search for the timetables of trains/buses within 500 m of their current position, which can be useful when they are going to nearby stations or already at bus stops. On the other hand, *alphabetical search* allows users to find the timetables of trains/buses by a particular station name, which can be helpful when they make a journey plan in advance.
- **Check the real-time status of railway services:** Using this function, users can avoid any possible inconvenience due to service changes.
- **Bookmarks:** Users can get easy access to timetables for vehicles that they frequently use by bookmarking pairs of stations and train lines, and stations and bus routes.
- **Automatic notification of in-station information:** TT automatically notifies users of points of reference for a nearby platform and facilities (e.g., stairs, escalators, toilets, etc.) within 2 m of their current position. The notification consists of a sound alert and a short description of the spot. If the user gets notification of a nearby platform, he can

<sup>2</sup> <http://www.apple.com/accessibility/iphone>

<sup>3</sup> <http://www.mturk.com/mturk/welcome>

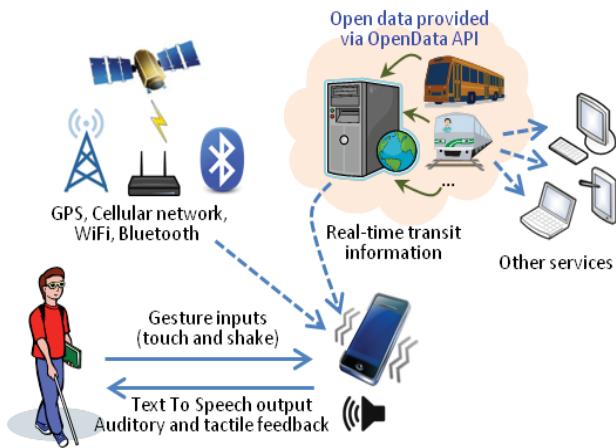


Figure 1. TalkingTransit system architecture.

directly skip to the page containing timetables of trains in that platform.

As illustrated in Figure 1, TT system architecture consists of user smartphone, positioning infrastructure, and open data infrastructure. Positioning infrastructure including GPS, WiFi, and Cellular network allows the user to get his current location, and search nearby stops and stations. BLE is used in the railway station, which has been recognized as an appropriate technology for indoor positioning because of its range (approximately 1~2 meters), low power consumption and cost-effectiveness. Open data infrastructure provides real-time transit information via OpenData API not only TT but also many third-party services. TT is running on a touch-based smartphone equipped with sensors for positioning. The user interacts with TT using gestural input and Text-to-Speech (TTS) output with auditory and tactile feedback.

TT is implemented on iOS 7 platform, and currently running on Apple iPod touch and iPhone 5S which have GPS and Bluetooth. TT makes use of the device's built-in accelerometer and gyroscope sensors to detect shake-motion events. We also used AVSpeechSynthesizer API included in iOS 7 and higher platforms to offer TTS output without using VoiceOver.

### 3.2 Requirement Analysis

Given that touch screen interfaces, which highly rely on visual channel, have become common for mobile devices like smartphones, we have particularly focused on the interaction design for visually impaired users. The current system was developed through an iterative design process in consultation with a blind teacher of Special Needs Education School for the Visually Impaired at the University of Tsukuba. Since he works with visually impaired students, his comments were really helpful to incrementally improve our system. First, we developed a prototype system running on iOS, and conducted a pilot study to understand potential requirements for a better system. Our first design for the user interfaces was based on VoiceOver which is used by more than 100,000 blind people [18]. The main interaction with the prototype was performed by 3-finger swipes following VoiceOver's gesture for scrolling between pages. Users can navigate the list with swipe up and down, select an item with swipe right, and go back to previous page with swipe left. We tested our prototype with 10 visually impaired users (6 male and 4 female), each of whom used the system for about an hour. This testing identified the following requirements for ensuring a better user experience:

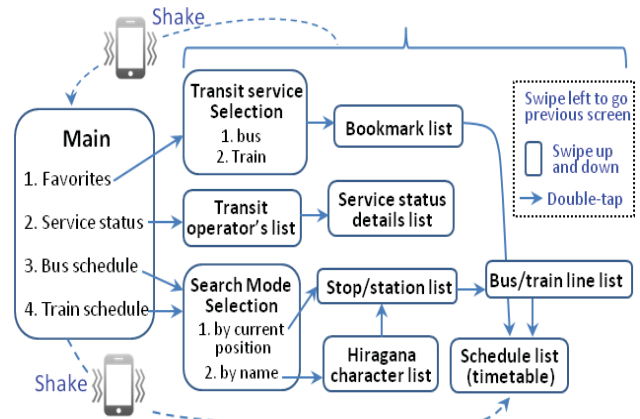


Figure 2. Screen transition flow and performed gestures of TT.

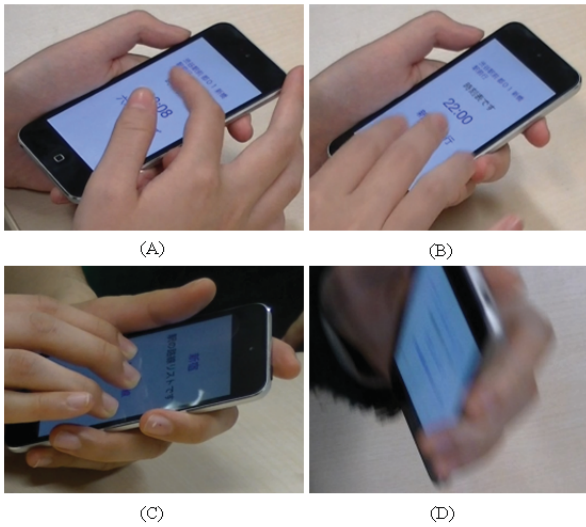
- One- or two-finger swipe and double tap would be easy to perform. Swiping left and right with three fingers is tiring.
- The demand for filtering huge text data to find desired information in a list should be reduced.
- The demand for following which page the user is in while navigating the application should be reduced.
- Explicit feedback for what happened after performing touch inputs should be provided.
- Direct access to timetables of frequently used vehicles should be provided.
- Location-based information in the subway stations for identifying a right platform to ride should be provided.

### 3.3 User Interface

Users interact with TT using a set of touch gestures (1- and 2-finger swipe up, down, left, right, single-tap, double-tap, and 3-finger long press) and a shake gesture. As shown in Figure 2, swipe up and down to navigate the list, double-tap to select, 2-finger swipe left to go previous page, single-tap to get description of the current page, 3-finger long press to bookmark, and a shake to go back to the main page. When starting the application, users can access transit information by selecting one of four items in the main menu: favorites, service status, bus, and train. From the favorites menu, users can see the list of registered vehicles, and directly access their timetables. In the service status menu, users can check the real-time status of 11 railway and subway transit operators whether there is a notification or not. If there are any messages from an operator, users can see the details by selecting the operator. In the bus and train schedule menu, users can find vehicle timetables by two ways: search by current position and by station names (ordered by Japanese alphabet called Hiragana). For example, with location-based search in the bus schedule menu, users can get the list of bus stops within 500 m radius. Then they can select a desired stop, and route to access the timetable. Interacting with the three functionalities above would give a list of 10 items or less, which makes it very easy to navigate using swipe gestures.

#### 3.3.1 Fast Navigation

Searching by station name can be a challenge because there are more than 1500 bus stops and 1200 stations in Tokyo. To reduce search time to some extent, we categorized stops and stations by the first character of their name. Then, users are required to do the



**Figure 3. Users interacting with TT: (A) Navigating a list by passing items one by one, (B) jumping to a certain position, (C) bookmarking a vehicle, and (D) going back to the main page.**

following steps in order: (1) selecting the first character of a bus stop (one of 46 Hiragana characters), (2) selecting the stop in the list of all stops that start with that character (more than 35 items), (3) selecting a line number of the bus, and (4) finding a certain time in a timetable. Step 4 can be overwhelming as well even though the timetable list starts with the next arrival time. Thus, in order to reduce the demand for navigating a long list including steps 1, 2 and 4, we support fast navigation that can be activated by 2-finger swipe up and down, while 1-finger swipes navigate the items one by one (Figure 3A).

For faster navigation, we divided the long list into groups in a way that users can intuitively know how the items are grouped, and we tagged the first item of each group so that users can jump between the groups by performing 2-finger swipes. Our grouping strategies are as follows. For step 1, dividing Hiragana syllables into 5 consecutive characters; for step 2, dividing the bus stop list with the same first character into groups where the first two characters (syllables) are the same; and for step 4, dividing a timetable into every hour so that users can jump to the time of the first vehicle per hour (Figure 3B).

### 3.3.2 Shake-to-main

To reduce the demand for following which page the user is in while navigating the application, we provide ‘shake-to-main’ so that users can immediately go back to the main page from anywhere in TT (Figure 3D). We also added bookmark functionality. Users can add a vehicle to the bookmark list in the bus/train line list page by performing 3-finger long press (auditory feedback is provided when the gesture is recognized) and remove one from the bookmark list page by performing the same gesture (Figure 3C).

### 3.3.3 Rich Feedback

To let users ensure TT has recognized their inputs as they intended, we provide feedback for every gesture input. When users launch TT, audio information about the existence of any notification from transit operators (e.g., “There are service changes currently in effect, so please check the transit status

**Table 1. Gestures and corresponding auditory feedback**

Gesture	Description	Sound
1- and 2-finger swipe up/down	Navigate a list	Page flip
	If last item	Page flip and ding
2-finger swipe left	Go previous	Whooshing
3-finger long press	Add a favorite	Short bell ring
	Delete a favorite	Tossing trash
Shake	Go main	Chimes
Double-tap	Select an item	Glass bell hit
Single-tap	Get description	Bounce
None	BLE detection	Message notification

menu”) is offered with vibrotactile feedback. Auditory feedback is provided for every gesture input as shown in Table 1. We used different sound effects, which are somewhat relevant to its gesture (e.g., whooshing sound for swiping gestures) so that it allows users to easily identify gestures they performed.

## 3.4 In-station Information

At the same time, we provide in-station information based on user’s current position. It may be noted that extracting information through BLE markers, which have a greater range than NFC or RFID, is particularly useful for visually impaired users, as it enables them to simply walk along a concourse or aisle and receive information seamlessly without having to get near any marker. When a smartphone detects a BLE marker’s signal, TT receives the marker’s unique ID. Then TT retrieves relevant information about the marker – a short description of the place, the floor number, latitude and longitude coordinates of the marker’s position, etc. – via OpenData API. Among this information, only the place description is read aloud to the users. If users detect a marker installed near a platform (stairs, elevators and escalators), they can directly access schedules of trains on that platform by shaking their smartphones. This feature would be very helpful for visually impaired riders to find a right platform or exit, especially in large stations like Shinjuku station that has 30 platforms and 66 exits. As a part of the open data infrastructure mentioned in Section 1, 42 BLE markers were deployed in Shinjuku station near toilets, lockers, and exits. 10 BLE markers were installed at stairs near 8 platforms, 1 toilet, and 1 exit of New South Exit concourse of Shinjuku station where we conducted a field test (Figure 4).

After refining the prototype as described above, we consulted the blind teacher to ensure usability improvements before conducting



**Figure 4. Participant receiving information from BLE marker**

a user study. Generally, he was satisfied with the refined design of TT but he commented that users should be able to check the current time when navigating timetables. Thus we added a feature for getting the current time by 2-finger single tap from any page of the application.

## 4. EVALUATION

To verify the ease-of-use and usefulness of TT, we conducted experimental evaluation with 11 visually impaired participants in the laboratory. Reading websites using mobile devices with a screen reader like VoiceOver is generally well accepted by visually impaired users. Thus searching a website of timetables using VoiceOver can be a practical solution although it is not created for blind people. Therefore, TT was compared to a mobile website that we developed providing the same information using VoiceOver. For a fair comparison as much as possible, we designed the site's structure almost the same as TT's screen flow. In addition, when users access a timetable, the page scroll bar moves near the item (schedule) closest to the current time so that they can quickly find the next vehicle schedule, which gives a similar navigation experience as with TT. The client side was developed using JavaScript and jQuery Mobile. PHP was used for the server side. Users can see the site with Safari on iOS mobile devices using VoiceOver.

### 4.1 Participant

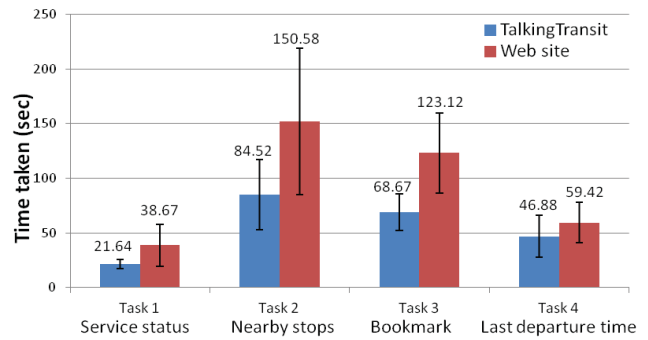
11 visually impaired participants (3 male and 8 female; P1-P11) were recruited for the study. Their degree of visual impairments varied: 8 of them were blind and 3 had low vision (1 of them had only light perception). The average age of the participants was 19.9 (SD = 1.5). To obtain transit information, all smartphone users were using a native application, and the others were using a feature phone's service. 5 participants said they also often ask information to train station staffs or other riders. The entire study took approximately 2 hours. The whole process of the experiment was conducted in Japanese, and was video taped for later analysis.

### 4.2 Procedure

Considering the possible usage scenarios of TT, we asked participants to perform the following four tasks: (1) check the service status of the given transit operator, (2) search the nearest bus stop or subway station where you can ride the given bus route or train line, and find the next vehicle schedule 30 minutes from now, (3) bookmark the given vehicle, and (4) find the last departure time of bookmarked vehicle in step 3.

Each participant performed three trials of each task for both systems. Participants used Safari on iPod touch with VoiceOver when browsing the mobile website. Given operator, station and vehicle for each task was different in every trial. We also set different current position for each session to avoid learning effect. We set the current time as 13:15 for both sessions, but set different locations at our laboratory and Tokyo Dome (about 1.5 km away from our laboratory) respectively. At the beginning of each session, we conducted a training session for all participants until they felt familiar with both systems. The order in which systems were used was counter-balanced across the participants.

At the end of each trial, participants were instructed to return to the main page. Each trial began when the participant performed a touch input in the main page, and ended when the participant answered the given question. When the participants had difficulty



**Figure 5. Average task completion time in seconds for both systems. Shown with standard deviations.**

in performing the task, the experimenter assisted them to perform the proper gesture to continue the task. After finishing each task, participants assessed their subjective mental workload involved in performing the task using the NASA Task Load Index (TLX) [7]. We also asked the participants to answer a questionnaire about each system at the end of each session.

## 4.3 Results

To evaluate ease-of-use, we measured task completion time as a quantitative indicator and used NASA-TLX for assessing mental workload as a qualitative indicator. For evaluating usefulness of TT, we conducted a questionnaire survey. Each participant performed 3 trials of the 4 tasks for each of the 2 systems, making a total of 264 trials. They completed all trials successfully except for the 5 trials in task 2: for 3 trials, they mistakenly thought that they should find the next vehicle after 13:30 (participants were supposed to find the next vehicle after 13:45 which was 30 minutes from "now"); for the other 2 trials, they selected right stop (station) for the given vehicle line but not the closest one from the current location.

### 4.3.1 Task Completion Time

The mean time for 3 trials of a task was considered as task completion time per task. However, regarding the completion time of task 2, we used only the records of successful trials to calculate the mean time (3 participants who made the mistakes in task 2 were able to complete at least one or two trials). The average completion time for each task is shown in Figure 5. Paired t-test revealed that TT was significantly faster than browsing the web site with VoiceOver in all tasks: service status ( $p < 0.013$ ), nearby stops ( $p < 0.001$ ), bookmark ( $p < 0.001$ ) and last departure time ( $p < 0.035$ ).

### 4.3.2 Subjective Ratings

Participants were asked to rate on 6 subscales of the NASA-TLX questionnaire for each task: Mental Demands, Physical Demands, Temporal Demands, Effort, Own Performance and Frustration. Each of these dimensions was rated within a 100-point range with 5-point increments. Then we calculated and used an overall workload score (WWL) based on a weighted average of ratings on the 6 subscales [7]. Table 2 shows the average WWL score for each task. Paired t-test found that participants felt significantly less workload with TT when performing the tasks for service status ( $p < 0.017$ ), nearby stops ( $p < 0.049$ ) and bookmark ( $p < 0.027$ ), showing that our system could provide simple and intuitive user interfaces.

**Table 2. NASA-TLX WWL scores (0-100) for each task (Mean, SD). Lower means less workload.**

Tasks	TalkingTransit	Web site
1. Service status	22.85 (15.16)	35.64 (19.94)
2. Nearby stops	34.25 (18.95)	41.81 (22.51)
3. Bookmark	30.76 (19.51)	40.19 (18.00)
4. Last departure time	29.08 (18.19)	34.96 (16.68)

After each session, we asked participants to complete a brief questionnaire to investigate the usefulness of the system used in that session. Participants rated 5 statements using a 5-Likert scale (1=Disagree strongly, 5=Agree strongly). The list of statements, mean values, and significant differences are shown in Table 3. A Wilcoxon test found that the following items were significant: *Useful* ( $p<0.03$ ), *Easy to use* ( $p<0.03$ ) and *Would use on smartphone* ( $p<0.01$ ). There were no significant differences regarding both *Easy to lean* and *Felt in control* showing that participants could get used to both interaction techniques without much difficulty. These results indicate that participants felt more comfortable and were able to get familiar with TT easily. In addition, we asked participants to choose easier to use system for each task. Generally VoiceOver users were either positive or neutral about the web site. However, when they asked to indicate their favorite of the two systems, all participants preferred TT to the web site (Table 4).

#### 4.3.3 User Feedback

Overall, participants found TT was easy to use because of its simple and intuitive user interfaces. Even participants who have not experienced touch screens were able to easily use TT. P11 stated “*I was reluctant to own a smartphone, but after using TT, I found it easy.*” Participants commented positively about TT’s ability to navigate fast and provide rich auditory feedback. P7 said, “*It was quite good to get sound notification upon reaching the end of a list.*” 3 Participants particularly liked ‘shake-to-main’. A number of users said they anticipated public release of TT so that they could use it in their daily lives.

We also investigated additional features for improving the user experiences with TT. P3 and P11 suggested that jumping to the first and last items with 3-finger swipes would be useful. Some had difficulty with long-press gestures. The average number of performed gestures to add a bookmark, which requires a long-press gesture, was 1.5. P1 and P3 commented that it would be better to change the bookmark gesture from 3-finger long-press to double-tap. Moreover, participants mentioned that providing additional information such as a list of all bus stops on a route, surrounding point-of-interests, and fare information would be helpful.

**Table 3. Questionnaire results (Mean, SD). Starred items were rated significantly higher for TalkingTransit.**

Statement	TalkingTransit	Web site
Useful*	4.82 (0.40)	4.09 (0.83)
Easy to use*	4.45 (0.69)	3.55 (0.93)
Easy to learn	4.82 (0.40)	4.27 (1.01)
Felt in control	4.45 (0.69)	3.82 (0.98)
Would use on smartphone*	4.64 (0.67)	3.64 (1.12)

**Table 4. User’s preference of both systems for each task. The number of users choosing each option is displayed.**

Tasks	TT	Web site	Neutral
1. Service status	7	1	3
2. Nearby stops	9	1	1
3. Bookmark	9	2	0
4. Last departure time	5	4	2
Entirely	11	0	0

## 5. DISCUSSION

The user study results indicate that TT allows users to access desired transit information quickly and easily. It was encouraging that users could intuitively understand the fast navigation feature. All users used this feature every time they encountered a long list. We observed that users seemed to feel a sense of control and freedom because of the shake-to-main feature that provided them an “emergency exit” through which they could escape from an unexpected situation and could start over like pressing a reset button. Regarding feedback, users preferred implicit manner (e.g. tossing trash sound for deleting a bookmark) rather than explicit manner (e.g., “This is the first item of a list”). Some users seemed to be annoyed at the verbose feedback of VoiceOver. 3 users said, “*VoiceOver talks too much!*” Although VoiceOver’s gestures allow users to use various applications, it may be difficult to provide user interfaces specialized for each application [9]. We demonstrated that utilizing smartphone’s built-in sensors and customized touch gestures, mobile applications can be made highly accessible to visually impaired users. Although all users thought TT was better than the site, some iPhone users liked our mobile web site design as well. Thus, it would be desirable to let them choose the system according to their preference. Providing more choice can bring higher satisfaction for each visually impaired person because their individual ability and attributes are varied (e.g., touch screen experiences, age, degree of visual impairments, etc.). Furthermore, TT can benefit elderly citizens who might have difficulty reading text in the small screen space.

In addition, to identify the feasibility of TT in the field, we conducted a user test at Shinjuku station with 3 blind participants (Figure 4). The test included about 15-minute training, 20-minute test and 15-minute interview. They walked about 50 m with an experimenter, passing the toilet, exit and two platforms in order along around New South Exit. Users could generally get information from BLE markers. All users were particularly pleased with getting schedules by shaking the device near a platform. They also commented that it would be more helpful with additional information about which train comes from which side of the platform. Because this information was not available in current open data, we gave feedback about information needs to the open data project community for improving the breadth and quality of data. One participant mentioned that he wanted BLE markers to be deployed anywhere in the street so that he can go shopping and enjoy traveling.

## 6. CONCLUSION

In this paper, we have proposed a public transit information system, TalkingTransit – a smartphone-based location-aware system for visually impaired passengers integrating IoT and Open Data infrastructures. We co-designed TT with blind users to

enable them to obtain mass transit information in Tokyo. Unlike existing systems, TT doesn't require any additional hardware, and provides access to information anytime anywhere, which makes TT readily usable using off-the-shelf smartphones. Our user study demonstrated that our interaction design including fast navigation, shake-to-main and rich auditory feedback could give better user experience than existing approaches that mainly use VoiceOver. The user study revealed the potential of combining IoT and Open Data that foster cost-effective application developments for the visually impaired. Currently, we are planning real-world deployment of TalkingTransit in future.

## 7. ACKNOWLEDGMENT

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