Disability and Rehabilitation, July 2005; 27(13): 769–779

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A relative access measure to identify barriers to efficient transit use by persons with visual impairments

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Abstract

Purpose. Persons with visual impairments or blindness can face significant restrictions to their efficient travel, especially when attempting transit transfers and using a large, multi-modal terminal. Little is known about what makes some tasks much harder than others. This paper presents an approach to empirically measure the difficulty of a variety of transit tasks.

Method. An experiment was conducted at an urban transit terminal, with three other transit modes nearby. Thirty persons with visual impairments attempted to make five simulated transfers between these modes. Errors and time to complete these tasks were collected in order to quantify the nature of various barriers to efficient travel for this group. In total, 20 locations were visited. Completion times were compared to a sighted traveler to determine a measure of the time penalty, or 'relative access measure.'

Results. Two basic findings are reported. Empirical data showed that different types of transit tasks and locations had a wide range of difficulty and inherent time penalties. Some tasks like crossing a difficult street, finding unmarked track doors, and finding inconsistently placed amenities were quite time consuming and sometimes impossible to accomplish. Other tasks, like walking to a street corner and crossing a simpler street, had much lower penalties and could be completed with ease.

Conclusions. The placement of additional cues, those of identity and direction, provided with auditory signage, were able to eliminate much of the uncertainty and time restrictions associates with transit use and navigation for persons with visual impairments.

Keywords: *Blind navigation, disability, orientation & mobility, transit use*

Introduction

Much time and effort has been devoted to making transit more accessible to those with physical or mobility impairments. However, beyond the obvious observation that persons with vision loss have problems that restrict efficient travel and use of transit, there is little understanding of what these restrictions are and how to identify and improve them. Some of the most difficult transit tasks faced by those without useful vision are: finding locations such as bus stops, boarding areas and track doors, amenities such as ticket booths and fare machines, in addition to problems finding the correct vehicle, especially the identity of buses or trains, and making transfers [1–4]. These reported difficulties are usually caused by the lack of access to spatial information and relationships that are available to the typical person through visual cues such as maps, signs, and the ability to preview the environment.

Marston and Golledge [5] identified five types of information and spatial knowledge that are restricted or unavailable without vision, especially in unfamiliar areas. They are:

- Specific information and positive identification at locations.
- Spatial information accessed from a distance.
- Directional cues to distant locations.
- Self-orientation and location.
- Integrated model of the space.

Unlike the physical, structural, and absolute barriers such as stairs, narrow door openings, or buses without lifts that people using a wheelchair face, people who are blind face functional barriers (lack of

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ISSN 0963-8288 print/ISSN 1464-5165 online
DOI: 10.1080/09638280400014790

available information about spatial arrangements and uses at a location). These barriers are also 'relative' as this information can be learned with familiarity and practice. However, in unfamiliar environments, these barriers can limit a person's accessibility or freedom of movement to the same degree as a physical barrier.

This paper discusses the use of a 'relative access' model that can be used to measure the time penalty caused by the lack of suitable environmental cues for persons with visual impairments. We then present results of a field test that used the relative accessibility measure and involved a major transit center where four different public transit modes were present. We were able to demonstrate that some tasks are more difficult to accomplish than others. We further demonstrate that additional cues can be helpful in improving access for those with visual impairments.

Measuring 'relative access'

One way to measure how access is restricted for certain groups or individuals is to compare the effort of travel (such as time or distance) for that group or individual to a user with less restricted travel abilities. In this section, the travel times of persons with no useful vision are compared to a sighted person, to determine the excess time, or penalty, for travel without vision. If a person who was blind took 10 minutes to walk from the entrance of a train station to the proper boarding gate and a sighted person took only two minutes, there would be an extra time penalty of eight minutes for the trip without sight. A ratio accessibility measure can be formulated to show the excess time or distance required by people who have restrictions on their travel. For this example, it would be expressed as ((10/2) − 1), or four times more than that required with sight. *Relative accessibility* [6] can be formulated as:

$$R_{iklm} = \frac{d_{ikl}}{d_{ikm}} - 1.0 \qquad (1)$$

where:

d_{ikl} is the time or distance from i to the desired location that offers activity k to serve a person at i with access type l.

R_{iklm} = relative accessibility of activity k from location i for person type l relative to person of type m.

In this paper a person of type m is the sighted walker and a person of type l represents those who are visually impaired. With this formulation, a relative access score of 0.0 would represent a location that could be reached by the sighted and the blind traveler in the same amount of time. A score higher than 0.0 would represent an excess time penalty caused by lack of vision.

To measure the effect that limited environmental cues have on efficient travel by persons with visual impairments, we used Talking Signs® Remote Infrared Audible Signage (RIAS), which enables those with limited or no sight to gain identity and directional cues, which are often missing without sight. RIAS consists of a receiver that allows a user to learn about an environment by scanning about with a hand-held device and hearing the identity of locations outfitted with transmitters. Walking in the direction to which one is pointing gives a straight path to the location that was heard and identified. This technology has been widely tested in transit environments [1–5,7–11].

These previous experiments have shown that RIAS can provide faster, safer, and more confident and independent travel in many types of environments. However, little has been done to study what are the most difficult locations in a complex transit environment, in order to provide a better understanding of the true cause of the 'penalties' of transit use for this group. This knowledge should help transit planners as they strive to make access to their facilities more equitable for all members of society. Using the relative accessibility model we will identify and contrast barriers within a complex transit environment.

Location of research experiment

The overall objective of this project was to measure and identify barriers to efficient transit use. A multi-faceted experiment was conducted at the San Francisco Caltrain terminal, a 12-track train station that occupies a full block face at the main entrance (see Figure 1). Three other transit modes are located nearby: (1) a cab stand located on a side street of the station; (2) a light-rail station located on the opposite side of the other side street; and (3) several bus stops with shelters across the street in front of the terminal. A total of 51 RIAS transmitters were located in the train station and the surrounding area to identify all doorways, track gates, and amenities such as ticket windows, concession stands, bathrooms, and contact points for the three other travel modes. At crosswalks RIAS transmitters also provided 'real time' information about the status of the pedestrian 'Walk' signal. Detailed information about how RIAS promotes faster and safer street crossings is provided elsewhere [2,8,11].

Subjects and research design

Thirty legally blind persons were tested, ranging in age from 19 to 67, of which 20 had no useful vision (light perception or less). We report here only on those 20 participants. A field test was conducted where the participants simulated making five transit mode transfers, visiting locations and amenities along the way, for a total of 20 location-finding

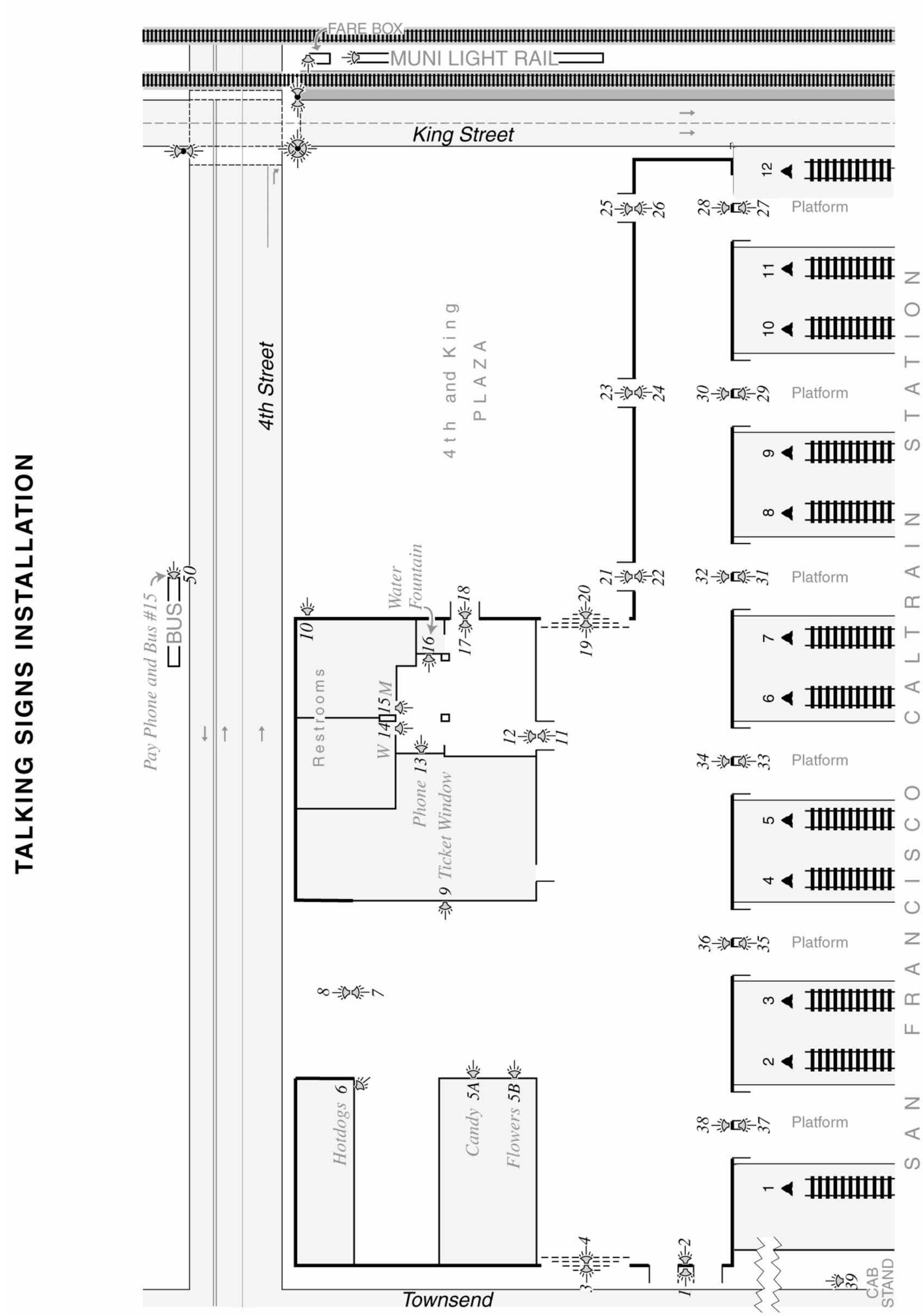

Figure 1. Talking Signs® Installation at Caltrain Station.

tasks. To make this experiment realistic, people were allowed to ask for help (but not from the research staff) and these requests for assistance, errors, and travel and search times were recorded to quantitatively measure the time constraints for different types of transit locations and tasks. Eleven participants used their regular methods of travel, while another nine participants used RIAS. This format allowed for a comparison of the time it took to complete the tasks both with and without the use of RIAS.

Modeling impedance of different transit tasks

The field test data are examined in the light of how the environment and the placement of locations and their cues affect the blind traveler with respect to the relative access measure. We show that time penalties are not based just on the individuals' skills and vision, but can also be applied to various locations and transit tasks in and around a transit terminal.

Since RIAS has the potential to give many of the missing cues to a blind traveler, we use this technology to help distinguish the 'real' problems of blind travel and those that are caused by missing environmental cues, and we will model those effects on accessibility. This should lead to a broader knowledge of the major barriers to successful and independent travel for this group and how providing basic spatial information such as directional and identity cues, or better placement and consistency of locations, can help to mitigate these problems.

Times to find the correct locations were compared to the 'optimal' time based upon the familiar sighted user's (FSU) travel time to determine the extra time it took to perform these tasks without vision. This time penalty, caused by the lack of visual cues, can also be formulated to obtain a measure of 'relative' access as compared to absolute access. Situations exist that block some persons with blindness from completing or even starting travel, such as difficult intersections or especially, travel in a new environment. For these persons, travel times are often much longer than for the typical user, and this can be termed a matter of *relative accessibility*. They *do* have access to locations and opportunities, but the extra time spent searching and traveling can decrease the number and types of activities they can perform in a given time frame. Building on equation 1, we can introduce a frequency term, so that relative access can account for the number of times specific tasks are repeated in order to accomplish movement within an environment.

$$R_{iklm} = \frac{f_{ikl}\, d_{ikl}}{f_{ikl}\, d_{ikm}} - 1.0 \tag{2}$$

where:

f_{ikl} = the frequency of each type of activity k from location i for those with access type l.

d_{ikl} is the time or distance from i to the desired location that offers activity k to serve a person at i with access type l.

R_{iklm} = relative accessibility of activity k from location i for person type l relative to person of type m.

In its typical use, this formulation can be used to compare relative access for multiple trips to the same or similar activity. A traveler might have to find four bus stops each day, while another might need to find multiple fare boxes or ticket windows. If that person faced travel restrictions or barriers, compared to a typical user, the time penalties would increase as the frequency of identical trips from i to k, increased. A modified and relaxed formulation is used here to measure trips to an activity k, from the previous location i. For example, the participants went to three different doors for the train boarding area, from different starting points. By adding those trip penalties, an average time penalty for finding an unmarked gate door can be revealed. The next section deals with measuring the relative access for various types of locations or activities. Later, a combined relative access measure that sums up this measure for all the various activities will be given.

Accessibility of grouped tasks and locations

Spatial placement of needed transit locations and amenities in an environment can aid accessibility, conversely, inconsistencies in their placement might exacerbate the difficulty of locating them. This section will examine different types of location categories and later we discuss the use of models to estimate the time penalties faced by this group in other environments.

Access problems for specific tasks

The first four location types examined included nine of the 20 test destinations. Figure 2 shows these nine locations grouped into the four specific types, along with their relative access measure (RAM). The averages for each group of locations are also shown, representing the frequency of each type of activity.

Unmarked sequential track doors

Participants started the experiment with their back at an unnamed track door, and it was explained to them that all the trains came in from behind them. Therefore, they were aware of the spatial arrangement of all track doors being located only at the back wall of the terminal. The doors to the train boarding area were not marked with Braille or any tactile information. Because of this, there was little possibility that a totally blind individual could find the proper door location, unless they asked for help from passers-by. Even when they found a door, they had no way to know if that was the correct door or if they should go to their left or right to continue their search. Finding track doors was also rated as the most difficult from the 26 transit tasks examined in the pre-test interview [2,3]. The difficulty of this task was also evident from the travel time data collected as participants visited three different track doors during the experiment. The extra time needed to find these three different unlabeled doors was quite

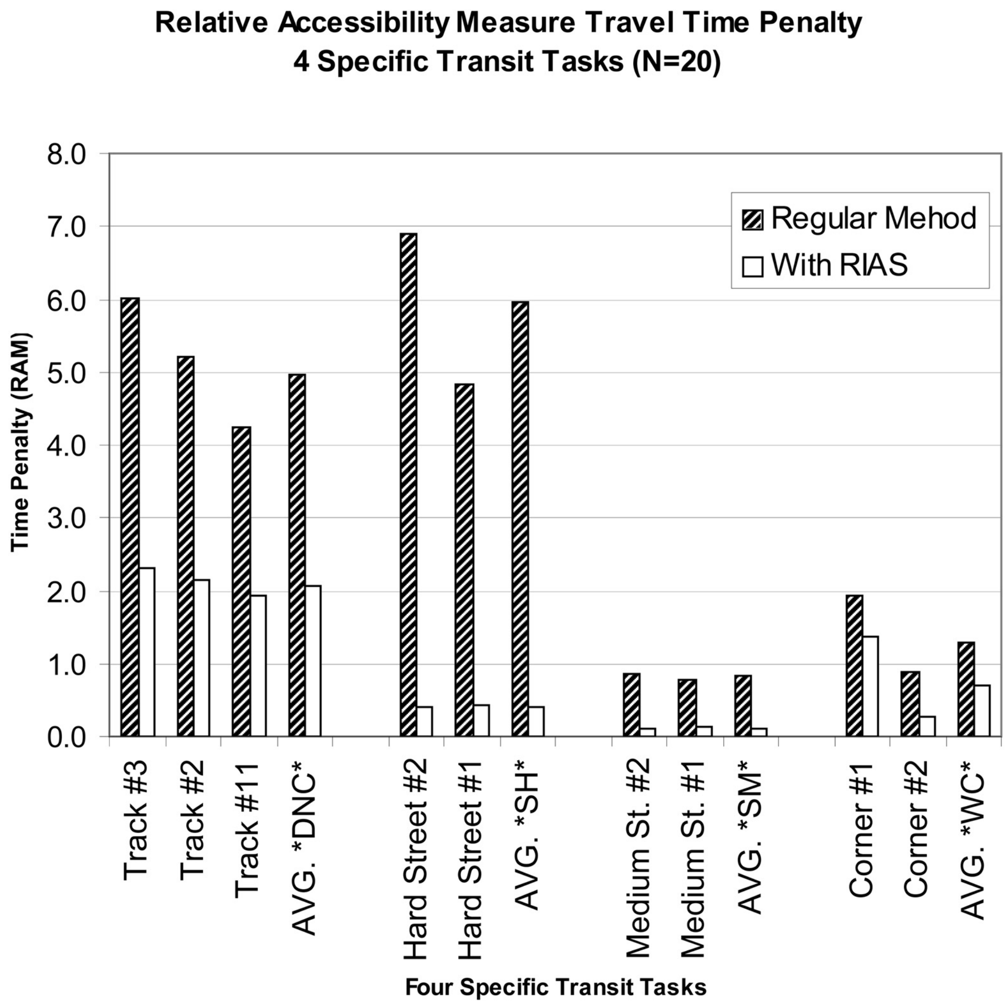

Figure 2. Travel time penalty (RAM) for four specific transit tasks.

similar, and the mean relative access measure (RAM) was 5.0 (the time penalty was 500% more than the FSU). The use of RIAS lowered this RAM to 2.1 (a time penalty of 210%). These penalties could be applied to other unlabelled doors that have some order but offer no other cues to their identity. These locations are referred to as 'Door, No Cues' or DNC in figure 2.

In one of the three tasks, people walked from the indoor phones to the boarding area for track 2. The travel and search times for those with RIAS were significantly faster than for those using their regular method of travel (no RIAS), with a t-test statistic for the two conditions of ($p < 0.0001$). In a different task, people walked from the ticket window to track #11. This door was located at the far end of the terminal where participants had not yet traveled. That area of the station was much less crowded and offered fewer people to ask for help. The travel times were significantly faster with ($p < 0.00002$). Finally, people were asked to go from the hot dog stand to track #3. The results were also significant ($p < 0.005$).

Hard difficulty street crossings

People with visual impairments receive training on crossing streets, and these locations certainly offer many non-visual cues. Blind travelers use auditory cues from traffic to align themselves for a street crossing and also to understand the flow of traffic. However, as the experiment showed, some streets are just too dangerous for them to cross because of high-speed traffic and complicated traffic flows, such as turn lane cycles. King Street (a side street at the Caltrain station) is a high-speed arterial road, and the nearest stop light from the crossing is two long blocks away so traffic moves at a high speed. In addition, most of the cars on 4th Street turn right onto King, so there is almost a constant flow of traffic, except for the short walk cycle. Participants crossed to or from the mid-street transit platform on King St. twice in the experiment, and both directions were categorized as difficult. Some participants refused to cross the two lanes of traffic on their own, and others had to wait through several cycles of the light to understand the traffic flow. Crossing this street in both directions had a mean relative access measure (RAM) of 6.0, (a time penalty of 600%), while with RIAS the RAM was .4 (extra time was only 40% more than a sighted pedestrian). These locations are referred to as 'Street, Hard Difficulty' or SH.

In the first hard street crossing task, people crossed from the train terminal side of King St. to the Light Rail side. The t-test statistics for the two conditions showed a significant difference ($p < 0.009$). During the second hard street crossing task, they made the second crossing of King Street in the opposite direction. This direction, toward the Caltrain terminal, was even harder, because the traffic turning right from 4th St. was across the street and harder to hear and comprehend. This problem and the high speeds kept some people from even attempting the crossing. Overall, t-tests showed a significant difference ($p < 0.007$), between using RIAS and not using RIAS.

Medium difficulty street crossing

Crossing 4th Street was very different than crossing King Street. 4th Street is a congested city block with many cars and cabs stopped at the terminal and had slow traffic. Therefore, there were many audible cues to the traffic and turn cycle and much less danger from high-speed traffic. Orientation and Mobility (O&M) instruction and the participants' skills are well represented in this task. Participants who used their regular aids and skills were able to cross this street in both directions with a RAM of .82. With RIAS, participants were able to cross the streets with a RAM of only .12. This location was labeled 'Street, Medium Difficulty' or SM. An intersection with stop signs and little traffic might represent an easy street.

During the first task of crossing a medium difficulty city street, people crossed from south to north on 4th St. On the north side was a one-lane dedicated bus lane, which was usually vacant. The south side had two lanes with a third (turn) lane at the corner. This was a much more typical congested city street, with cars parked in front of the terminal. The block was quite short and also had a traffic signal at the other end, so there was no high-speed traffic. Because of the bus lane, there were no vehicles turning onto the street, and few cars went straight across King. Most cars turned right at the terminal. The RAM for participants with their regular navigation was .6. Participants using RIAS had, on average, a RAM of 0.0 (no longer than the FSU!). Again, the RIAS showed a significant difference ($p < 0.001$).

During the second task of crossing a medium difficulty city street, people walked south across 4th Street and this proved a bit harder than going the other direction. The turn lanes were at the opposite side of the street; so auditory cues were a bit harder to pick up than when the right turns and traffic were directly in front of them. Those who used their regular navigation skills had a RAM of .7 and with RIAS the RAM was .06. Student t-tests showed that this difference was significant as well ($p < 0.0004$).

Walking to a street corner

Twice in the experiment, participants walked out of the terminal and along a street to a street corner. There are many non-visual cues to help identify a busy intersection. O&M training efforts are well demonstrated by these results. Participants used dogs or their cane, and traffic noise to identify the street and its intersection. Both of these walks were at a significant distance from the start point, but this was not a difficult task for this group. The mean RAM was 1.3 for the people using their regular aids and skills, and when they used RIAS the RAM was .7. This task or location measure is referred to as 'Walk to Corner' or WC.

In the first walk to corner task, people were at the candy counter and were to walk out the main door, turn right, and walk to the corner. The regular method participants had a RAM of 1.5 and the *RIAS* participants had a RAM of 1.1, however, there was no significant difference between using RIAS and their regular methods. During the second walk to corner task, participants were asked to walk to the first corner that they had visited in the experiment. Although finding information about the street corner might be quite difficult, the task of finding a corner is something in which most people with blindness are well trained. The t-tests showed a significant difference ($p < 0.02$).

For these four specific transit tasks or locations, it can be seen how difficult it is to find unlabeled doors and how RIAS reduces the needless search time to collect this information. Crossing a difficult street can be such a barrier that one failed or stressful crossing may cause a trip to be abandoned. While the participants did quite well crossing the medium difficulty street, the use of RIAS in both of these street crossing tasks took away the uncertainty and stress of learning an intersection's traffic flow, signal cycle, and other idiosyncrasies. Without full attention to all these cues, any street crossing can lead to injury or even death. The task of walking to a corner was not too difficult for this group, but, again, RIAS helped speed up this process, especially in finding their way out of the building and on to the street.

Location types based on the availability of non-visual cues

The other 11 locations were not so easily categorized as to specific types of locations. They were grouped using the consistency of their placement (i.e., how easy they are to understand and locate) as well as whether or not other cues were available to inform the blind population. For example, it is usually a good spatial search heuristic to assume that the bathroom for one sex is near that for the other. Ticket sales are usually in a high-traffic and central area near the entrance to a terminal or near the tracks. Other locations, however, have no 'standardized' or rational legibility. They might have non-visual cues such as smells or distinctive sounds that might be heard (for example, one might hear deposited coins at a vending machine or people using a phone or buying a ticket). Air currents, light intensity and temperature changes can signal doorways and openings. Other locations offer little in the way of cues to their existence. Figure 3 shows the relative access measure (RAM) for participants with no useful vision on their first attempt for the other 11 tasks.

Random or inconsistent amenity placement with no cues

The two hardest locations to find were also directly necessary for successful transit and transfer use. Inconsistent placement and no cues made the bus stop and the Light Rail fare machine almost invisible to people without sight trying to use these modes. These two locations highlight the lack of access to information needed to effectively use transit.

The bus shelter in this experiment had no tactile information about which bus stopped there, and there was another shelter nearby, further confusing the participants. The start point for this task was adjacent to the shelter, but with no way to identify which bus stopped there, they had to search for help or other information. For those participants with no vision, t-tests showed a significant difference ($p < 0.006$).

Finding a bus stop is one of the hardest tasks for blind travelers. Indeed, in a previous experiment [1] and in this experiment's pre-test interview [2–3], participants rated it as one of the most difficult tasks. In addition, not one of the 15 participants in the experiment reported by Crandall and Bentzen [7] were able to find a bus pole that was identified by tactile signs. Bus stops can be located anywhere along the entire block face, and their signage, amenities, and cues are widely varied. Signage can be on trees, traffic sign poles, streetlights, or a separate pole. Stops can sometimes be identified by the location of a bench or shelter, but finding a bench

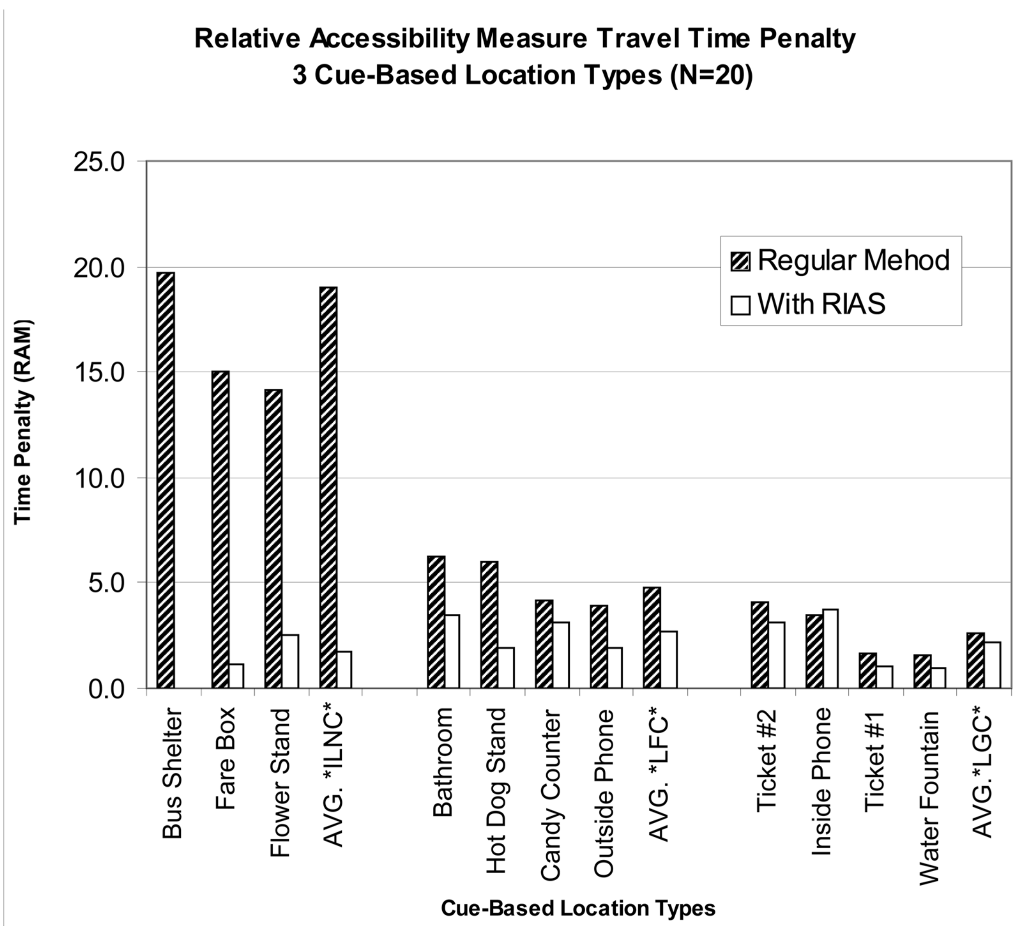

Figure 3. Travel time penalty (RAM) for cue-based location tasks.

does not always indicate a bus stop. Some shelters or benches are along the curb face, while others are set back near a building line. To exacerbate the situation, if there are no tactile or Braille markings, even when people find a stop they have no positive feedback about which bus stops there. These problems were clearly exposed in this experiment. The RAM for those who used their regular methods, including asking for help, was 20.0. Those who used RIAS knew exactly where they were and identified the correct bus stop with a RAM of 0.0. This kind of positive identification can be priceless to the traveler with visual impairments and can save much time, stress, and frustration, and help increase overall access.

Another hard task was to find the fare box at the Muni Light Rail station. The entrance ramp to the station was itself hard to locate, and, since there were no turnstiles to designate the start of the paid area, many people missed the fare box. It was placed in a position that did not correspond with typical 'environmental grammar,' meaning a common and consistent location. The RAM for the regular method users was 15.0, while the RIAS users had a RAM of 1.2 to identify the fare machine. The time advantage when using RIAS was also highly significant at ($p < 0.00006$).

An additional hard-to-find location was the flower concession, which was located in the main area of the terminal. The flower stand did not have much legibility because of the low level of activity there and the unexpectedness of this type of business being in a transit station. There were also few cues, insofar as there was usually no one in line talking to a clerk to give any auditory cues. Flowerpots also blocked counter access, for these reasons this location was categorized as another random or inconsistent amenity location with no cues. The RAM for participants who used their regular aids was 14.1, while those using RIAS had a RAM of 2.5. The t-test statistics for the two conditions showed a significant difference ($p < 0.0006$). These three locations, i.e., bus stop, fare box, and flower stand, were categorized as 'Inconsistent Locations and No Cues' (ILNC), and, for this type of location, the mean RAM was 19.0 and the RIAS users had a RAM of only 1.7.

Amenities with some or few cues

The bathrooms, hot dog stand, candy counter, and the outside public phones had some non-visual cues. This measure is 'Location, Few Cues' or LFC. In one task, people went from the restroom to the candy counter. This amenity was located in the main entrance hall of the terminal. There were often people around and the voices of the counter clerks were audible. The counter was 'L' shaped and quite long and this arrangement provided much room for errors by the participants. Usually, participants found a part of a counter and then asked others if candy was sold there. The smells of popcorn and candy did allow some users to locate the area when close. Only after getting a verbal response from the clerk did they know their location. This amenity was categorized as one with few cues. The regular method (No RIAS) participants had a RAM of 3.3 and, with RIAS, the RAM was 2.6. Although RIAS times were faster, there was no significant difference.

They also had to find the bathroom, which was located in a waiting room off the main terminal area. Once the waiting room is located, there are many obstacles of chairs, people, and pillars. The bathroom doors had the californium standard round 'F' or triangle 'M' tactile information. This location was categorized as an amenity with few cues. The *t*-tests showed a significant difference ($p < 0.03$).

Participants walked from the corner to an outside phone that was located about half way down the street from the starting point, and those participants who followed the curb could run into it. There was a wastebasket in front of the phone, and this obstacle slowed many people. Unlike the phone in the terminal, participants had not been to this location previously and there was rarely anyone using it to give auditory cues. Therefore, this amenity was categorized as one with few cues. The associated *t*-tests showed a significant difference ($p < 0.003$).

Finally, participants searched for the hot dog concession, which was a short walk from the ticket window. It was placed so close to the front exit that it seemed to confuse the participants. It was about 15 feet from the other two concessions that they had visited. At times there were voices at the counter to give some cues, so this amenity was categorized as one with few cues. The *t*-tests showed a significant difference ($p < 0.01$).

Four locations were categorized as those with 'Good Cues.' They are reviewed in [2] and not reported here. Overall, the data shows that the problems that cause persons with visual impairments to travel with less efficiency are not necessarily associated with an inherent disadvantage caused by the lack of vision. Inconsistent locations with no cues, difficult street crossings, and doors with no labels cause large time penalties and stressful travel, while locations with more environmental cues are much easier to find. It appears that it is often the lack of directional and location identity cues that cause the inefficient travel behavior (longer travel times) exhibited by many blind travelers. Fortunately, systems like RIAS can be used to improve access and user efficiency.

Relative access measures and successful mitigation

Time penalties increase as the number and types of trips increase. A more active traveler, who faces barriers to efficient travel, has more cumulative penalties than an inactive person. By summing up Equation 2, a formulation can be presented that compares two types of users, with different access mode criteria, over a wide range of activities. This formulation can be used to compare the daily, weekly, or longer variation in travel time for different groups. The cumulative *relative access measure* thus allows for examination of how time penalties combine, depending on the choice of activities, to restrict access due to daily or weekly time constraints.

$$R_{iklm} = \frac{\sum_k f_{ikl}\, d_{ikl}}{\sum_k f_{ikl}\, d_{ikm}} - 1.0 \qquad (3)$$

This equation is the same as Equation 2, except that time penalties are added together. Using this formulation, the access mode type can be varied to examine the overall time penalties or *relative access measures*. This formulation is modified here so that starting location i is relaxed to mean *any* location i for a trip to activity or location k. For example, the mean time penalty for trips to track doors is added to the penalty for crossing the hard street, and all the other types of locations, to produce the total time penalty of the 16 destinations reported in this paper.

Table I shows five different ways to judge the time penalties faced by people with vision restrictions:

- Mean times of the totally blind participants using their regular skills (including canes and dogs) divided by times of the familiar sighted user (FSU). This shows the RAM faced by blind travelers.
- Mean times of the totally blind participants using RIAS divided by times of the familiar sighted user (FSU). This shows the RAM when using RIAS.
- The difference between the two RAM coefficients.
- RAM time ratios for the regular method divided by the RAM ratios when using RIAS. This shows the extra time needed by regular users versus performance with RIAS.
- Time savings (in percent) when using RIAS instead of the regular skills (including canes and guide dogs).

A short discussion of Table I follows for the five rows of difficulty coefficients (RAM). The location variables with the highest degree of difficulty were (in decreasing order) ILNC, SH, DNC and LFC. The RAM ranged from 20.0 to 5.8. These types of locations can be so inconsistent in placement, legibility, safety, and availability of cues that there is no effective way to be trained to find or use them especially in an unfamiliar environment. The less difficult location variables were the WC and SM. These last two locations require skills that are well learned with O&M instruction, training, and practice. These 'less difficult' tasks still had RAMs from 2.3 to 1.8.

When using RIAS, the RAMs drop to a range of 3.7 to 1.1. Using RIAS lowered the RAM of all six location variables. The biggest savings were for the location variable ILNC, where the RAM was lowered by 17.3 (from 20.0 to 2.7). The next three locations most improved by RIAS were SH, DNC, and LFC, with a RAM savings range from 5.5 to 2.1. Even the lowest savings, WC and SM, were 0.7 and 0.6 respectively.

The same pattern exists when one computes the time penalty or RAM of using regular methods over that for RIAS. ILNC, SH, and DNC were still the most difficult locations, when compared to RIAS, with a range of 7.3 to 1.9, while the less difficult tasks were SM, LFC, and WC with a RAM difficulty rating of 1.6 to 1.3 more than when using RIAS.

It is important to realize how much time could be saved with the addition of more accessible cues, including directional and identity cues, in an

Table I. Relative accessibility measure coefficients for various locations.

Relative difficulty for Transit Tasks as measured by the *Relative accessibility measure* Variable name	Specific tasks and locations				General locations	
	Door No Cues DNC	Hard Street SH	Med. Street SM	Corner Walk WC	Inconsistent Location No Cues ILNC	Location Few Cues LFC
Blind, Regular Method/Sighted Baseline	6.0	6.9	1.8	2.3	20.0	5.8
Blind, with RIAS/Sighted Baseline	3.1	1.4	1.1	1.7	2.7	3.7
Difference between RAM coefficients	2.9	5.5	0.7	0.6	17.2	2.2
RAM ratios	1.9	4.9	1.6	1.3	7.3	1.6
% Time saved with RIAS versus Regular Method	48%	80%	38%	26%	86%	37%

environment that is lacking cues for the blind traveler. Using RIAS saved people searching for ILNC locations 86% of the regular method time, and it saved 80% of the time it took to normally cross a difficult street (SH). For location types DNC, SM, and LFC, the savings ranged from 48% to 37%. Even the lowest savings were notable, with the WC task saving 26% of the time that it took people to find these locations using their regular aids and travel skills.

Modeling transit task difficulty and mitigation

Using the above location RAM coefficients, three linear models were produced [2]. Models of these types could assist people interested in navigation without sight, especially transit operators, planners, and O&M instructors, to apply these findings to other environments. Producing a linear model of both experimental conditions and also of the time saved between the conditions can identify more completely which types of tasks present the most resistance to efficient travel. These types of models can be used to estimate the total travel time required for a blind traveler, based on the time for a sighted user. These and more advanced models would allow a better understanding of the difficulties that people without sight might face in a new environment, without the need to collect data from a group of blind users first. Architects and design professionals, especially transit planners, could test their designs before they are built in order to ensure the best compliance with Americans with Disabilities Act of 1990 (ADA) mandates. These types of models could help planners know where to concentrate their mitigation efforts and add to the body of knowledge about barriers to accessibility in urban environments. As the RAM models show, it is the environment, placement of destinations, and lack of cues that helps create the penalty to navigation without sight much more than the inherent lack of vision itself. A better designed and equipped environment would go a long way to ensure that this group could use the facilities with independence, efficiency, and dignity and would make the travel experience less stressful and provide a higher degree of personal safety.

Conclusion

There is no consistent restriction or time penalty that can be assigned to the overall travel and search times for travelers with visual impairments. These data and the subsequent models should allow planners to consider which locations demand attention in order to help mitigate barriers to access. Spatial knowledge acquisition, especially for people who are blind, can be increased [2] with proper attention to the consistent location of amenities. Accessibility for the blind can also be increased by giving more attention to providing cues to these locations, including the use of identity and directional cues such as those provided by RIAS. The continued existence and acceptance of such high penalties and barriers to independent travel should be questioned and examined by anyone concerned about providing access to urban opportunities and an equitable society for all people.

As used here, the relative access measure can be used to compare the efficacy of using assertive devices for persons with disabilities. It can also be used to measure the difficulty of different tasks or locations. This measure can be used to give empirical measurement to determine the excess effort required of those with mobility constraints, such as the extra travel distance required for those using wheelchairs.

Acknowledgments

We wish to thank the University of California Transportation Center and the California PATH Program of the University of California, in cooperation with the State of California Business, Transportation, and Housing Agency, Department of Transportation; and the United States Department of Transportation, Federal Highway Administration, for partial funding support. We also want to thank the management and staff of the San Francisco Caltrain terminal for allowing us to conduct this experiment, and the visually impaired participants who made this research possible.

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