Improving Public Transit Accessibility for Blind Riders by Crowdsourcing Bus Stop Landmark Locations with Google Street View

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Public transportation is a major key to independence, productivity, and community participation for people who are blind or severely visually impaired.

The American Foundation for the Blind
Accessible Mass Transit
Locating bus stops is a significant access barrier often because the bus stops are not clearly marked with non-visual indicators or are placed inconsistently off roadways.

The American Foundation for the Blind
Accessible Mass Transit
In a survey of 55 persons with visual impairments, **85% reported difficulties** in finding public transit pick-up points such as bus stops.

**R.G. Golledge et al**
Attitudes of Visually Impaired Persons Toward the Use of Public Transportation
J. of Vision Impaired & Blind, 1997
Navigating to a Bus Stop
1) Determine bus route
2) Find appropriate stop
3) Get on correct bus
4) Get off at correct stop
Navigating to a Bus Stop

1) Determine bus route
2) Find appropriate stop
3) Get on correct bus
4) Get off at correct stop
Roles of Technology

- Mobile auditory guide with GPS
- Online public transit trip planner
Roles of Technologies

Mobile auditory guide with GPS

Require data to build upon

Online public transit trip planner
Data Sources

- City government on-site auditing
- Mobile crowdsourcing
- Crowdsourced virtual auditing

Roles of Technologies

- Mobile auditory guide with GPS
- Online public transit trip planner
Data Sources

- City government on-site auditing
- Mobile crowdsourcing
- Crowdsourced virtual auditing
- Mobile auditory guide with GPS
- Websites with accessibility information

This talk is about...
What landmarks are useful for people with visual impairment to find bus stops?
Can we use Google Street View to find bus stops and identify surrounding bus stop landmarks?

Can crowd workers find bus stops and landmarks?
Find and label the following:

- Bus Stop Sign
- Bus Stop Shelter
- Bench
- Trash Can / Recycle Can
- Mail / News Paper Box
- Traffic Sign / Pole

Status:

Mission:
Your mission is to find and label a bus stop sign and landmarks near the sign.

Progress:
You have finished 0 out of 1.

Labeled Landmarks:

Qualifications:
- Bus Stop Auditor
- Bus Stop Explorer

Please enter any comments about this bus stop that may affect people with visual impairment (optional):

I cannot find any bus stop
Stop Information for E Thomas St & 16th Ave E

The stop is on the first street at or near the second street or landmark. See below for more details about Tunnel Stations and Bays.

Stop Id: 29274
Area: Seattle
Direction and Position: Eastbound / After the cross street or landmark
Shelter: Yes
Routes serving stop: MT 43-N, MT 8-E
Accessibility: Fully accessible

Comment: stop is South side, far

Tunnel Stations: The Downtown Seattle Transit Tunnel has five stations with four or more lettered stops, called Bays. The stations are International District Station, Pioneer Square Station, University Street Station, Westlake Station, and Convention Place Station. See
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Location of the bus stop

Absence/Presence of a shelter

Some accessibility information

Not all public transit organizations provide such information
Location of the bus stop

Absence/Presence of a shelter

Also, this information is still fairly coarse

Not all public transit organizations provide such information

**Tunnel Stations:** The Downtown Seattle Transit Tunnel has five stations with four or more lettered stops, called Bays. The stations are International District Station, Pioneer Square Station, University Street Station, Westlake Station, and Convention Place Station. See
Mobile Crowdsourcing
GoBraille [Azenkot 2011]; StopFinder [Prasain 2011]
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Users can provide bus stop information while they are waiting for the bus

The system requires users to be on-site
Crowdsourcing & Google Street View
Hara K., Le V., and Froehlich J.E. [ASSETS2012, CHI2013]
Crowdsourcing & Google Street View
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Amazon Mechanical Turk is an online labor market where you can hire workers to complete small tasks.
Mechanical Turk is a marketplace for work. We give businesses and developers access to an on-demand, scalable workforce. Workers select from thousands of tasks and work whenever it's convenient.

390,514 HITs available. View them now.

Make Money by working on HITs

HITs - Human Intelligence Tasks - are individual tasks that you work on. Find HITs now.

As a Mechanical Turk Worker you:
- Can work from home
- Choose your own work hours
- Get paid for doing good work

Find an interesting task Work Earn money

Get Results from Mechanical Turk Workers

Ask workers to complete HITs - Human Intelligence Tasks - and get results using Mechanical Turk. Register Now

As a Mechanical Turk Requester you:
- Have access to a global, on-demand, 24 x 7 workforce
- Get access to HITs completed in minutes
- Pay only when you're satisfied with the results

Fund your account Load your tasks Get results

or learn more about being a Worker
RQ1: What landmarks are useful for finding bus stops?

RQ2: Can we use Google Street View to find bus stops and landmarks?

RQ3: Can crowd workers find bus stops and landmarks?
Study One: Formative Interview Study

Study Two: Bus Stop Auditing

Study Three: Mechanical Turk Study
Study One: Formative Interview Study

Study Two: Bus Stop Auditing

Study Three: Mechanical Turk Study
Study Method

Phone-based semi-structured interviews

We recruited 18 people with visual impairments. Of these, 7 had no functional vision.

Age ranged from 24 to 67

Each session took ~40 minutes
We asked...
Patterns of public transit use
Challenges experienced
Coping strategies
Formative Study Findings

To find bus stops, participants mentioned using walking directions from transit trip planners.

Once participants reached the vicinity of the stop, they commonly searched for landmarks.
There's really no rhyme or reason for where they put bus stops. And there's no way to...tell where a bus stop [is], 'cause **you don't ever know where the pole is, or how it's marked**, or... anything like that.

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**Participant 3**
Age: 63, Blind
I look for landmarks... like a bus shelter at a certain place... or if there's a hedge, like bushes in front of a certain place and right by those bushes there's a newspaper rack or something like that then I know that it's my stop.

Participant 14
Age: 55, Blind
Mail Box / Newspaper Box
Traffic Sign / Pole
Information about landmark is useful, but not readily available
Can we collect these data from Google Street View?
Can we collect these data from Google Street View?

How well does the Street View data reflect the current state of physical world?
Physical bus stop

Vs.

Google Street View
Study One: Formative Interview Study

Study Two: Bus Stop Auditing

Study Three: Mechanical Turk Study
Study Method

1. Collecting bus stop pictures

Two groups of our research team visited and took pictures of bus stops across 4 areas.

2. Coding bus stop landmarks

We counted number of bus stop landmarks in Street View images and physical audit pictures.

Evaluated the concordance between Street View images and physical audit using Spearman rank correlation.
Collecting bus stop pictures
To investigate the robustness of the Google Street View data, we visited bus stops across 4 areas in 2 cities.
Four Audit Areas
Four Audit Areas

(a) Washington DC | (Dense Urban)

(b) College Park by UMD | (Suburban)
Four Audit Areas

(a) Washington DC | (Dense Urban)

(b) College Park by UMD | (Suburban)

(c) Downtown Seattle, WA | (Dense Urban)
Four Audit Areas

(a) Washington DC | (Dense Urban)
(b) College Park by UMD | (Suburban)
(c) Downtown Seattle, WA | (Dense Urban)
(d) Seattle by UW | (Semi-urban)
Four Audit Areas

Linear distance: 42.2 km

Number of Bus Stops: 179
Study Method

1. Collecting bus stop pictures

2. Coding bus stop landmarks
Study Method

1. Collecting bus stop pictures

2. Coding bus stop landmarks
Count landmarks in **Google Street View images**
Bus Stop Sign 1
Bus Stop Shelter 1
Bench 1
Trash Can 2
Mail Box 0
Pole 1

Google Street View

Explore mode: Find the closest bus stop and label surrounding landmarks

Mission:
Your mission is to find and label a bus stop sign and landmarks near the sign.

Progress:
You have finished 0 out of 1.

Labeled Landmarks:
- 0
- 0
- 0

Qualifications:
- Bus Stop Auditor
- Bus Stop Explorer

Please enter any comments about this bus stop that may affect people with visual impairment (optional):

I cannot find any bus stop

Submit
Count landmarks in physical audit pictures

- Bus stop sign
- Bus stop shelter
- Trash cans
- Pole
- Bench

<table>
<thead>
<tr>
<th>Physical Audit</th>
<th>Bus Stop Sign</th>
<th>Bus Stop Shelter</th>
<th>Bench</th>
<th>Trash Can</th>
<th>Mail Box</th>
<th>Pole</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
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<td>1</td>
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</table>
Study 2: Bus Stop Audit. Concordance between Google Street View and Physical Audit Data
Concordance between physical and GSV data

<table>
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<tr>
<th>Object</th>
<th>GSV Score</th>
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<tbody>
<tr>
<td>Bus Stop Sign</td>
<td>0.612</td>
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<tr>
<td>Bus Stop Shelter</td>
<td>0.877</td>
</tr>
<tr>
<td>Bench</td>
<td>0.875</td>
</tr>
<tr>
<td>Trash Can</td>
<td>0.715</td>
</tr>
<tr>
<td>Newspaper Box</td>
<td>0.776</td>
</tr>
<tr>
<td>Traffic Sign</td>
<td>0.811</td>
</tr>
</tbody>
</table>
Study 2: Bus Stop Audit. Concordance between Google Street View and Physical Audit Data

High concordance between physical and Street View data

Key point: Google Street View is a viable data source for up-to-date bus stop landmark info

Rundle et al., Using Google Street View to audit neighborhood environments. Amer. J. of Preventive Medicine 40, 1 (2011)
We will use landmarks counted by researchers in Google Street View as **ground truth** for Study 3: Mechanical Turk Study.
Study One: Formative Interview Study

Study Two: Bus Stop Auditing

Study Three: Mechanical Turk Study
Labeling Tool and Tasks

We asked turkers to complete 14-16 labeling tasks in one HIT

We paid $0.75 for each HIT

We navigated first time worker to go through four-stage interactive tutorial
Tutorial 1/4: Labeling Bus Stops
Your mission is to find and label bus stop landmarks in Google collected labels prior to their travel and know what bus sign. They can use such information to locate the exact position. You need to find and label the following bus stop landmarks.

Tutorial 2/4: Explore the Street View Scene!
Sometimes, you have to walk to find a bus stop. In this scene, you cannot initially see any bus stop. Let's work on the tutorial and find where the bus stop is. Please enter any comments about the bus stop that may affect people with visual impairment.

Tutorial 3/4: Identify a Missing Bus Stop
Sometimes, bus stops are missing in Street View images because of inaccurate data. In this tutorial, you will learn how to report the missing bus stops in Street View images.

Tutorial 4/4: Labeling Bus Stop Landmarks
In this final tutorial, you will learn all categories of landmarks that you have to find and label.

Labeled Landmarks:
- [Icon]
- [Icon]

Qualifications:
- Bus Stop Audience
- Bus Stop Location

Please enter any comments about the bus stop that may affect people with visual impairment.
Study Method

We used 150 out of 179 bus stops we visited.

We used ground truth labels that we generated in the Study 2 to assess quality of turkers’ labels.

We evaluated turker labels based on presence and absence of label types.
Assessing Label Quality

Ground Truth Labels
Assessing Label Quality

Turker Labels

Explore mode: Find the closest bus stop and label surrounding landmarks
4/6 correct overall
Results

153 distinct turkers completed 3,534 labeling tasks.

Each bus stop was labeled by at least 21 distinct turkers.

The median labeling time per task was 44.7s.

The average number of labels per task was 3.15.

When compared with our ground truth dataset, overall turker accuracy was 82.5%.
“Technically” correct but not part of the bus stop.
Turker Majority Vote Group

Group of 1 turker

Group of 3 turkers

Group of 5 turkers

Group of 7 turkers

Hara K., Le V., and Froehlich J.E. [CHI2013]
Study 3: Mechanical Turk Study

Overall Accuracy

Average Accuracy (%)

- 1 Turker: 82.50%
- 3 Turkers: 85.90%
- 5 Turkers: 86.60%
- 7 Turkers: 87.30%

Number of Turkers in a Group
Overall Accuracy

Accuracy increases with the number of turkers in the group

Study 3: Mechanical Turk Study

1 Turker: 82.50%
3 Turkers: 85.90%
5 Turkers: 86.60%
7 Turkers: 87.30%

Number of Turkers in a Group
Overall Accuracy

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Accuracy saturates after 3 turkers.

Study 3: Mechanical Turk Study
Overall Accuracy

Study 3: Mechanical Turk Study

Average Accuracy (%)

1 Turker: 82.50% ± 0.5%
3 Turkers: 85.90% ± 0.5%
5 Turkers: 86.60% ± 0.5%
7 Turkers: 87.30% ± 0.5%

Number of Turkers in a Group

Stderr: 0.5%
A single turker can provide bus stop landmark data with **82.5% accuracy**

With majority vote, it goes up to **87.3%**
Limitation and Future Work
We counted these labels as “mistakes”.

Label Placement
Image Age

GSV: July 2011

Physical Audit: March 2013

GSV: July 2011
Difficult Scenes
Lighting/Shadow and Blur
Summary

Bus stop landmarks such as bus stop shelters help people with visual impairment to locate bus stops.

Turkers can find bus stop landmarks with 82.5% accuracy from Google Street View.
This work is supported by

Google
Faculty Research Award

NSF

at&t
Questions?

Improving Public Transit Accessibility for Blind Riders by Crowdsourcing Bus Stop Landmark Locations with Google Street View

Kotaro Hara, @kotarohara_en
Inaccurate Bus Stop Locations

Bus stop
We collect bus stop locations from Google’s Transit data, and automatically drop turkers to nearby locations.
Sometimes bus stop locations are missing. We cannot automatically situate turkers in these cases.
## Bus Stop Signs

<table>
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<th># Bus Stop Signs in Physical Audit Data</th>
<th># Bus Stop Signs in GSV Images</th>
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<tbody>
<tr>
<td>R1</td>
<td>R2</td>
</tr>
<tr>
<td><img src="image1.png" alt="Image 1" /></td>
<td><img src="image2.png" alt="Image 2" /></td>
</tr>
<tr>
<td><img src="image7.png" alt="Image 7" /></td>
<td><img src="image8.png" alt="Image 8" /></td>
</tr>
<tr>
<td><img src="image13.png" alt="Image 13" /></td>
<td><img src="image14.png" alt="Image 14" /></td>
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Krippendorff’s $\alpha = 0.937$  

$\alpha = 0.761$
## Bus Stop Signs

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Krippendorff’s $\alpha = 0.937$

$\alpha = 0.761$

Alpha below 0.8 is not satisfactory
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<td>1</td>
</tr>
<tr>
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<td>1</td>
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\[ \alpha = 0.972 \]

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<tbody>
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<td>Bus Stop Sign</td>
<td>0.972, 0.916</td>
<td></td>
</tr>
<tr>
<td>Bus Stop Shelter</td>
<td>0.991, 0.955</td>
<td></td>
</tr>
<tr>
<td>Bench</td>
<td>0.940, 0.870</td>
<td></td>
</tr>
<tr>
<td>Trash Can</td>
<td>0.886, 0.946</td>
<td></td>
</tr>
<tr>
<td>Newspaper Box</td>
<td>0.957, 0.938</td>
<td></td>
</tr>
<tr>
<td>Traffic Sign</td>
<td>0.866, 0.874</td>
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Result

We obtained high quality landmark count data for both GSV and physical audit data ($\alpha > .866$).