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

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Cynthia L. Bennett[§], Vicki Le[†], Sean Pannella[†], Robert Moore[†],
Kelly Minckler[§], Rochelle H. Ng[§], Jon E. Froehlich[†]

UNIVERSITY OF MARYLAND [†]
COMPUTER SCIENCE UNIVERSITY OF MARYLAND
HCIL
makeability lab
dub
UNIVERSITY of WASHINGTON [§]

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

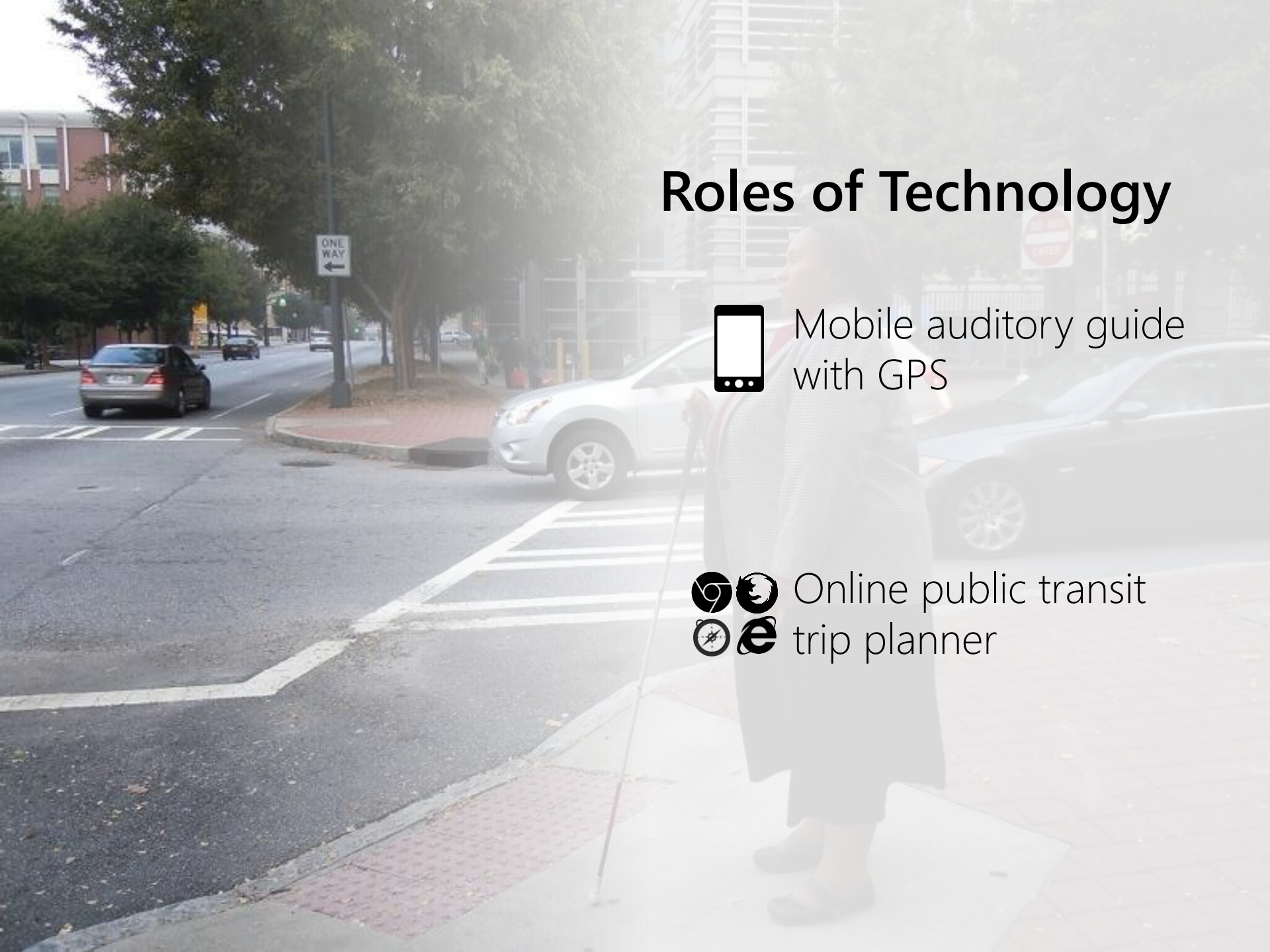
In a survey of 55 persons with visual impairments, **85% reported difficulties** in finding public transit pick-up points such as bus stops

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
DO NOT
ENTER


Navigating to a Bus Stop
1) Determine bus route
2) Find appropriate stop
3) Get on correct bus
4) Get off at correct stop
DO NOT
ENTER


ONE WAY
DO NOT ENTER

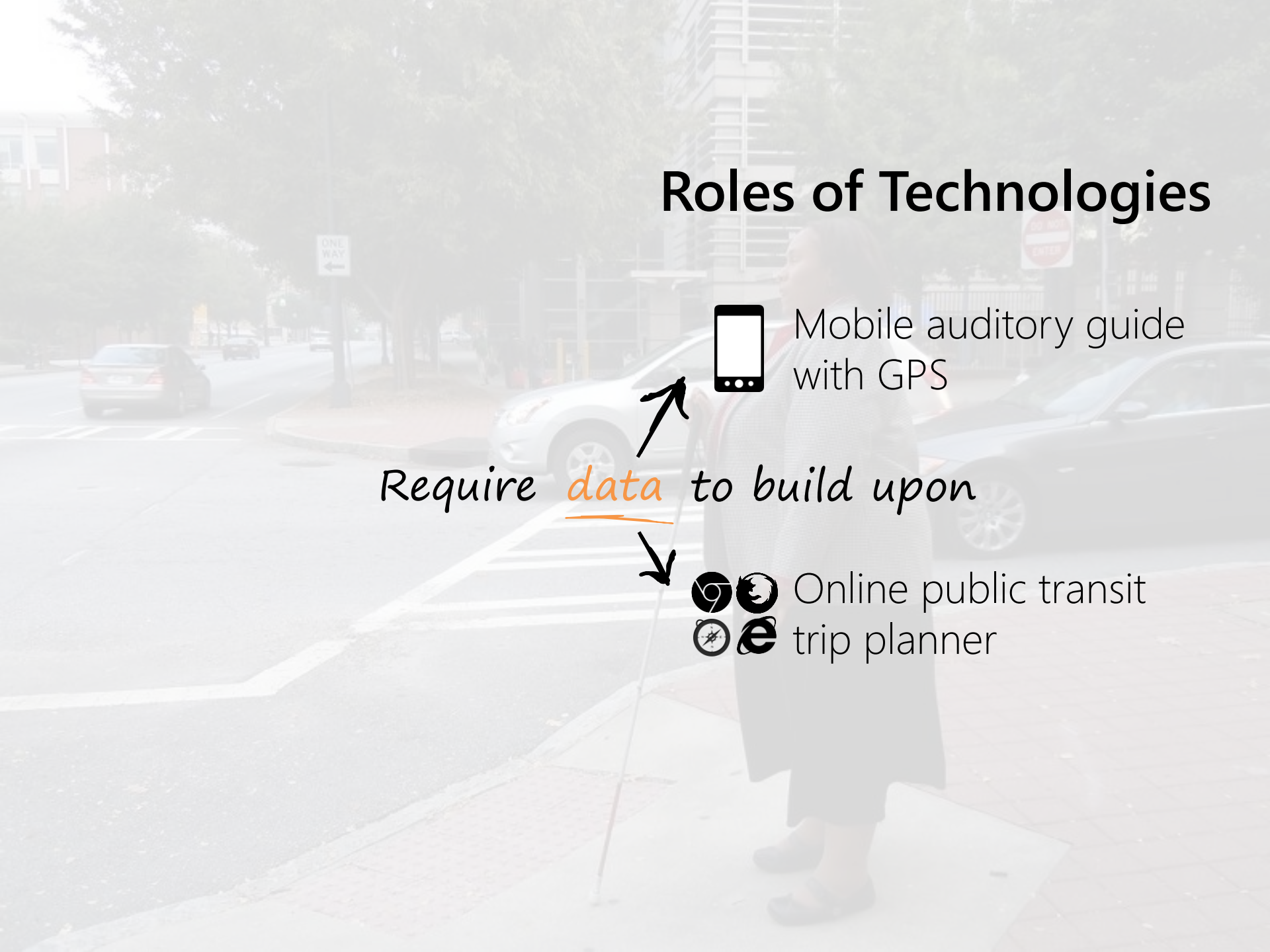


Roles of Technology

Mobile auditory guide with GPS

Online public transit trip planner

Roles of Technologies



Data Sources

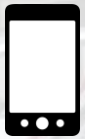
City government on-site auditing

Mobile crowdsourcing

Crowdsourced virtual auditing

data

Roles of Technologies



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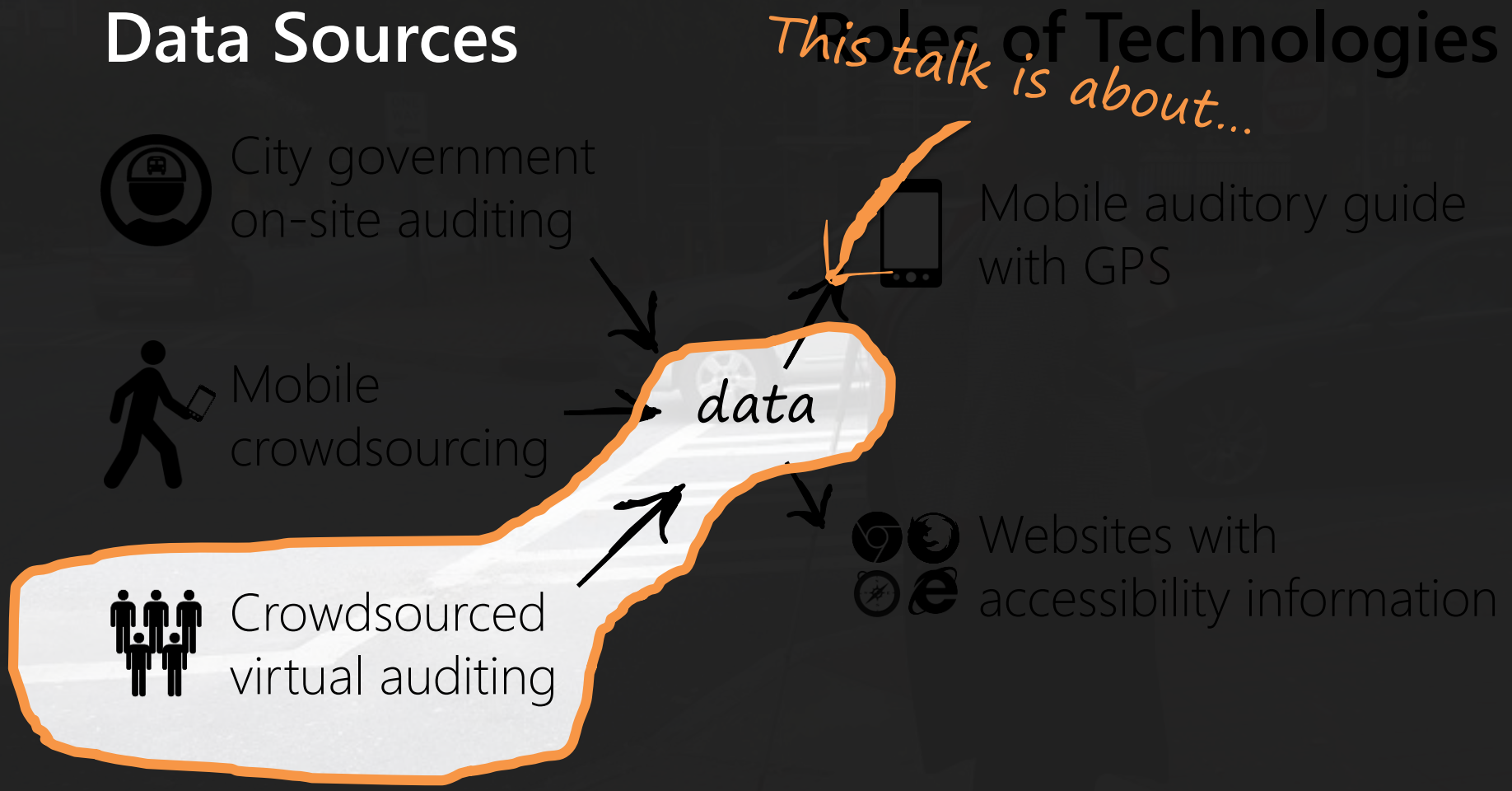
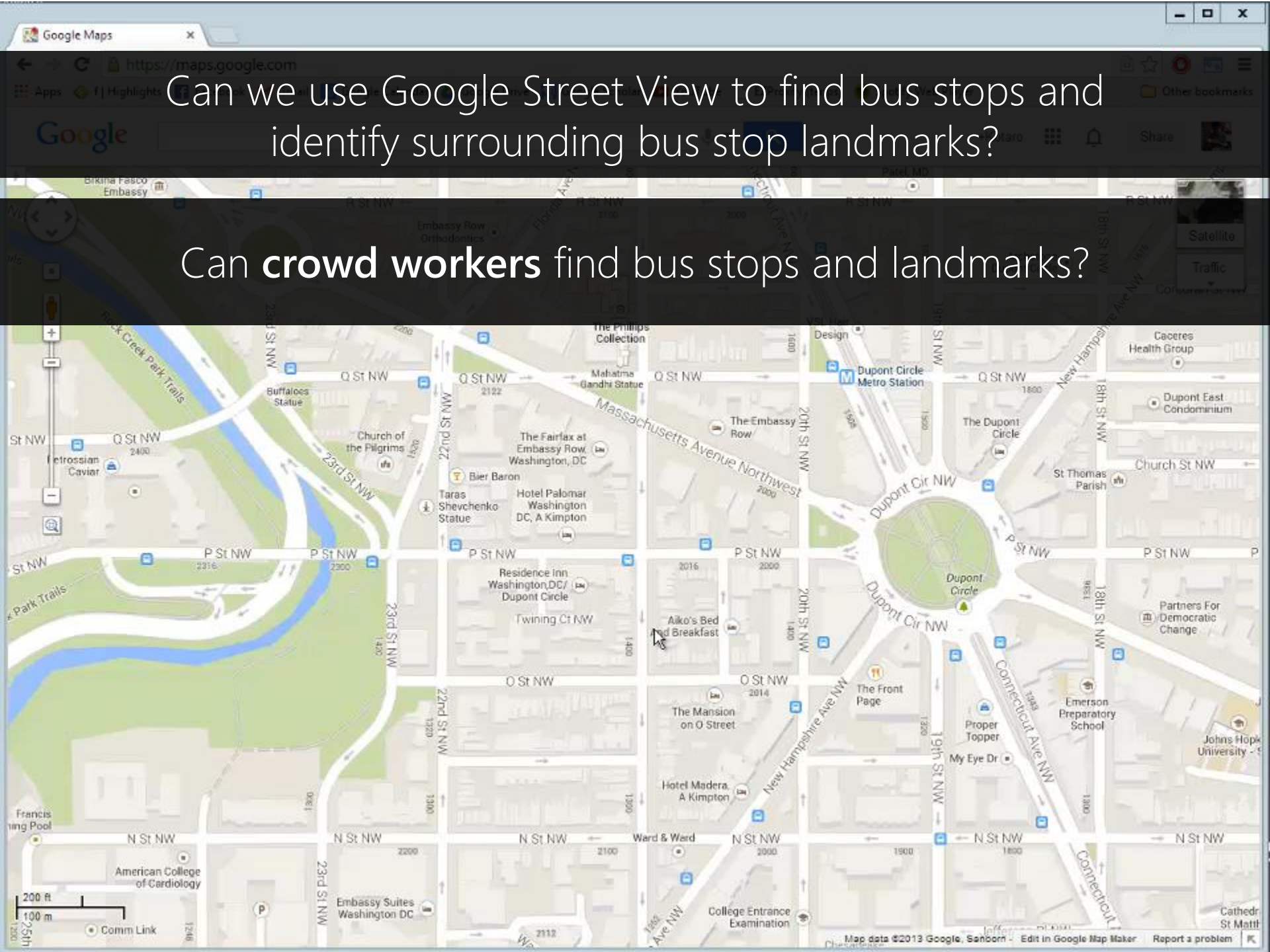
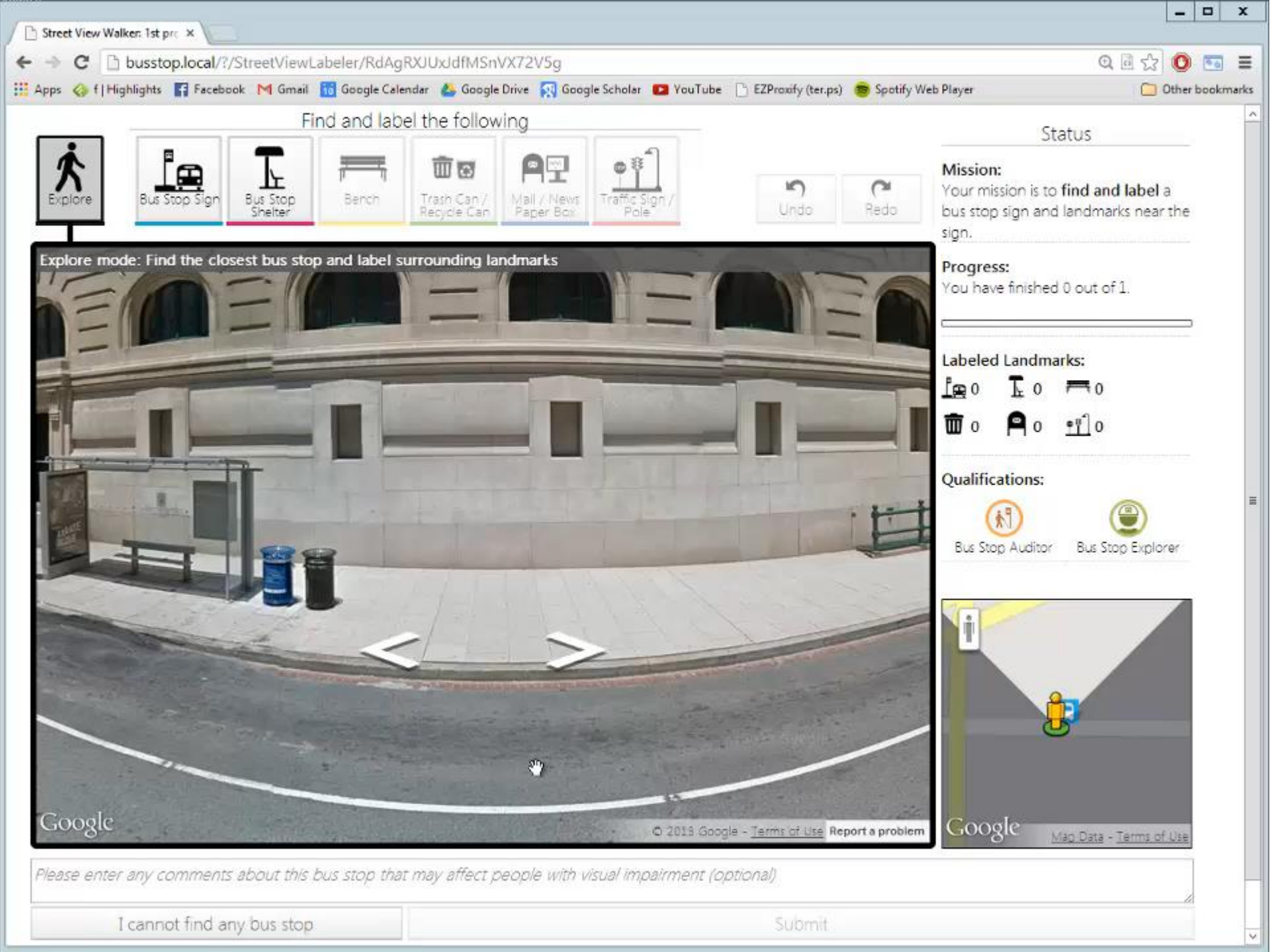



What landmarks are useful for
people with visual impairment to find bus stops?
BUS STOP
THE BUS
301-324-2877
Next Bus
RIDE


Google Maps
https://maps.google.com
Can we use Google Street View to find bus stops and identify surrounding bus stop landmarks?
Can **crowd workers** find bus stops and landmarks?
Massachusetts Avenue Northwest
Dupont Cir NW
Dupont Circle
Dupont Circle Metro Station
The Embassy Row
The Fairfax at Embassy Row, Washington, DC
Hotel Palomar Washington DC, A Kimpton
Residence Inn Washington,DC/ Dupont Circle
Twining Ct NW
Aiko's Bed and Breakfast
The Mansion on O Street
The Front Page
Proper Topper
My Eye Dr
Emerson Preparatory School
Partners For Democratic Change
Hotel Madera, A Kimpton
Ward & Ward
College Entrance Examination
Embassy Suites Washington DC
American College of Cardiology
Comm Link
Church of the Pilgrims
Buffaloes Statue
Taras Shevchenko Statue
Bier Baron
Mahatma Gandhi Statue
The Phillips Collection
Design
Caceres Health Group
Dupont East Condominium
The Dupont Circle
St Thomas Parish
Church St NW
Rock Creek Park Trails
Q St NW
P St NW
O St NW
N St NW
20th St NW
22nd St NW
23rd St NW
18th St NW
19th St NW
New Hampshire Ave NW
Connecticut Ave NW
Map data ©2013 Google, Sanborn · Edit in Google Map Maker · Report a problem


Street View Walker: 1st pr
busstop.local/?/StreetViewLabeler/RdAgRXJUxJdfMSnVX72V5g
Apps
f | Highlights
Facebook
Gmail
Google Calendar
Google Drive
Google Scholar
YouTube
EZProxify (ter.ps)
Spotify Web Player
Other bookmarks
Find and label the following
Explore
Bus Stop Sign
Bus Stop Shelter
Bench
Trash Can / Recycle Can
Mail / News Paper Box
Traffic Sign / Pole
Undo
Redo
Explore mode: Find the closest bus stop and label surrounding landmarks
Google
© 2013 Google - Terms of Use
Report a problem
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:
0
0
0
0
0
0
Qualifications:
Bus Stop Auditor
Bus Stop Explorer
Google
Map Data - Terms of Use
Please enter any comments about this bus stop that may affect people with visual impairment (optional)
I cannot find any bus stop
Submit

King County
Always at your service

HOME | NEWS | SERVICES | DIRECTORY | CONTAC search

Metro Transit

Online Trip Planner

Timetables
Route # Go

You are in: Metro Online > Trip Planner

- Metro Online Home
- Trip Planner
- Tips for using Trip Planner
- About Trip Planner
- Trip Planner Notices
- Commuter Trip Plan (Print or PDA)
- Point to Point Schedules (Print or PDA)

Dept. of Transportation
Metro Transit Division

King Street Center
201 S Jackson St
Seattle, WA 98104

Plan Trip | Find Schedule | Find Routes | Find Stops

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

Online Trip Planner

King County Metro Transit

Metro Online Home
Trip Planner
Tips for using Trip Planner
About Trip Planner
Trip Planner Notices
Commuter Trip Plan (Print or PDA)
Point to Point Schedules (Print or PDA)

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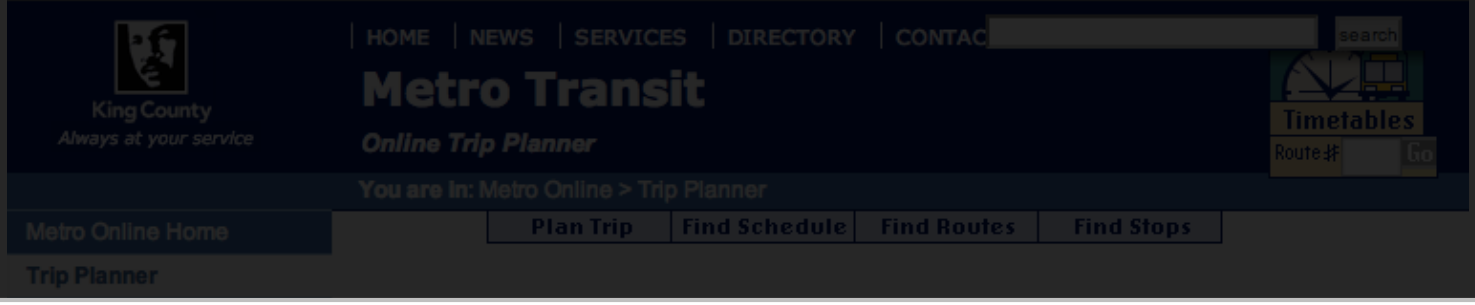

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Accessibility	Fully accessible
Comment	stop is South side, far

Location of the bus stop

Absence/Presence of a shelter

Some accessibility information

Comment stop is South side, far

Not all public transit organizations provide such information

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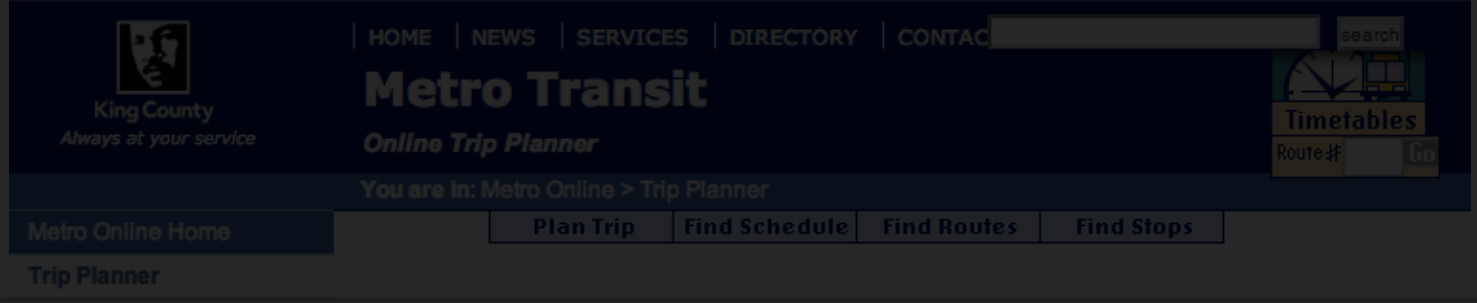

Direction and Position Eastbound / After the cross street or landmark

Location of the bus stop

Shelter Yes

Absence/Presence of a shelter

Routes serving this stop

Also, this information is still fairly coarse

Accessibility Fully accessible

Some accessibility information

Comment stop is South side, far

Comment stop is South side, far

Not all public transit organizations provide such information

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Mobile Crowdsourcing

GoBraille [Azenkot 2011]; StopFinder [Prasain 2011]

Mobile Crowdsourcing

GoBraille [Azenkot 2011]; StopFinder [Prasain 2011]

Users can provide bus stop information while they are waiting for the bus

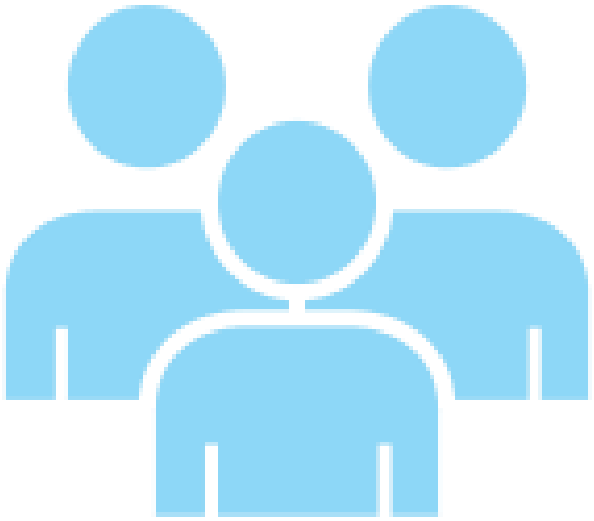
The system requires users to be on-site

Crowdsourcing & Google Street View

Hara K., Le V., and Froehlich J.E. [ASSETS2012, CHI2013]

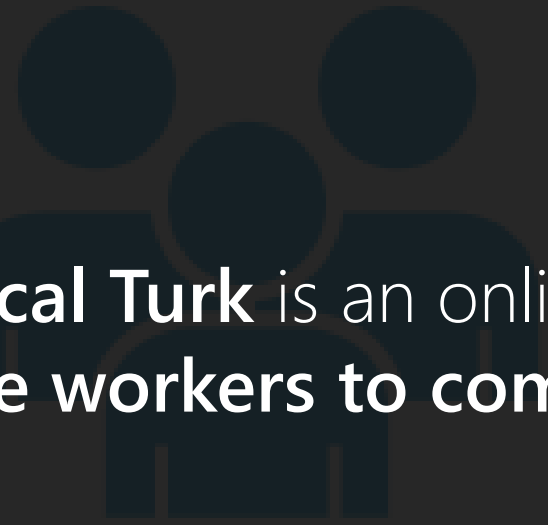
Crowdsourcing & Google Street View

Hara K., Le V., and Froehlich J.E. [ASSETS2012, CHI2013]



amazon®

mechanical turk
beta



Amazon Mechanical Turk is an online labor market where **you can hire workers to complete small tasks**

amazon
mechanical turk
beta

Amazon Mechanical Turk

https://www.mturk.com/mturk/welcome

Apps | f | Highlights | Facebook | Gmail | Google Calendar | Google Drive | Google Scholar | YouTube | EZProxify (ter.ps) | Spotify Web Player | Other bookmarks

amazonmechanical turk
Artificial Artificial Intelligence

Already have an account?
Sign in as a Worker | Requester

Your Account | HITs | Qualifications

Introduction | Dashboard | Status | Account Settings

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.

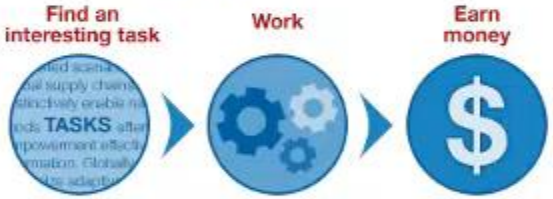
390,514 HITs available. View them now.

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 HITs Now

or learn more about being a **Worker**

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:

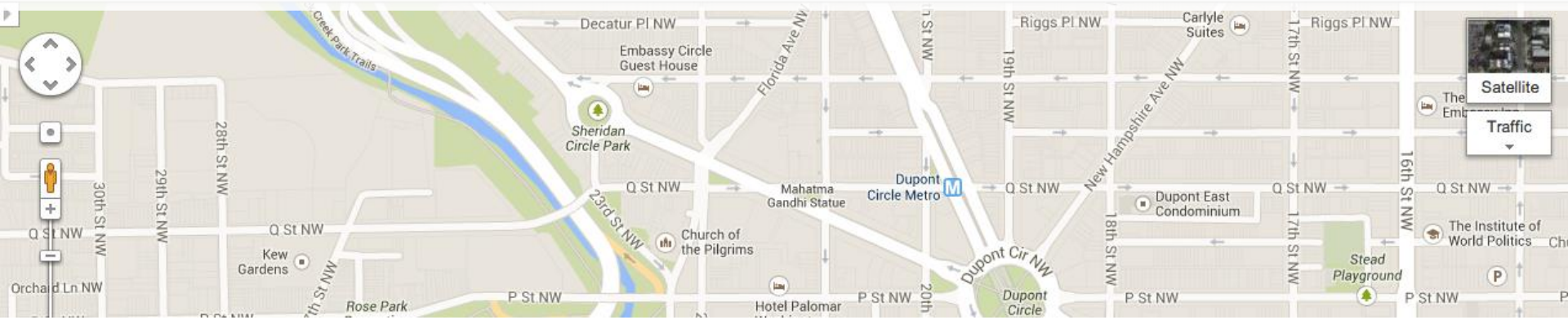
- Have access to a global, on-demand, 24 x 7 workforce
- Get thousands of HITs completed in minutes
- Pay only when you're satisfied with the results

Get Started

An amazon.com company

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?

amazon mechanical turk beta

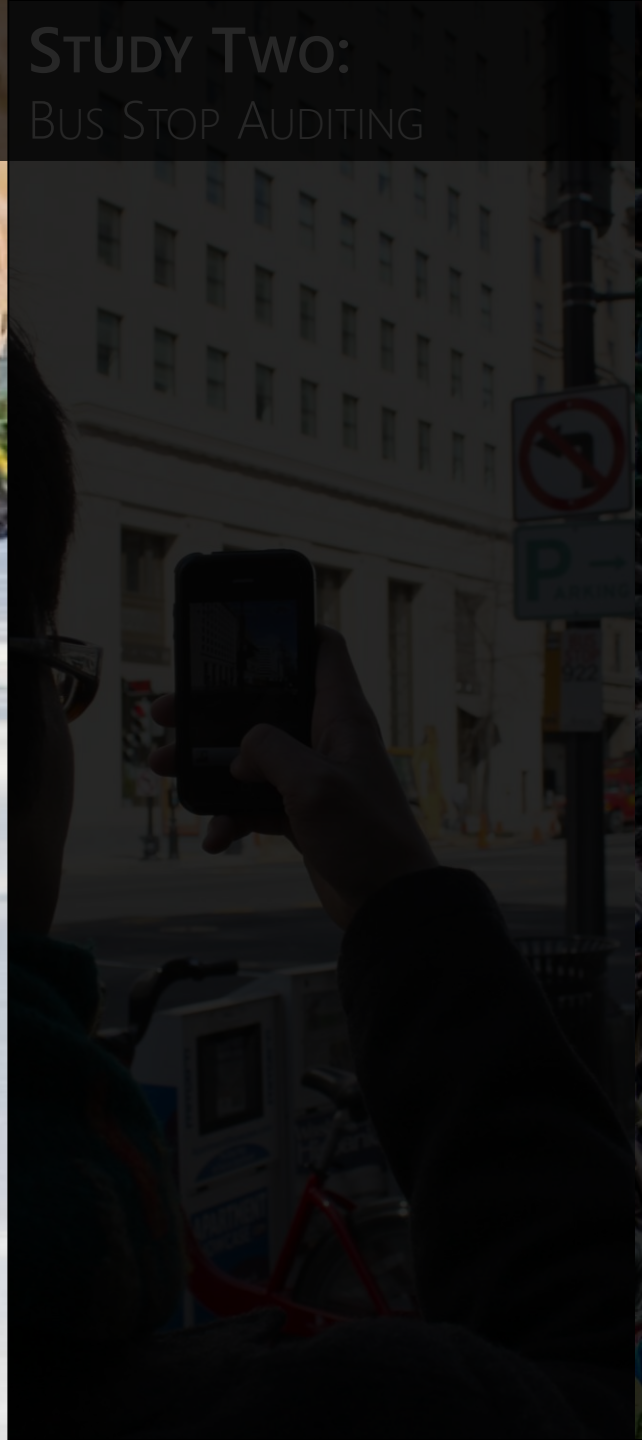
Study One:
Formative Interview Study

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

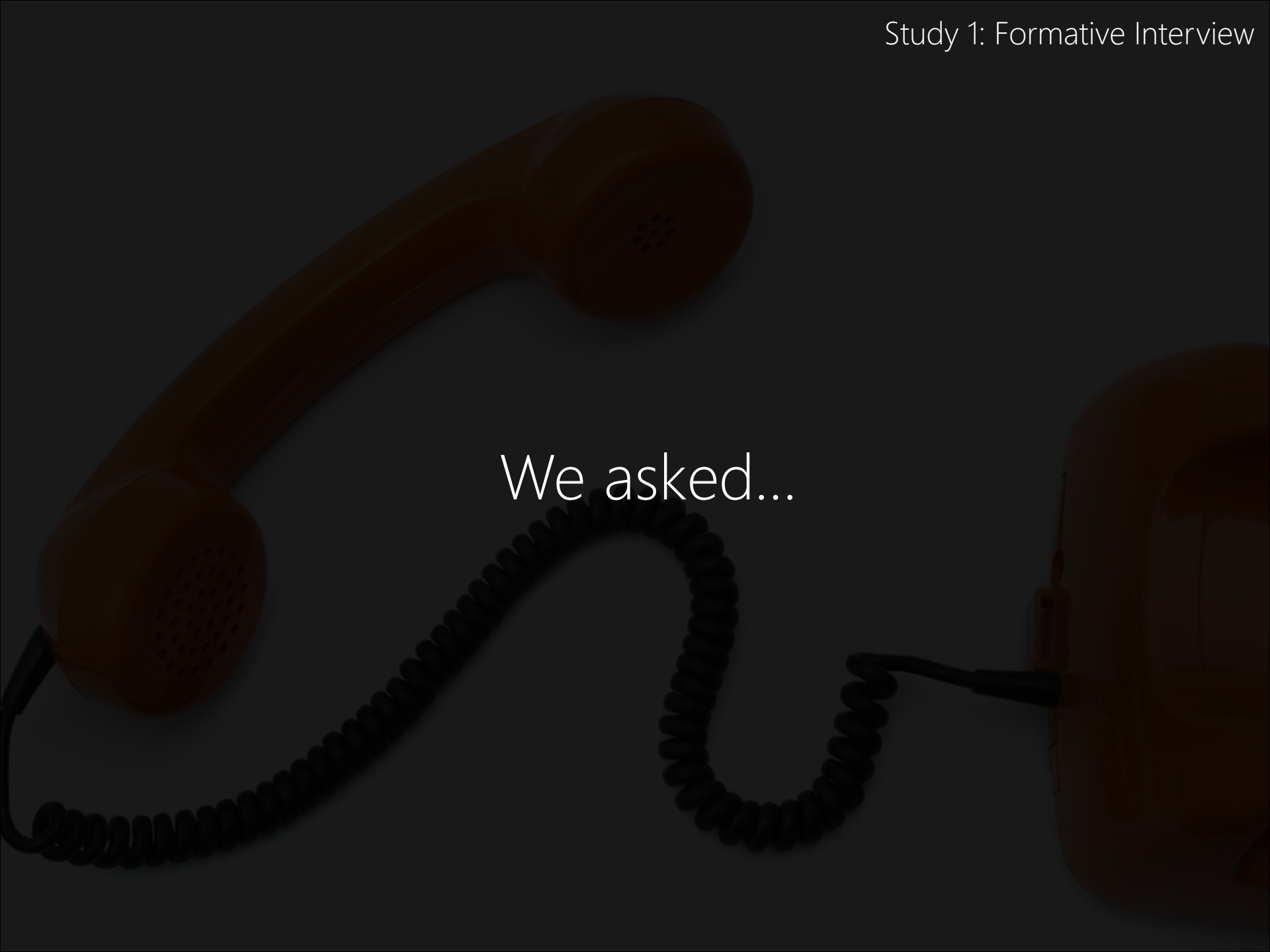
Study Method

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

Importance of landmarks

Formative Study Findings

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

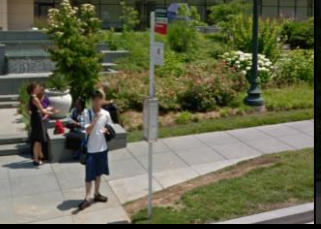
Once participants reached the vicinity of the stop, **they commonly searched for landmarks**

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.

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



Bus Stop Sign

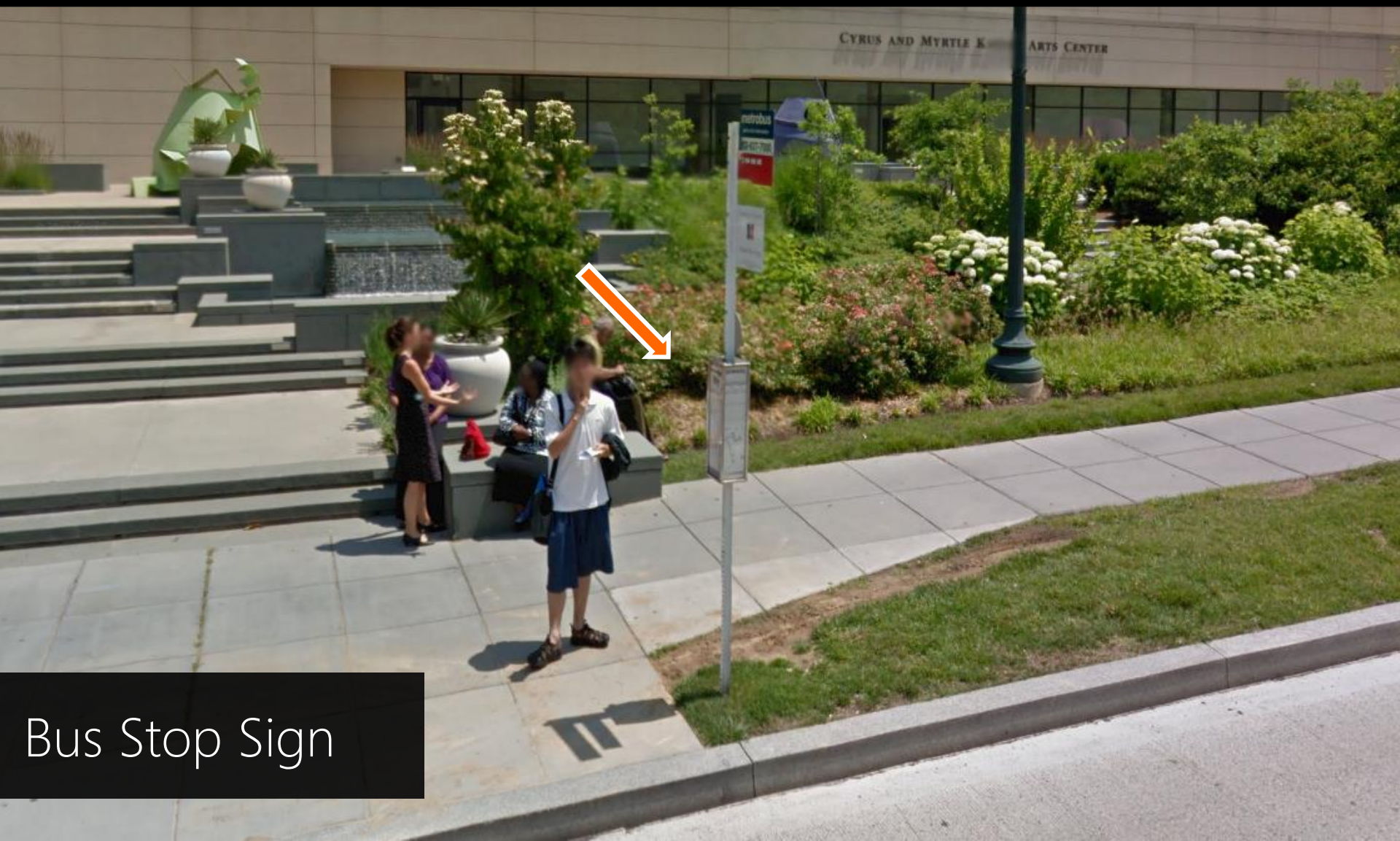
Bus Stop Shelter

Bench

Trash Can

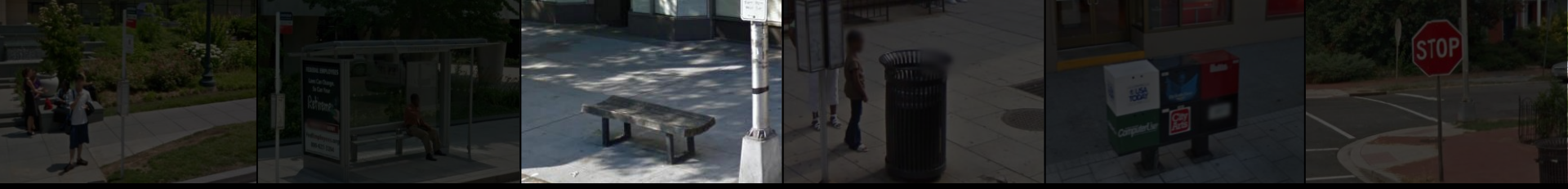
Newspaper Box

Traffic Sign



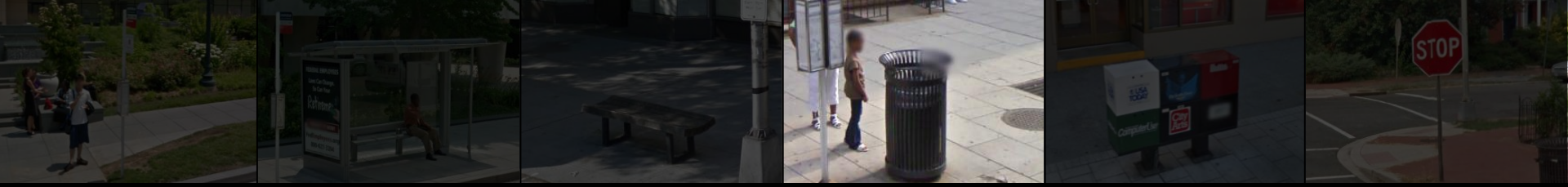
Bus Stop Sign


Bus Stop Sign
Bus Stop Shelter
Bench
Trash Can
Newspaper Box
Traffic Sign
FEDERAL EMPLOYEES
Laws Can Change,
So Can Your
Retirement
800-627-3394
STOP
Bus Stop Shelter



Bus Stop Sign | Bus Stop Shelter | **Bench** | Trash Can | Newspaper Box | Traffic Sign

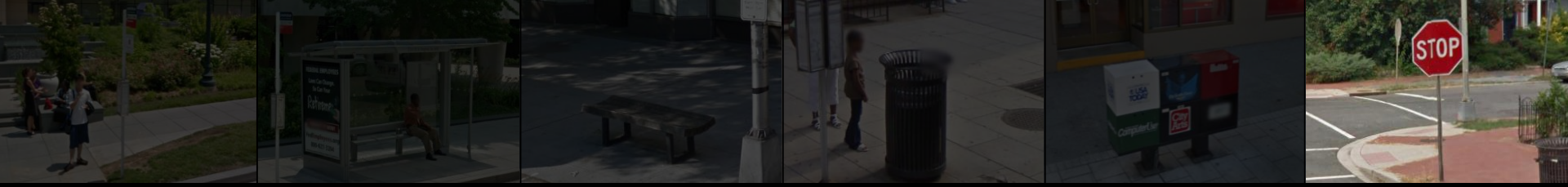
Bench



Bus Stop Sign | Bus Stop Shelter | Bench | **Trash Can** | Newspaper Box | Traffic Sign

Trash Can / Recycle Can


Bus Stop Sign
Bus Stop Shelter
Bench
Trash Can
Newspaper Box
Traffic Sign
Verizon wireless
DROID DOES
USA TODAY
ComputerUser
City Arts
Mail Box / Newspaper Box

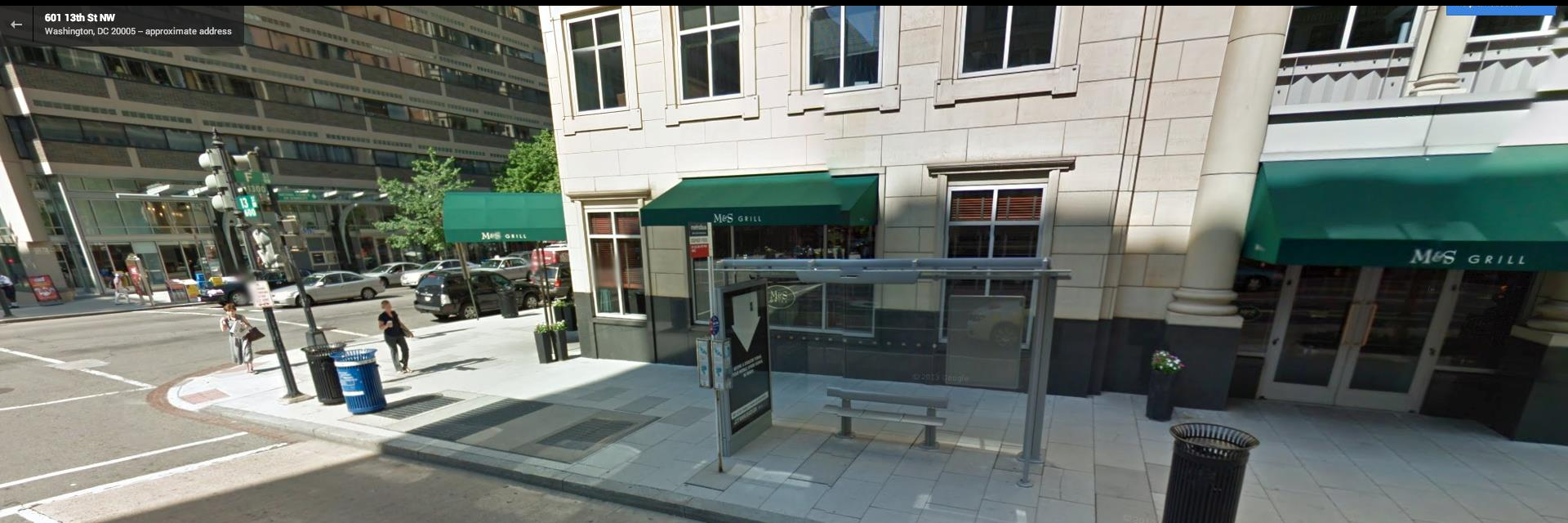


Bus Stop Sign | Bus Stop Shelter | Bench | Trash Can | Newspaper Box | **Traffic Sign**

Traffic Sign / Pole

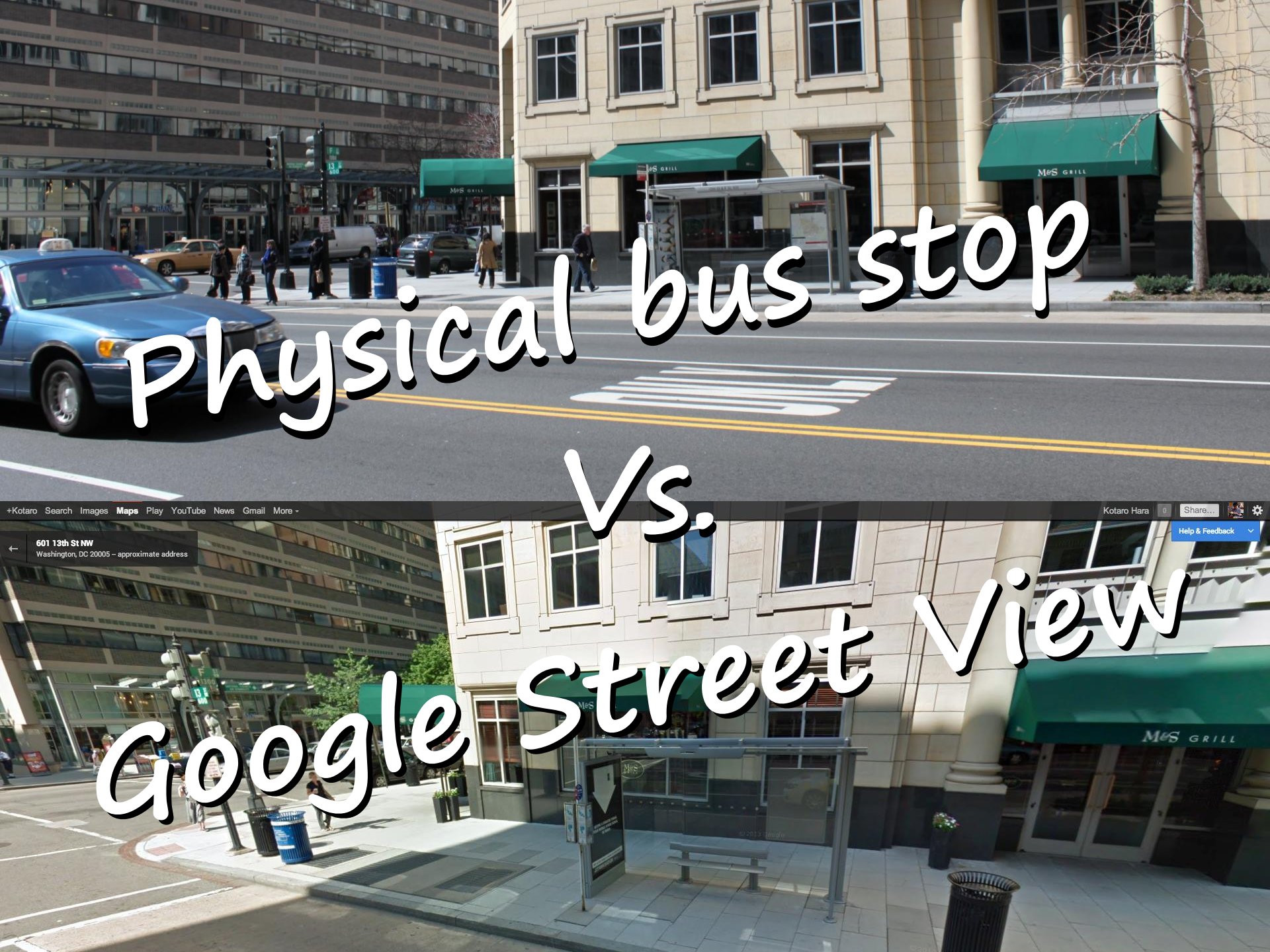
Information about landmark is useful, but **not readily available**

Can we collect these data from Google Street View?



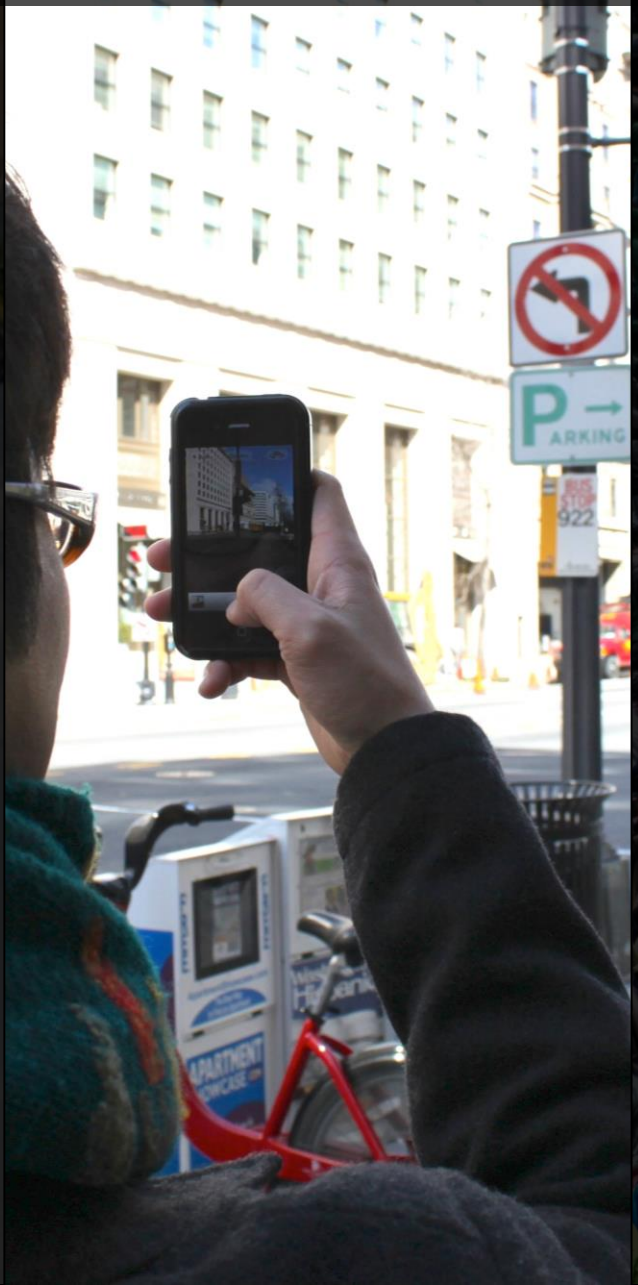
Can we collect these data from Google Street View?

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

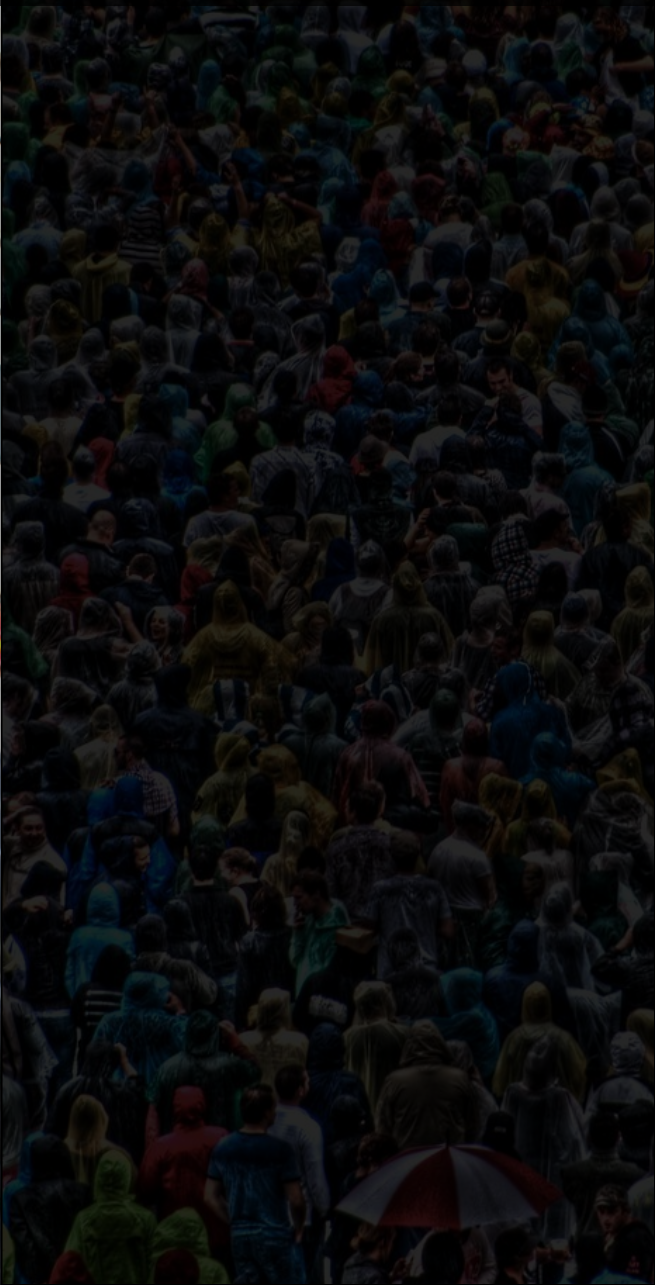

Physical bus stop
Vs.
Google Street View
+Kotaro Search Images Maps Play YouTube News Gmail More
Kotaro Hara
Share...
Help & Feedback
601 13th St NW
Washington, DC 20005 – approximate address
M&S GRILL

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

Physical audit pictures

2. Coding bus stop landmarks

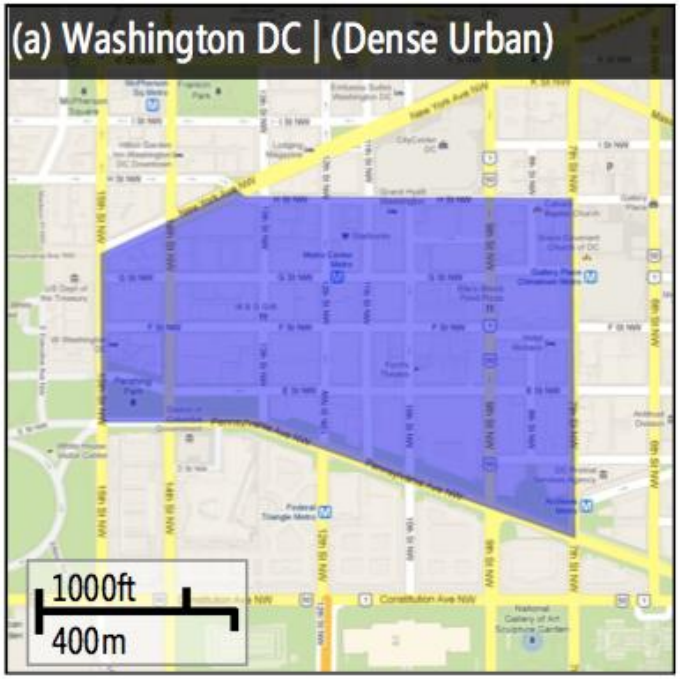
We **counted number of bus stop landmarks** in Street View images and physical audit pictures

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



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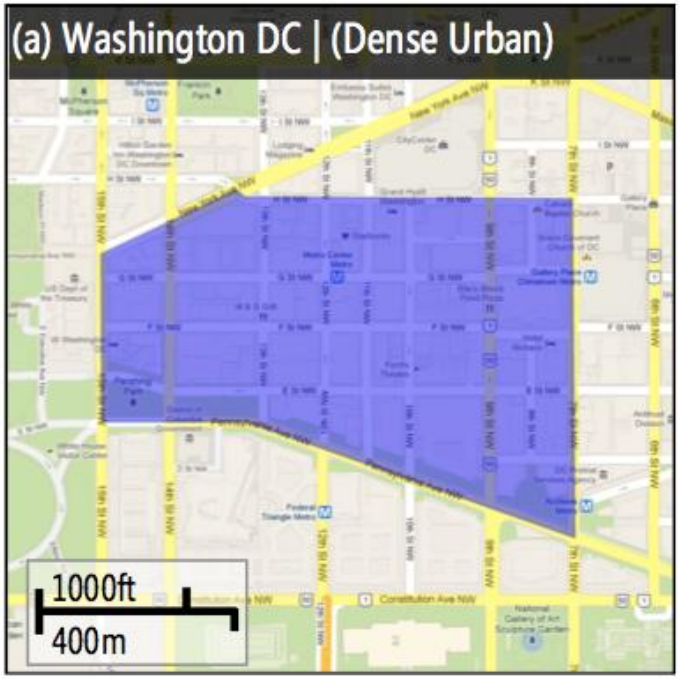

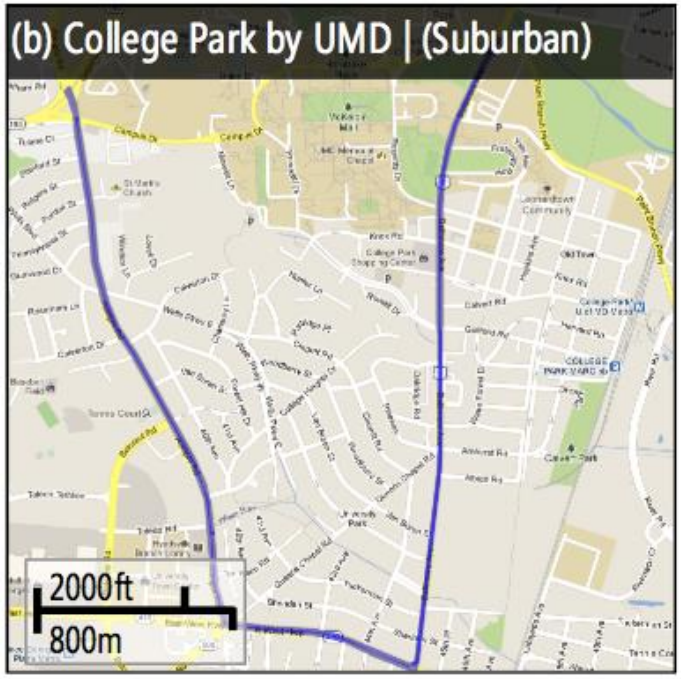

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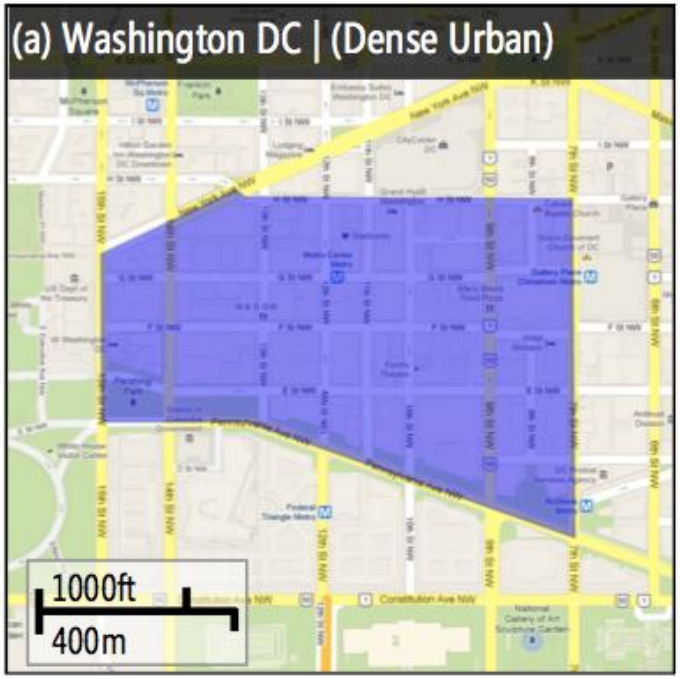

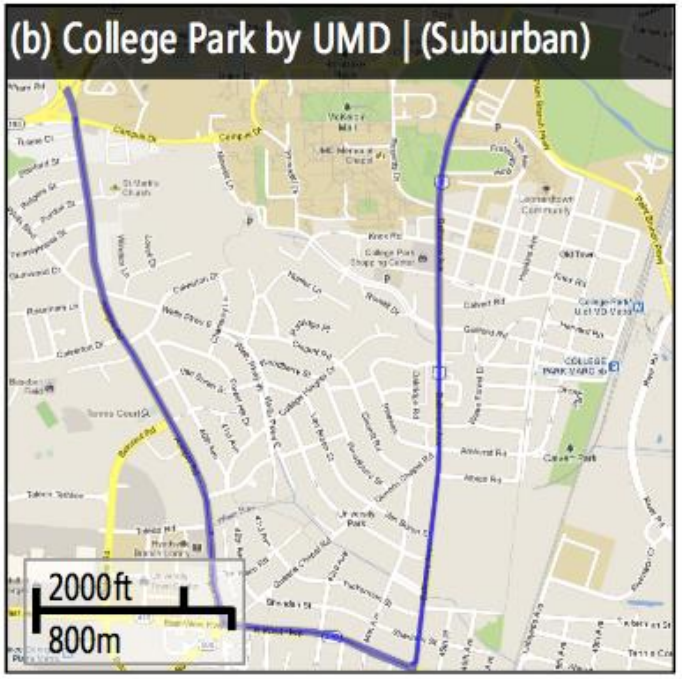

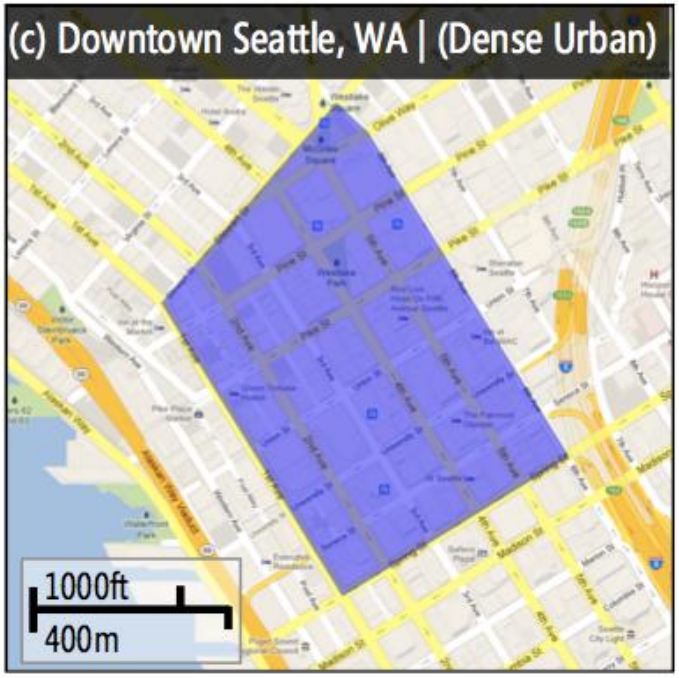

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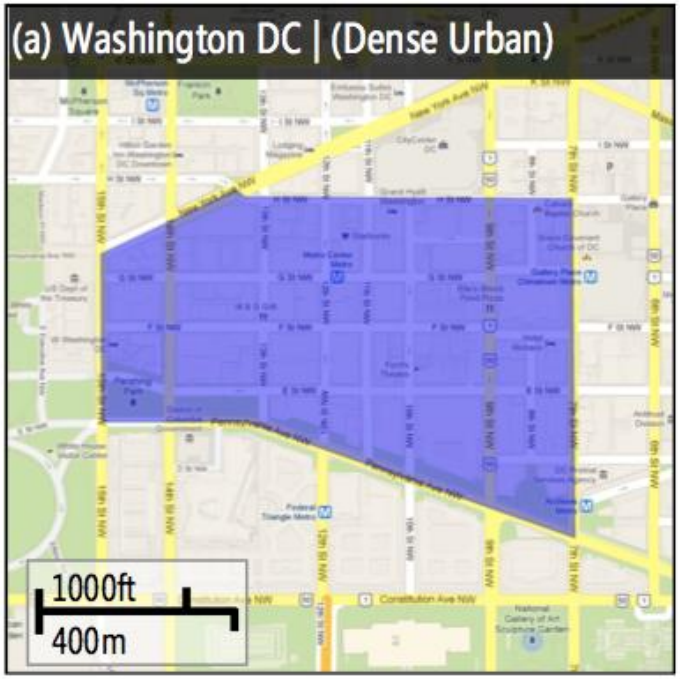

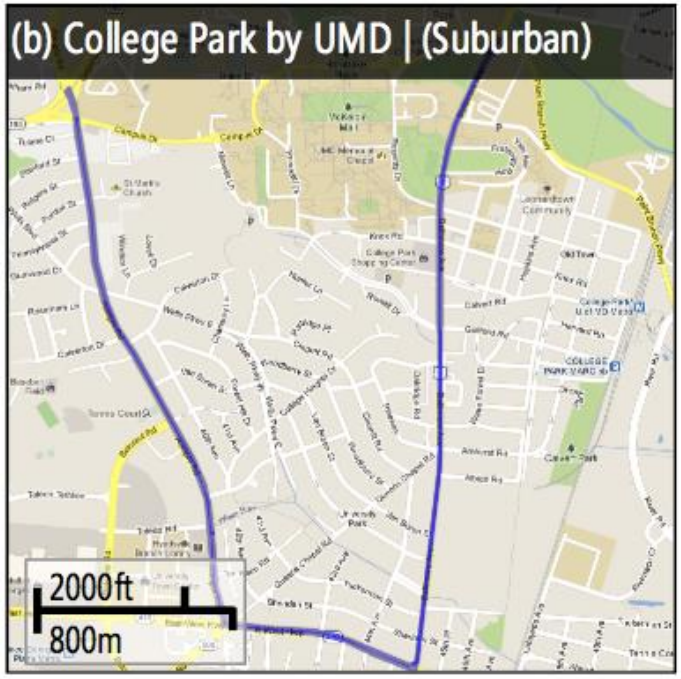

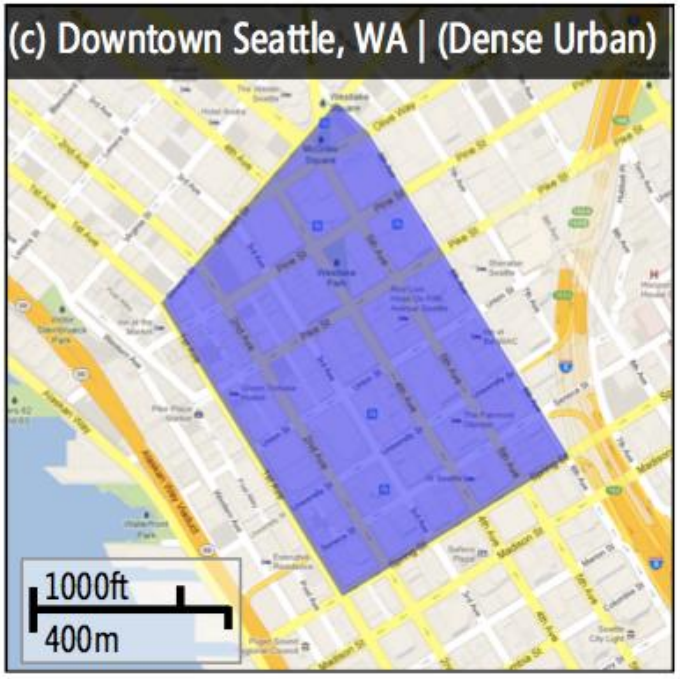

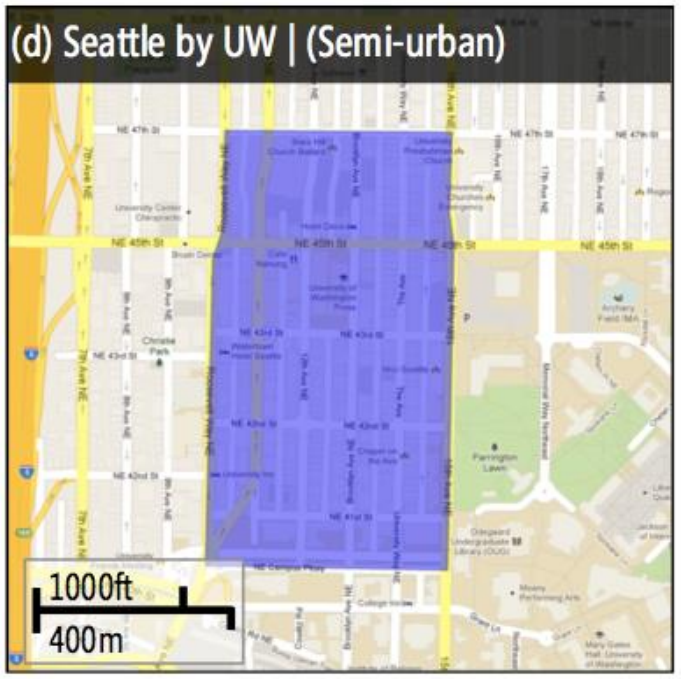

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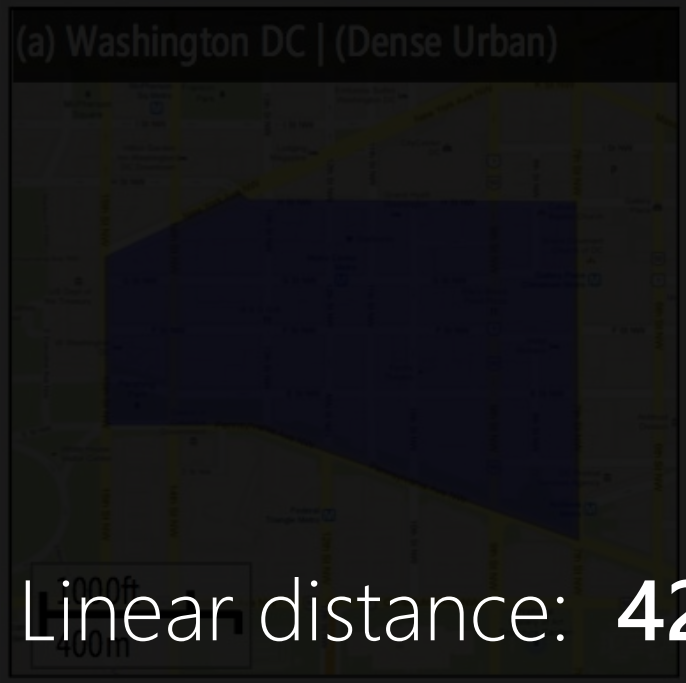
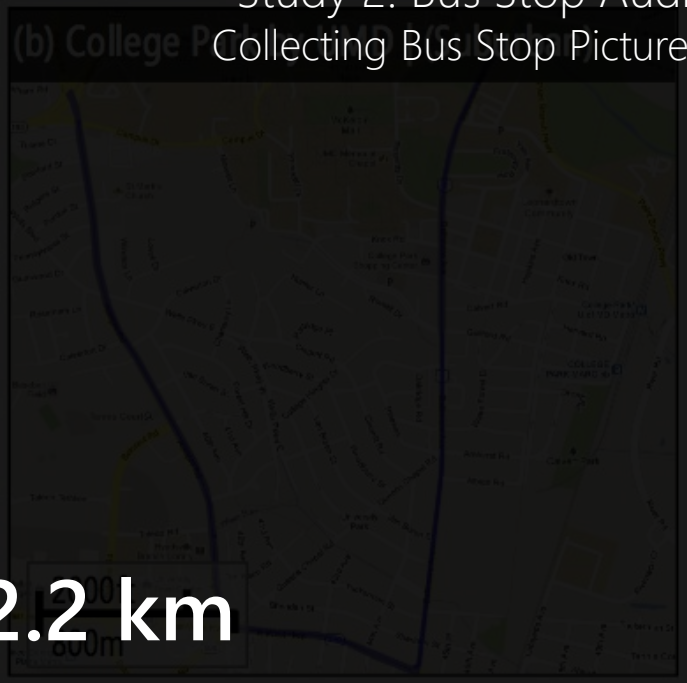
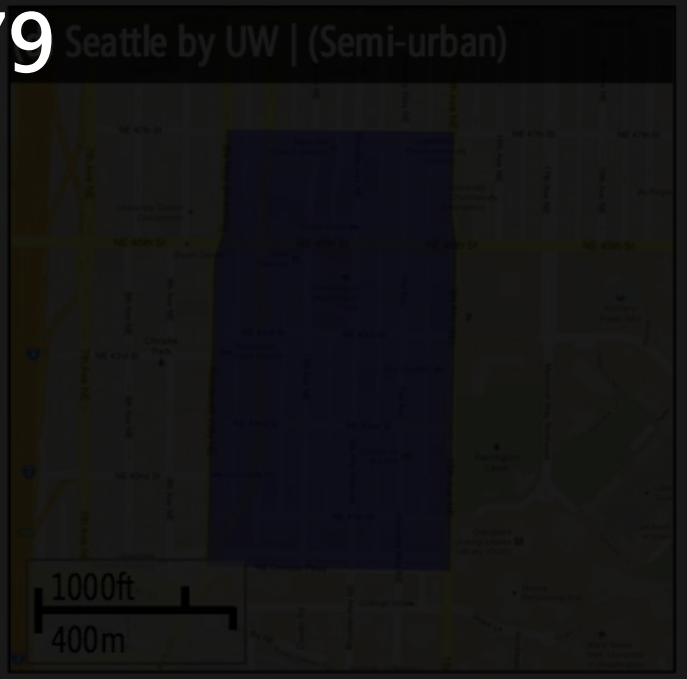
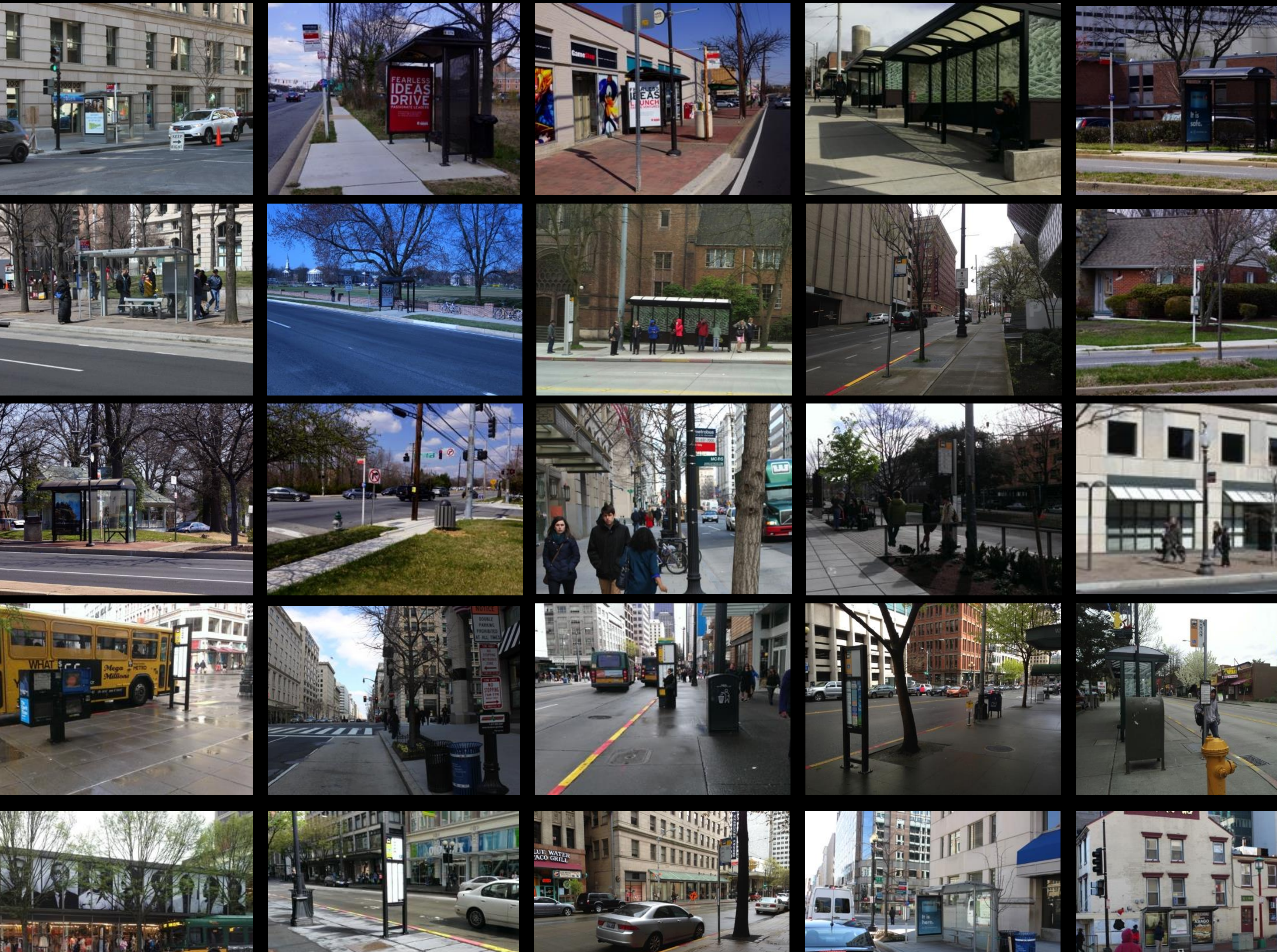




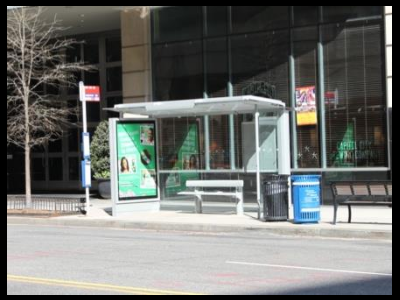
Linear distance: **42.2 km**

Number of Bus Stops: **179**




KEEP RIGHT
FEARLESS IDEAS DRIVE
FEARLESS IDEAS LAUNCH
GameStop
It is safe.
metrobus
Mega Millions
METRO
NOTICE
DOUBLE PARKING PROHIBITED AT ALL TIMES
NO STOPPING
BLUE WATER TACO GRILL
It is here.

Bus Stop 1





Bus Stop 2



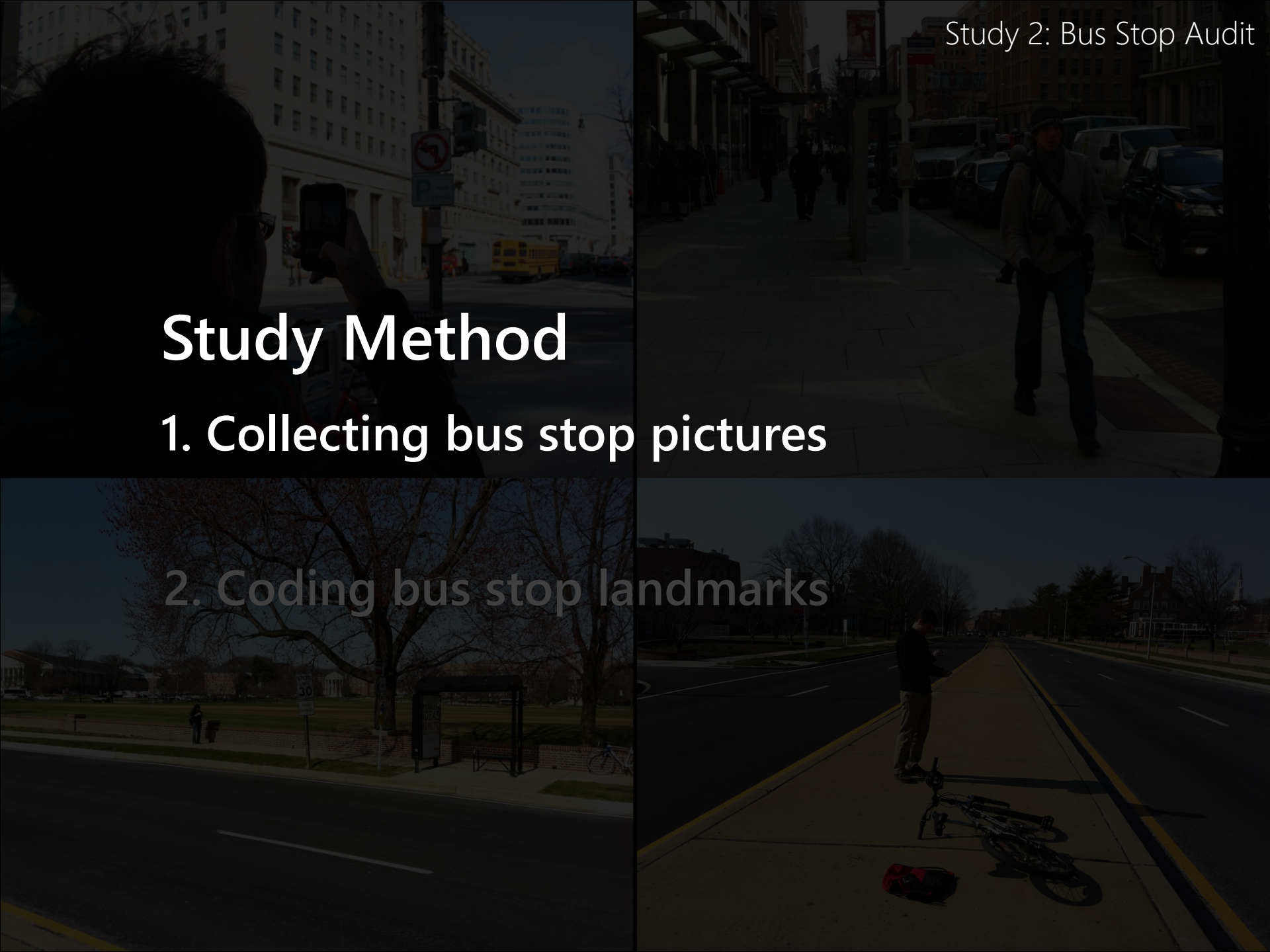


Bus Stop 3




Bus Stop 179



Study Method

1. Collecting bus stop pictures

2. Coding bus stop landmarks

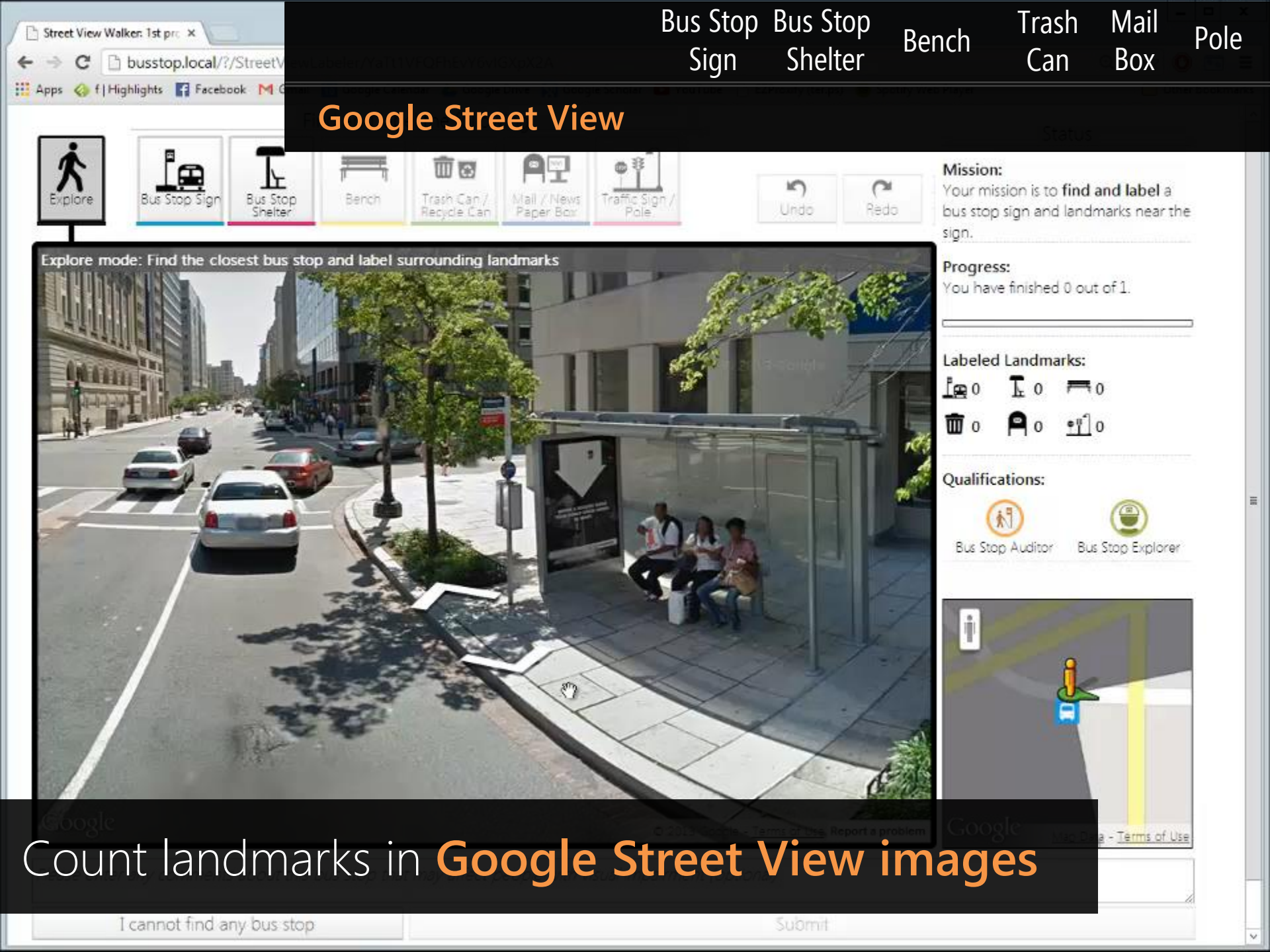
Study Method

1. Collecting bus stop pictures

2. Coding bus stop landmarks

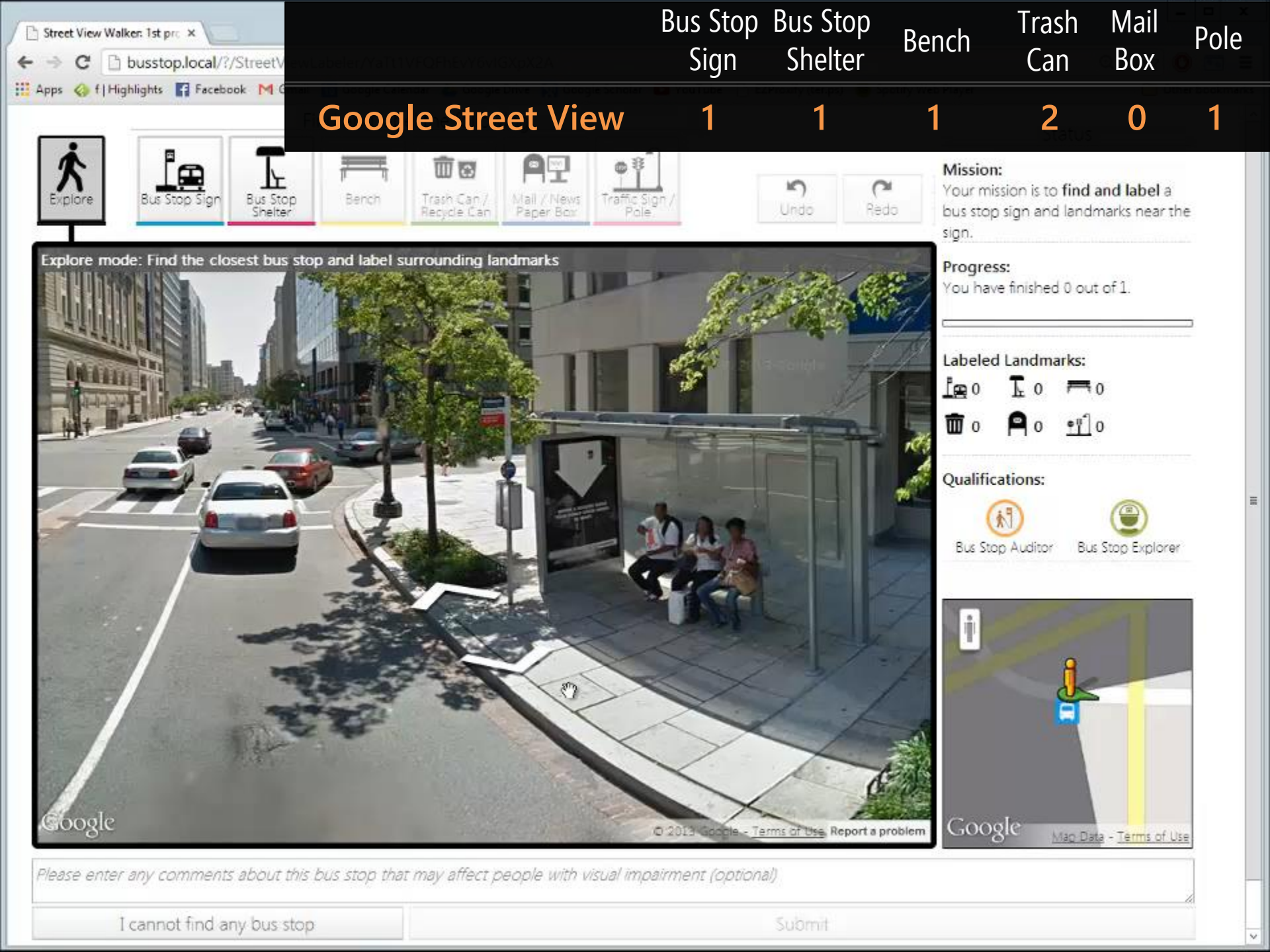
Bus Stop Sign | Bus Stop Shelter | Bench | Trash Can | Mail Box | Pole

Google Street View

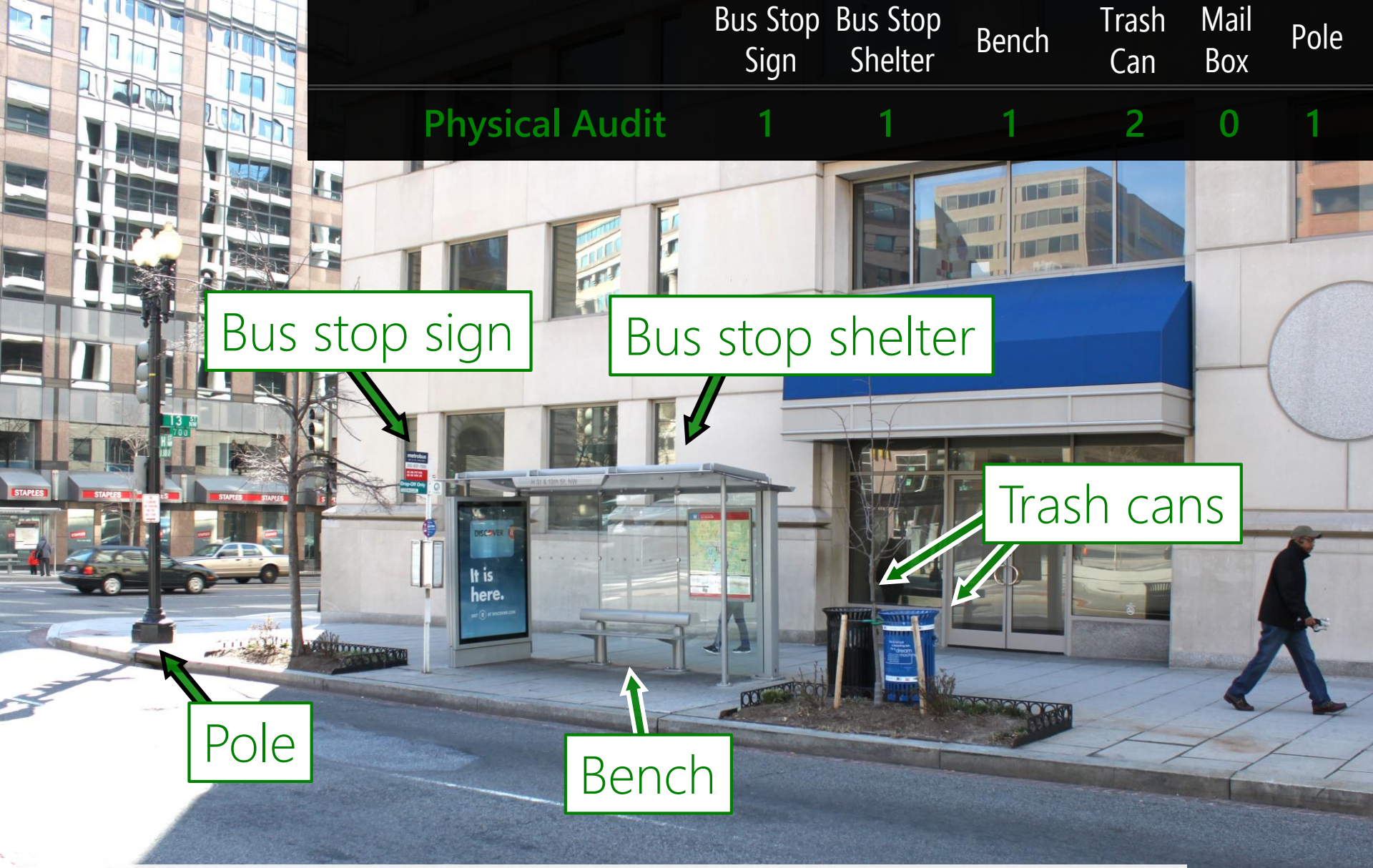


Count landmarks in **Google Street View images**

	Bus Stop Sign	Bus Stop Shelter	Bench	Trash Can	Mail Box	Pole
Google Street View	1	1	1	2	0	1

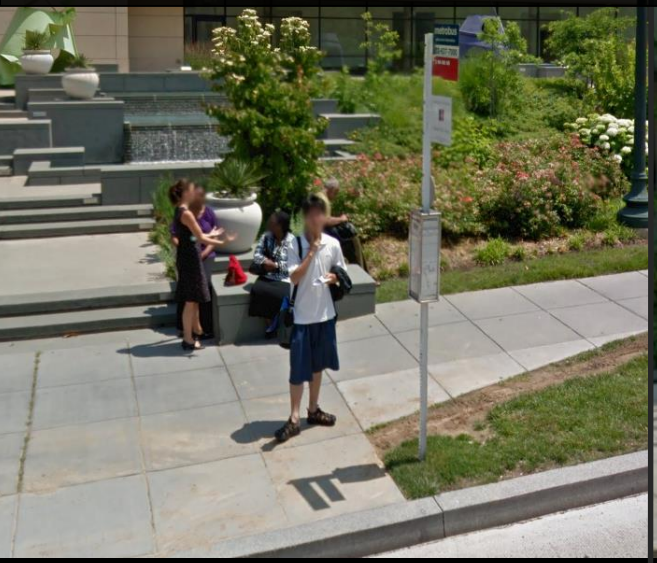


	Bus Stop Sign	Bus Stop Shelter	Bench	Trash Can	Mail Box	Pole
Physical Audit	1	1	1	2	0	1



Count landmarks in **physical audit pictures**

Study 2: Bus Stop Audit. Concordance between Google Street View and Physical Audit Data



Bus Stop Sign

Bus Stop Shelter

Bench

Trash Can

Newspaper Box

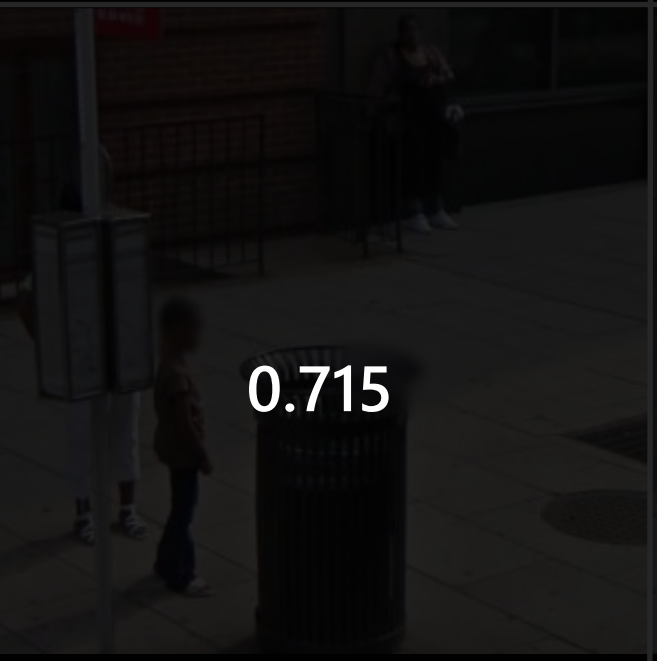
Traffic Sign

Concordance between physical and GSV data

Bus Stop Sign

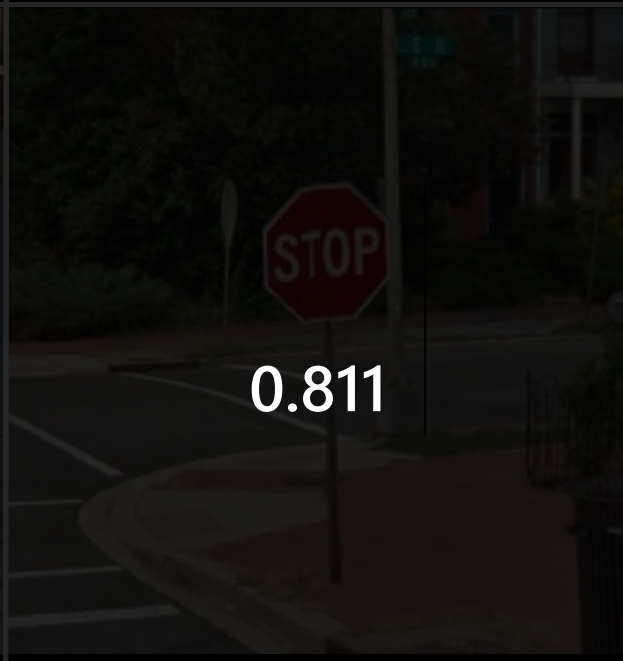
Bus Stop Shelter

Bench



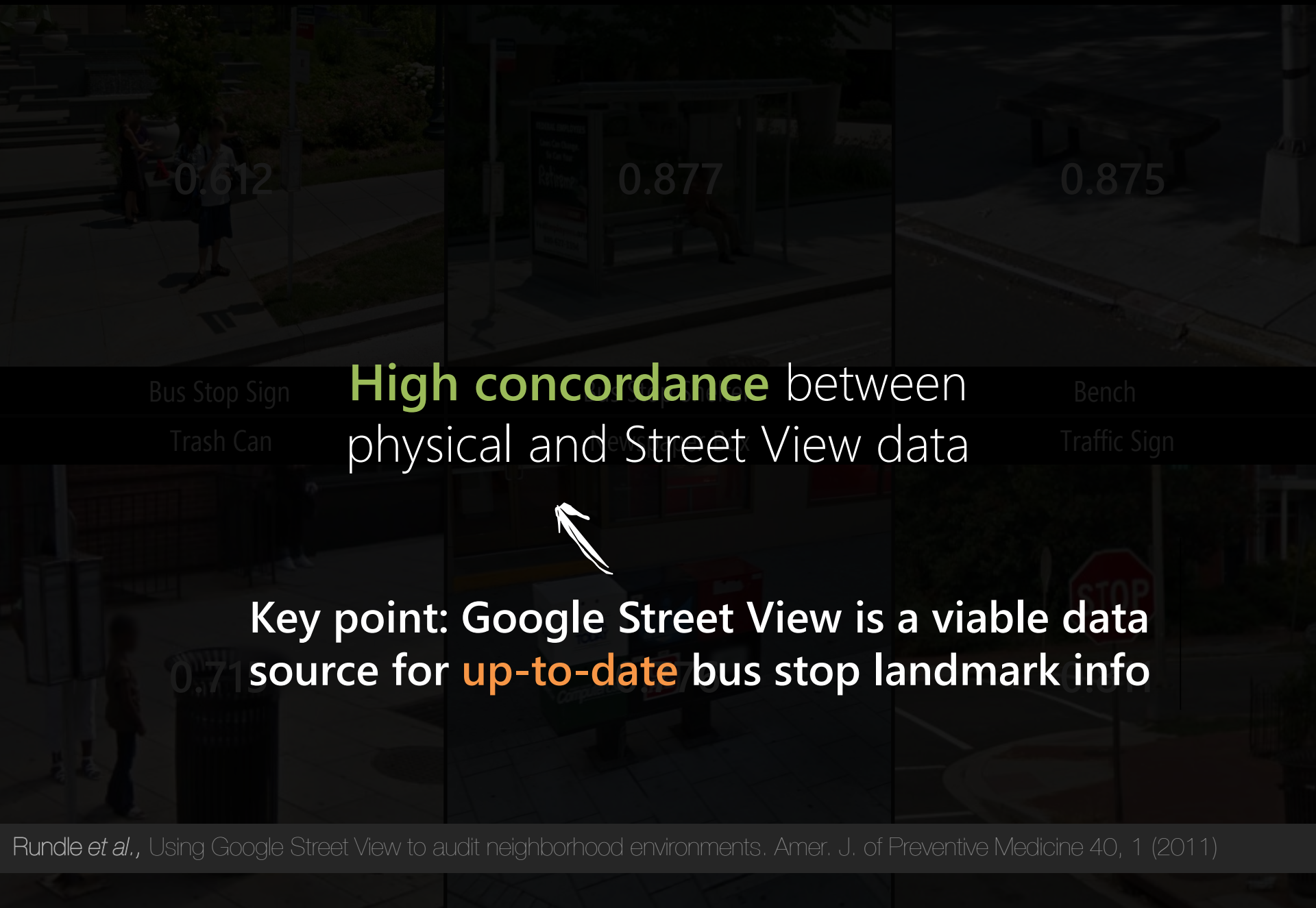
Trash Can

Newspaper Box



Traffic Sign

Study 2: Bus Stop Audit. Concordance between Google Street View and Physical Audit Data

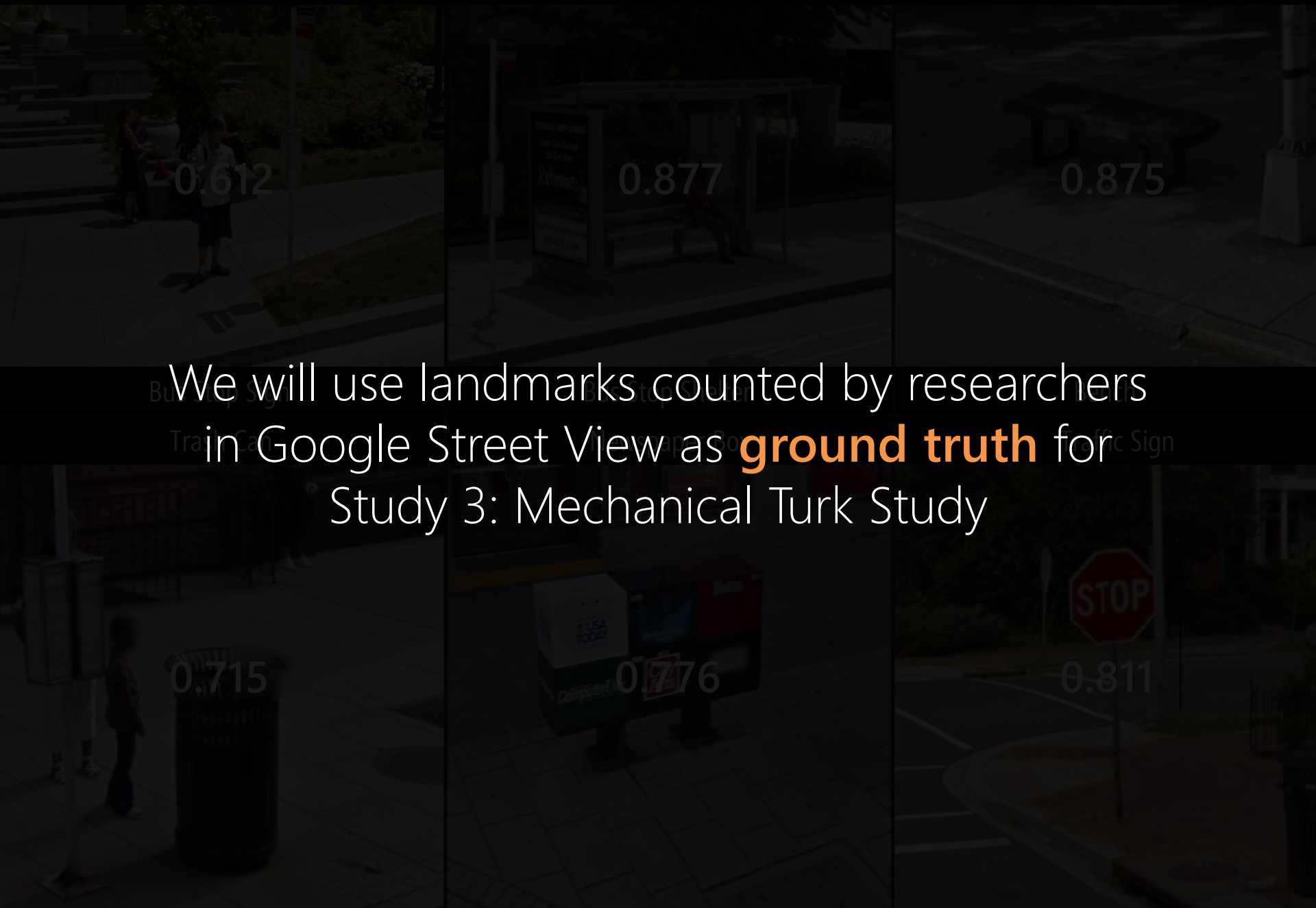


High concordance between physical and Street View data

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)

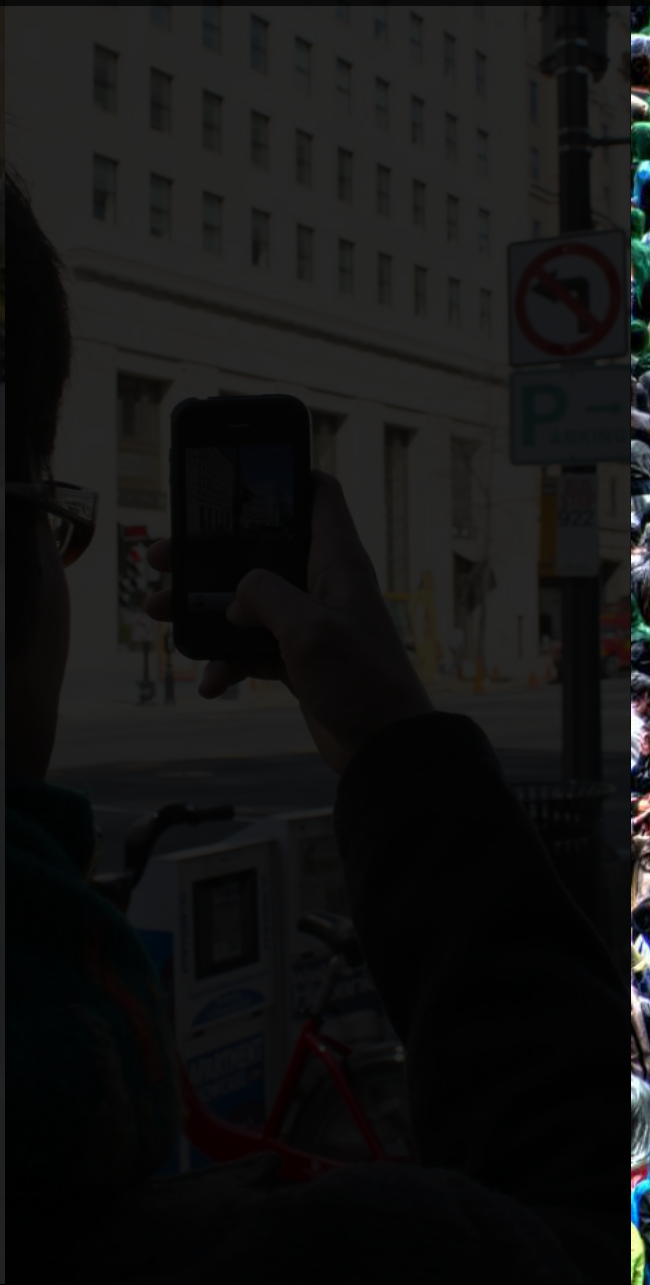
Concordance between physical and GSV data



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**

Street View Walker: 1st pr

busstop.local/?/StreetViewLabeler/BusStopAuditor

Apps | f | Highlights | Facebook | Gmail | Google Calendar | Google Drive | Google Schola

Tutorial 1/4: Labeling Bus Stops

Your mission is to find and label bus stop landmarks in G
collected labels prior to their travel and know what bus st
sign. They can use such information to locate the exact p
You need to find and label the following bus stop la

busstop.local/?/StreetViewLabeler/BusStopExplorer

Apps | f | Highlights | Facebook | Gmail | Google Calendar | Google Drive | Google Scholar | YouTube | EZProxify (ter.ps) | Spotify Web Player | Other bookmarks

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.

OK

Labeled Landmarks:

0 0 0

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

busstop.local/?/StreetViewLabeler/BusStopAbsenceReporter

Apps | f | Highlights | Facebook | Gmail | Google Calendar | Google Drive | Google Scholar | YouTube | EZProxify (ter.ps) | Spotify Web Player | Other bookmarks

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.

OK

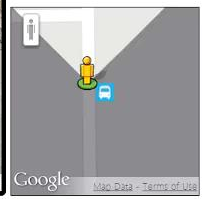
Labeled Landmarks:

0 0 0

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

busstop.local/?/StreetViewLabeler/BusStopLandmarkAuditor

Apps | f | Highlights | Facebook | Gmail | Google Calendar | Google Drive | Google Scholar | YouTube | EZProxify (ter.ps) | Spotify Web Player | Other bookmarks

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.

OK

Labeled Landmarks:

0 0 0

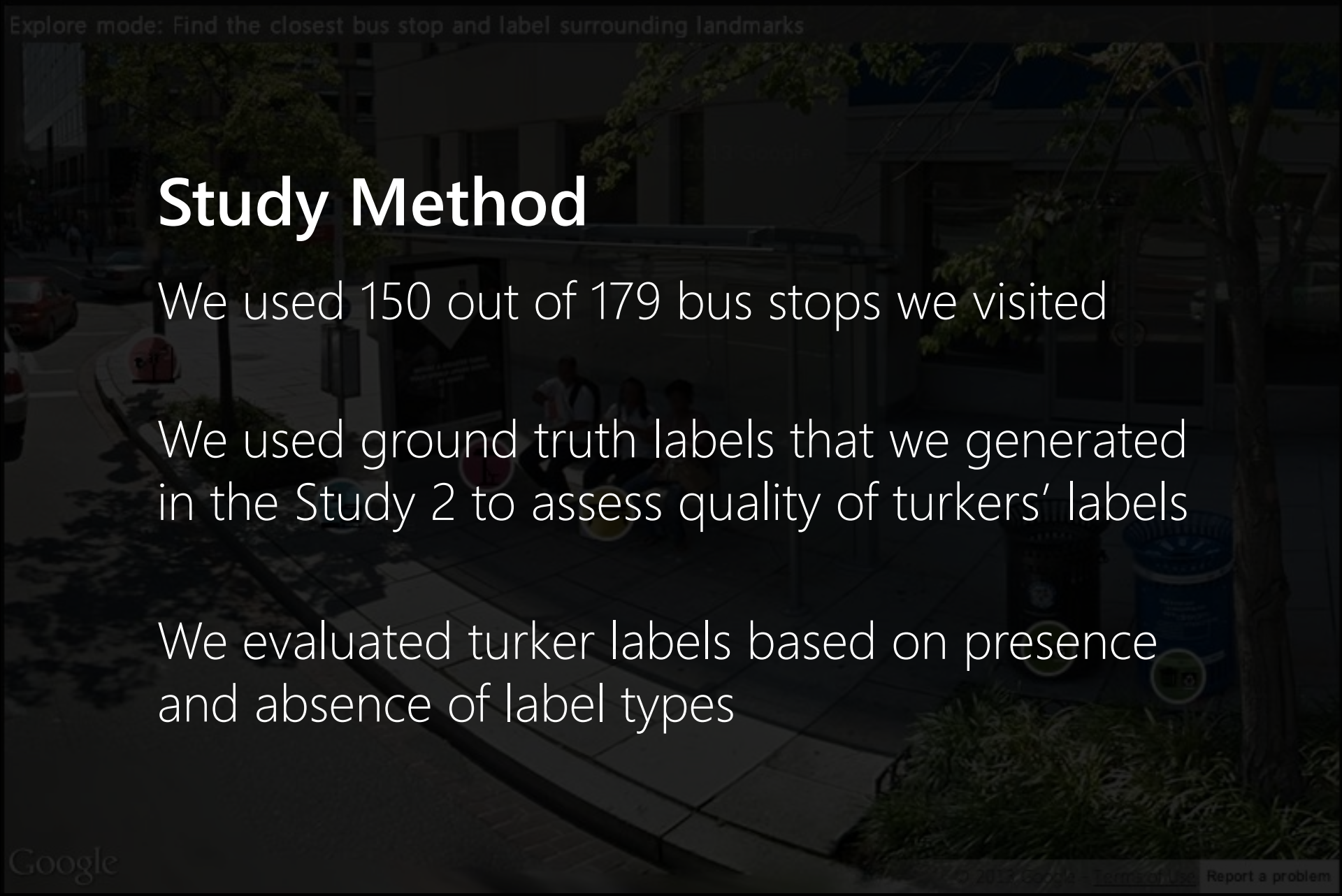
0 0 0

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

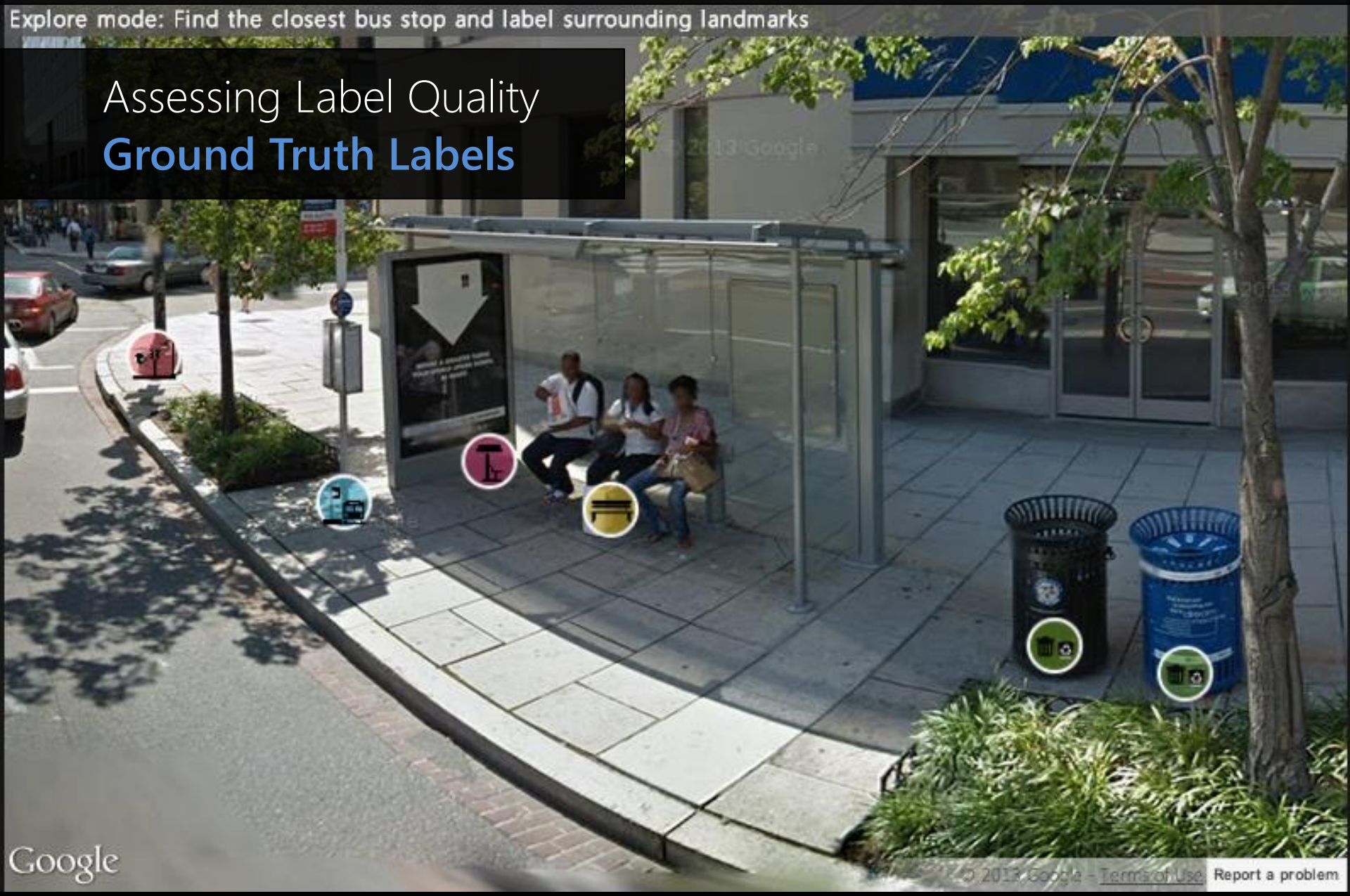


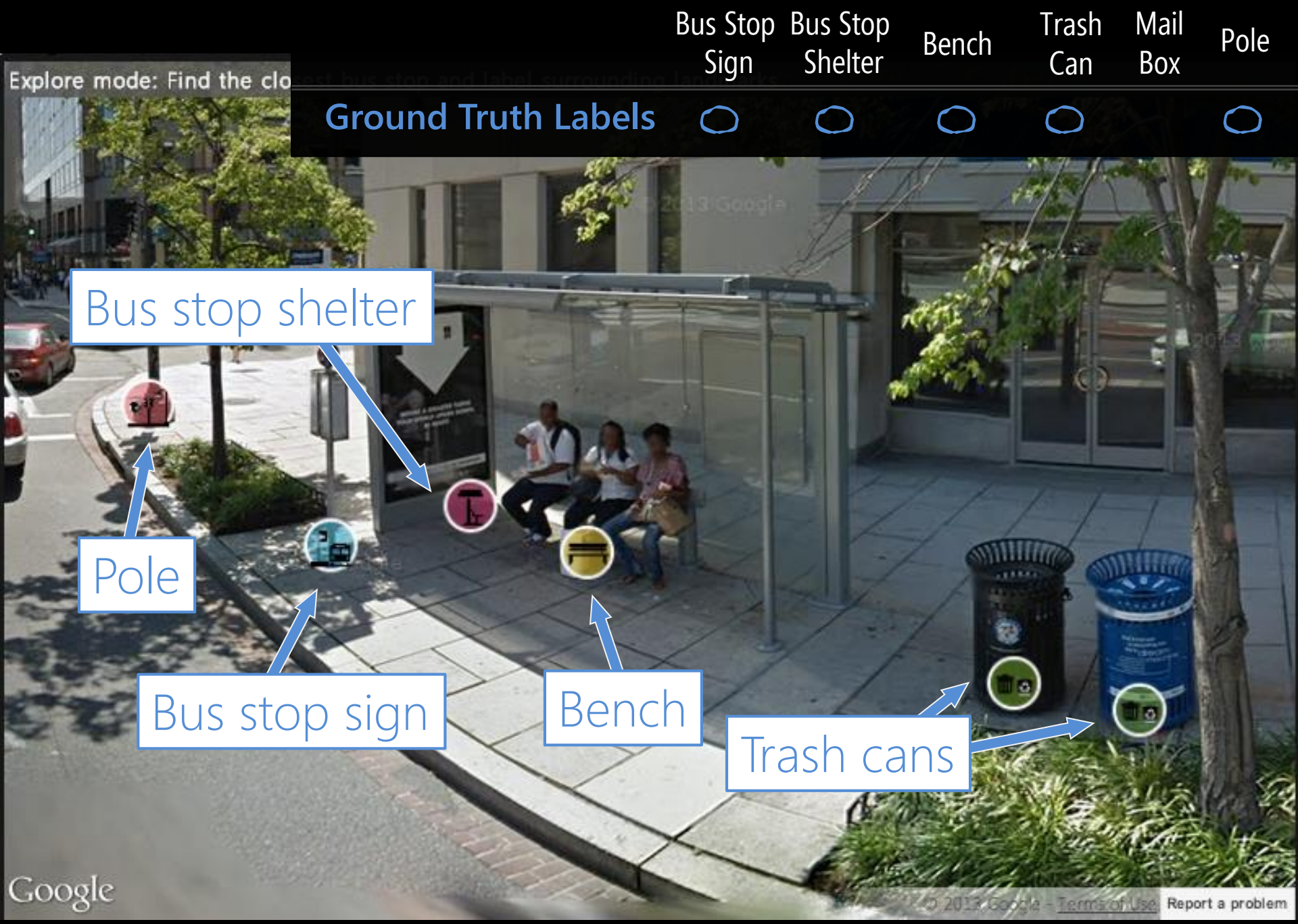
Study Method

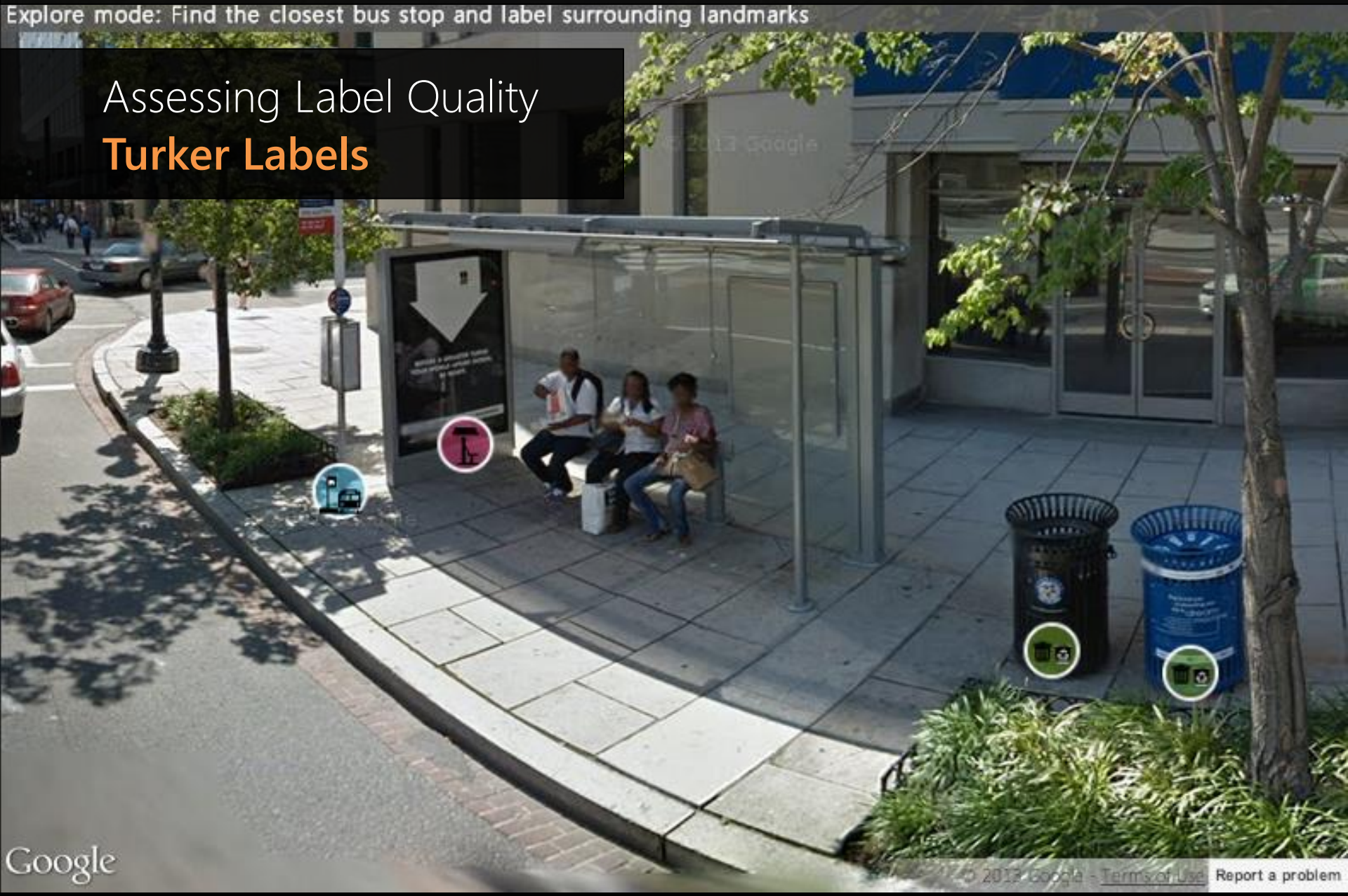
We used 150 out of 179 bus stops we visited

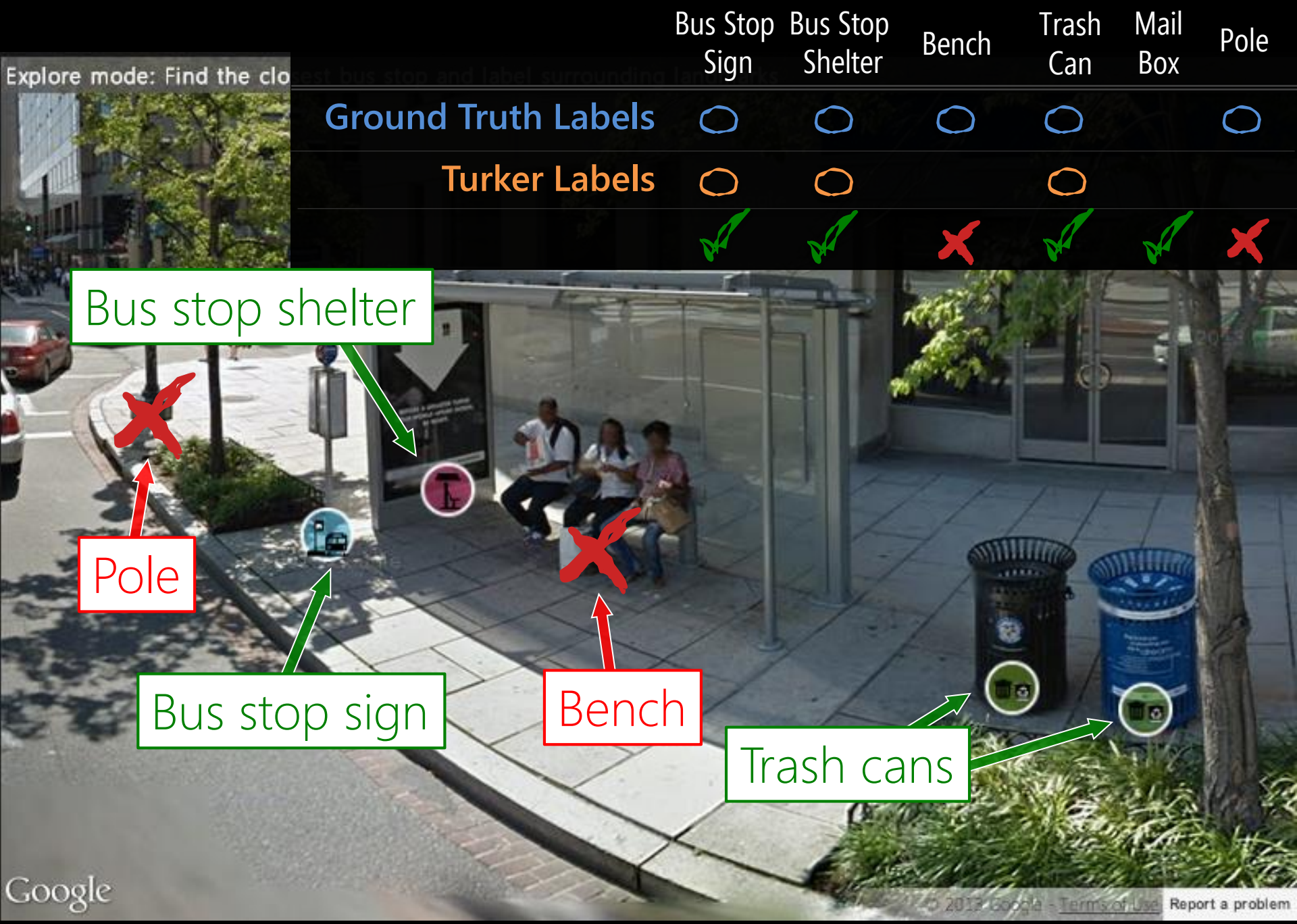
We used ground truth labels that we generated in the Study 2 to assess quality of turkers' labels

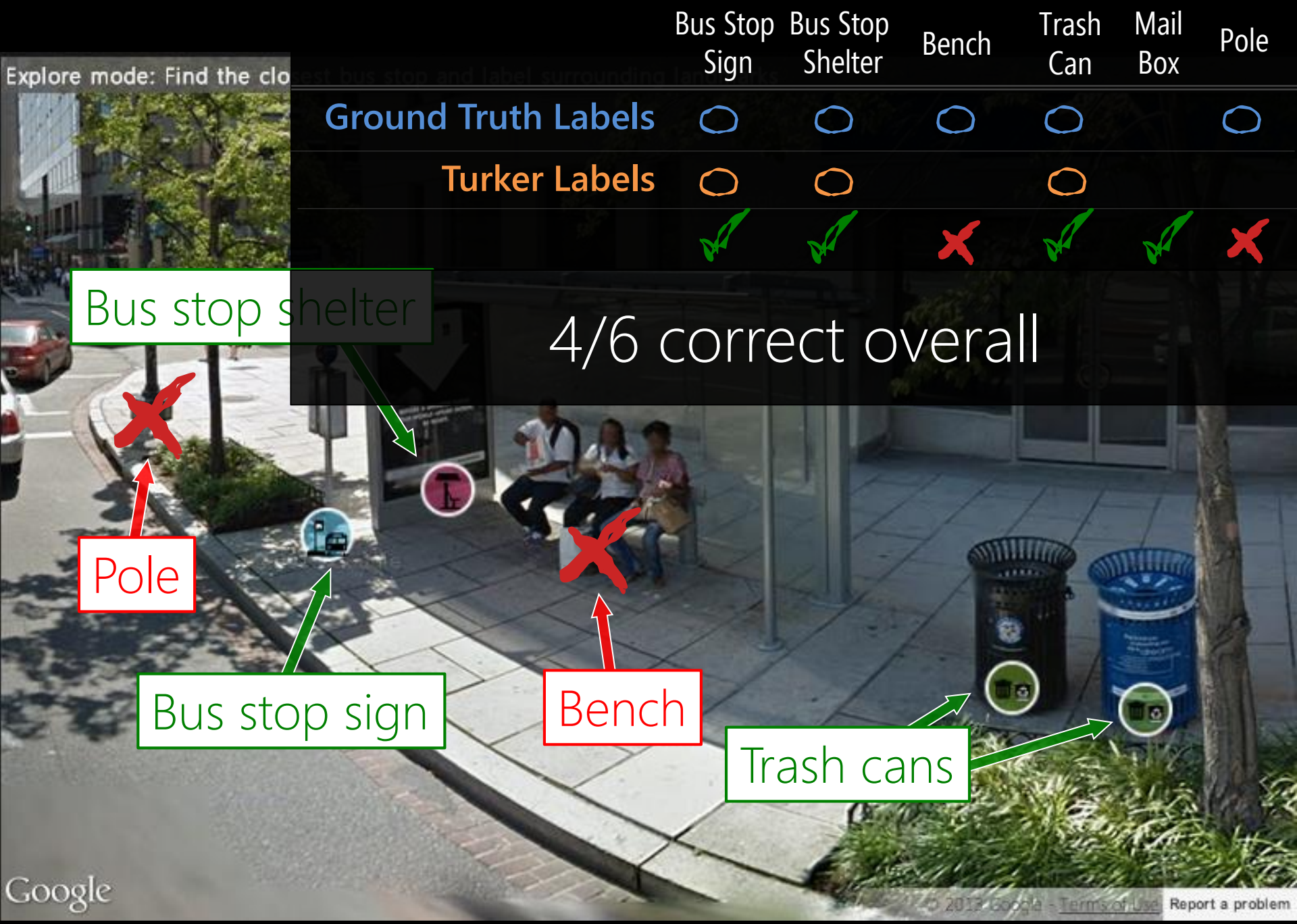
We evaluated turker labels based on presence and absence of label types


Explore mode: Find the closest bus stop and label surrounding landmarks
Assessing Label Quality
Ground Truth Labels
Google
Report a problem


Bus Stop Sign
Bus Stop Shelter
Bench
Trash Can
Mail Box
Pole
Ground Truth Labels
Explore mode: Find the clo
Bus stop shelter
Pole
Bus stop sign
Bench
Trash cans
Google
Report a problem


Explore mode: Find the closest bus stop and label surrounding landmarks
Assessing Label Quality
Turker Labels
Google
Report a problem


Explore mode: Find the clo
Bus Stop Sign
Bus Stop Shelter
Bench
Trash Can
Mail Box
Pole
Ground Truth Labels
Turker Labels
Bus stop shelter
Pole
Bus stop sign
Bench
Trash cans
Google
Report a problem


Explore mode: Find the clo
Bus Stop Sign
Bus Stop Shelter
Bench
Trash Can
Mail Box
Pole
Ground Truth Labels
Turker Labels
4/6 correct overall
Bus stop shelter
Pole
Bus stop sign
Bench
Trash cans
Google
Report a problem

Results

153 distinct turkers completed 3,534 labeling tasks

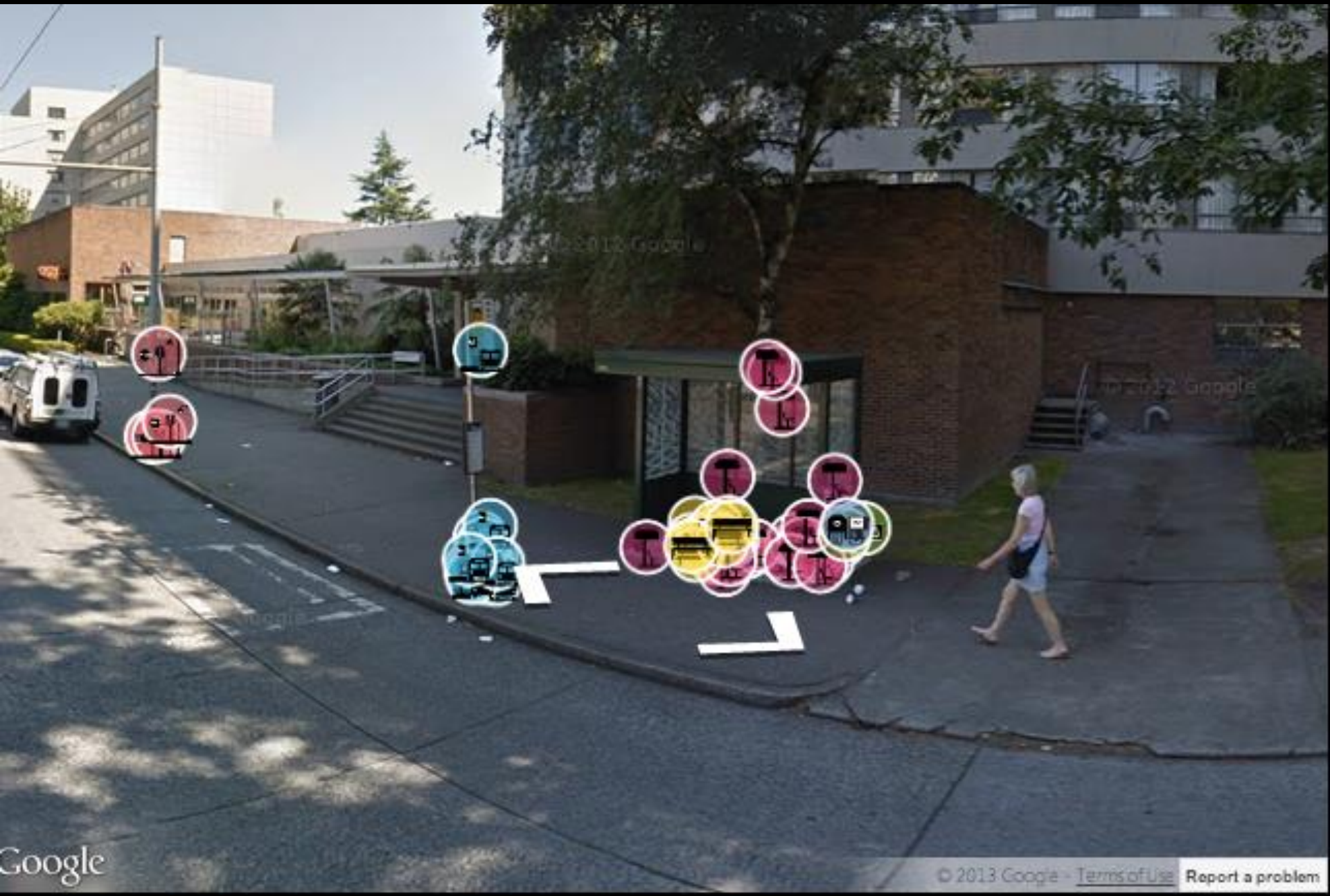
Each bus stop was labeled by at least 21 distinct turkers

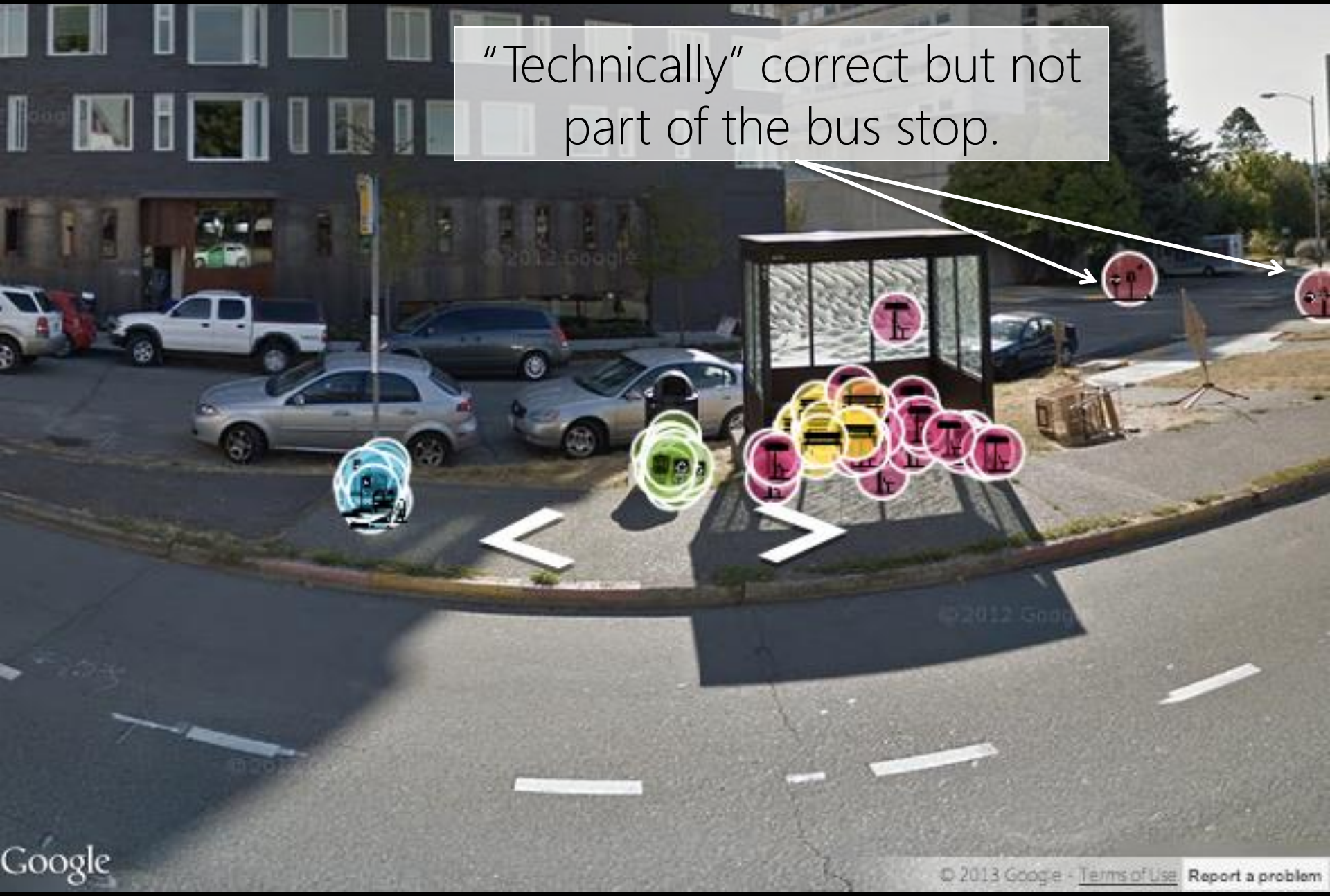
The median labeling time per task was 44.7s

The average number of labels per task was 3.15

When compared with our ground truth dataset,
overall turker **accuracy was 82.5%**


Google
© 2013 Google - Terms of Use
Report a problem


Google
© 2013 Google - Terms of Use
Report a problem


"Technically" correct but not part of the bus stop.
Google
© 2013 Google - Terms of Use
Report a problem

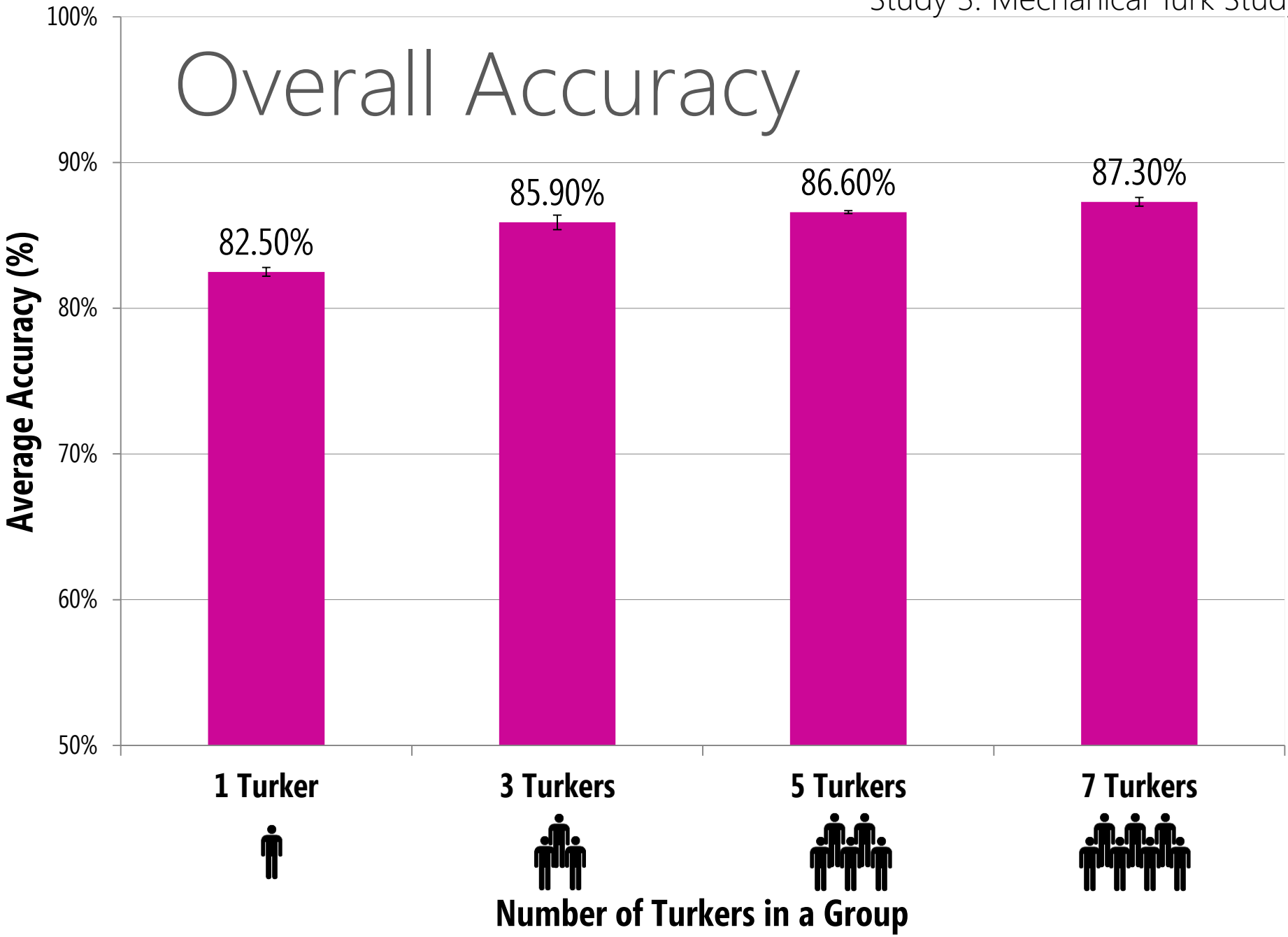
Turker Majority Vote Group

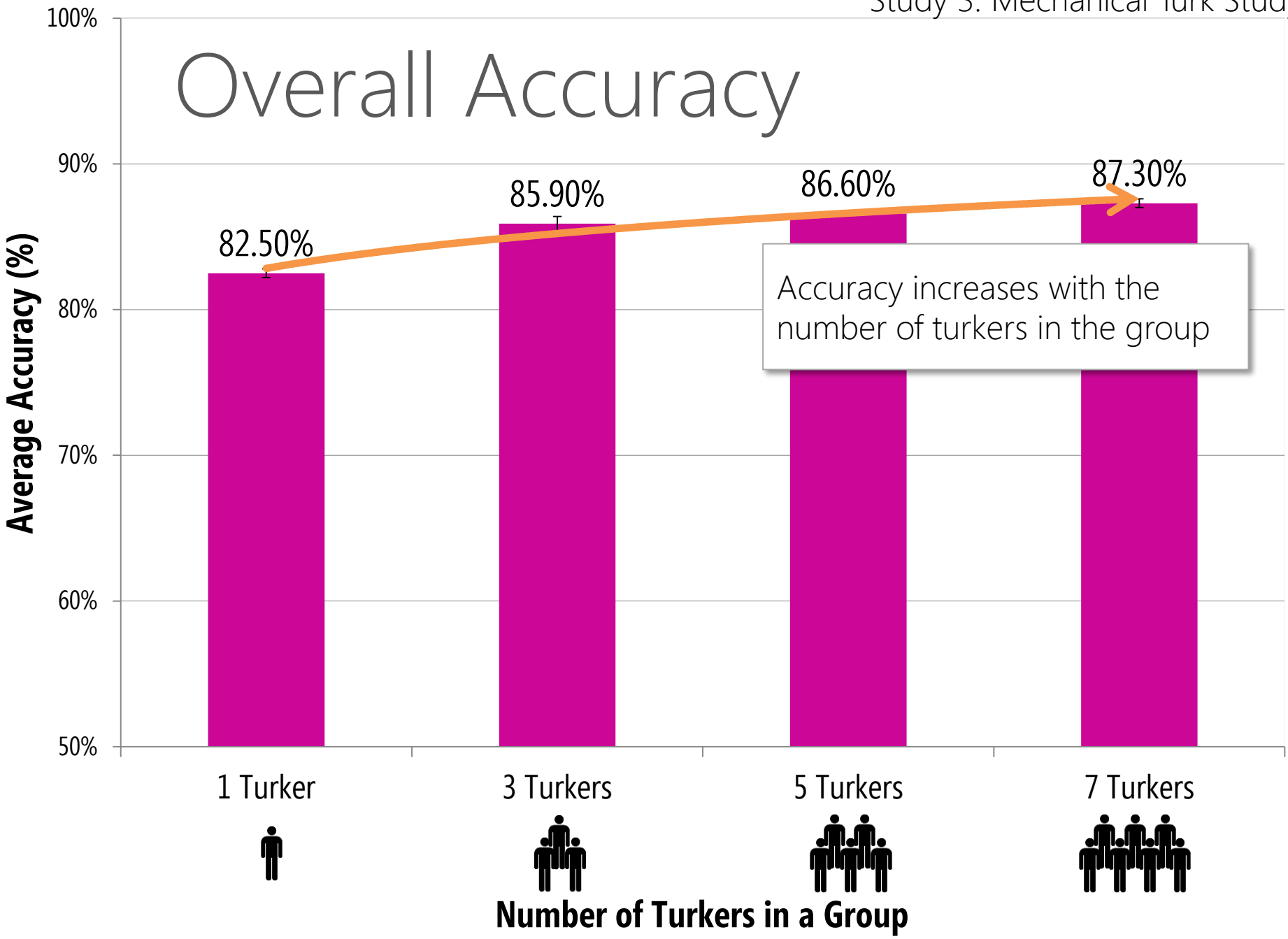
Group of **1** turker 

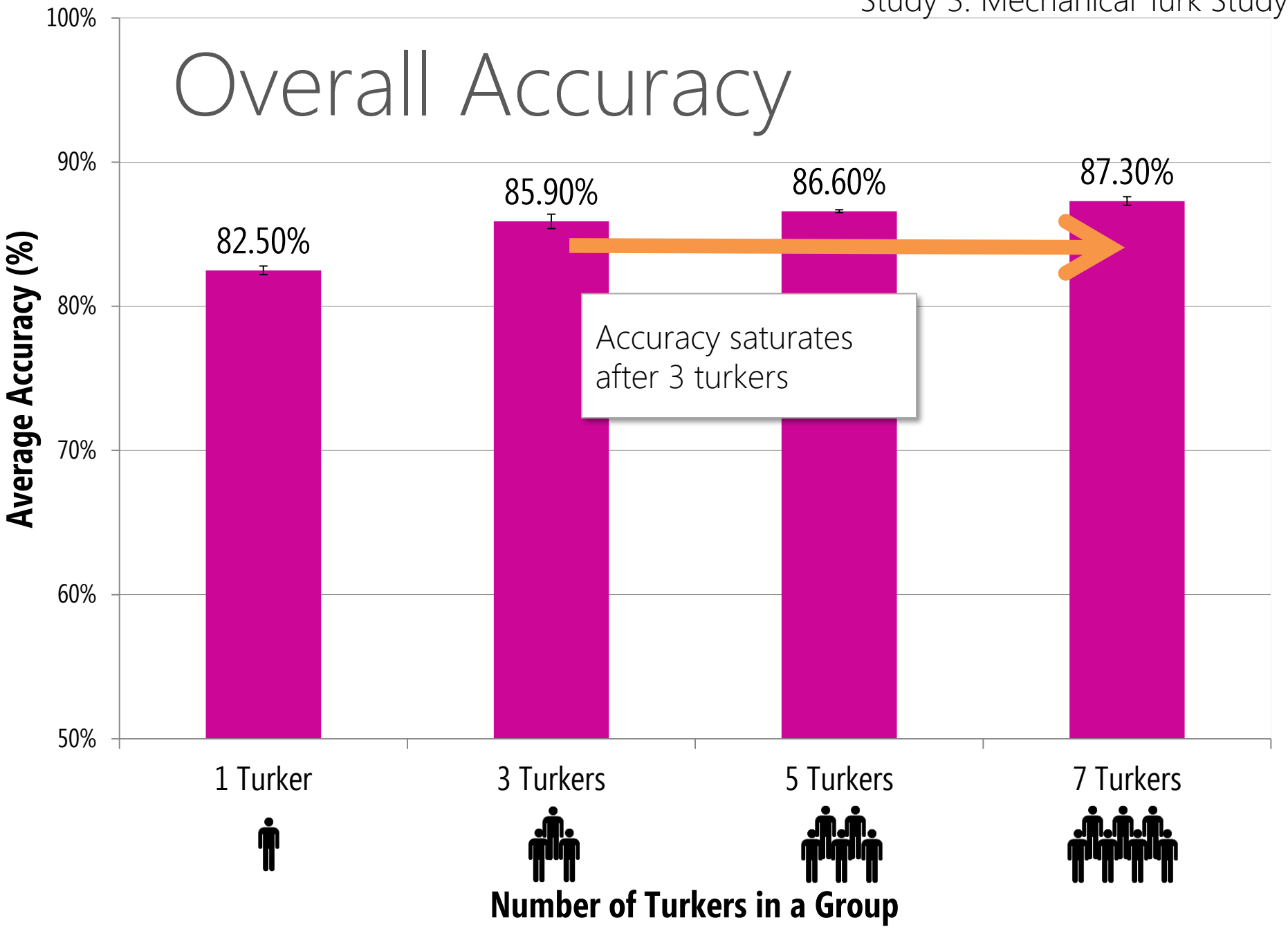
Group of **3** turkers 

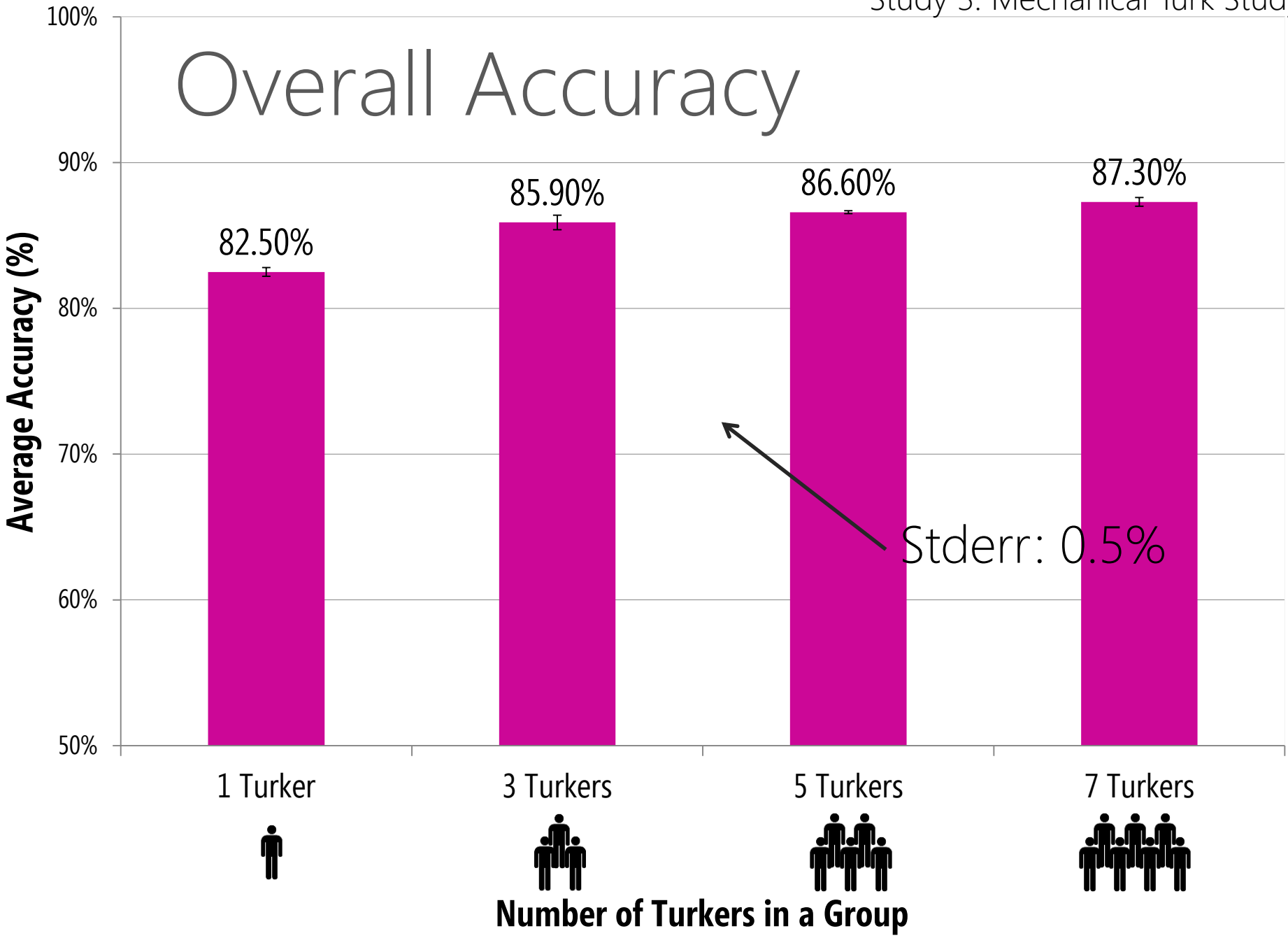
Group of **5** turkers 

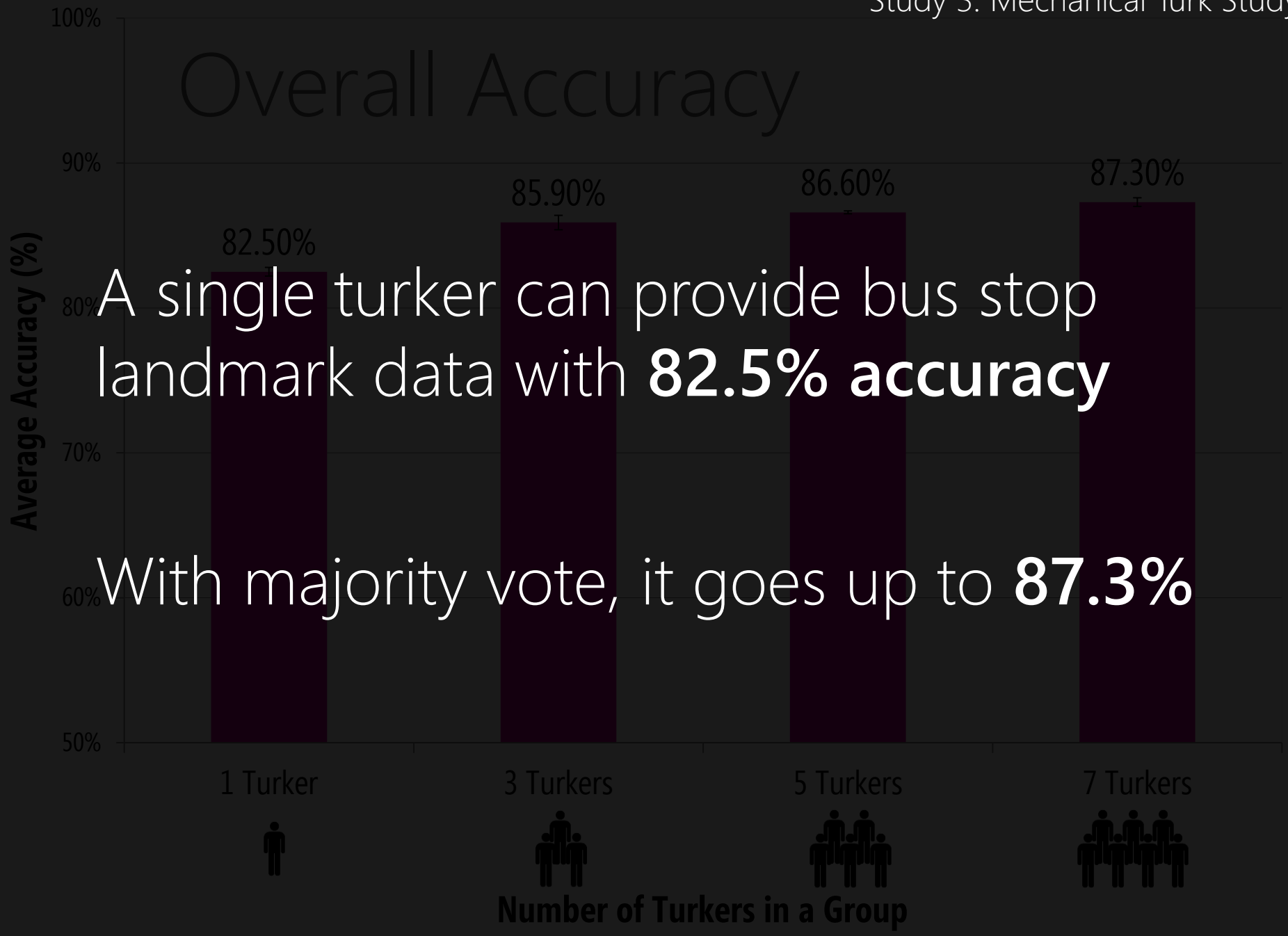
Group of **7** turkers 


Overall Accuracy
100%
90%
80%
70%
60%
50%
Average Accuracy (%)
82.50%
85.90%
86.60%
87.30%
1 Turker
3 Turkers
5 Turkers
7 Turkers
Number of Turkers in a Group


Overall Accuracy
100%
90%
80%
70%
60%
50%
Average Accuracy (%)
82.50%
85.90%
86.60%
87.30%
Accuracy increases with the number of turkers in the group
1 Turker
3 Turkers
5 Turkers
7 Turkers
Number of Turkers in a Group


Overall Accuracy
100%
90%
80%
70%
60%
50%
Average Accuracy (%)
82.50%
85.90%
86.60%
87.30%
Accuracy saturates after 3 turkers
1 Turker
3 Turkers
5 Turkers
7 Turkers
Number of Turkers in a Group

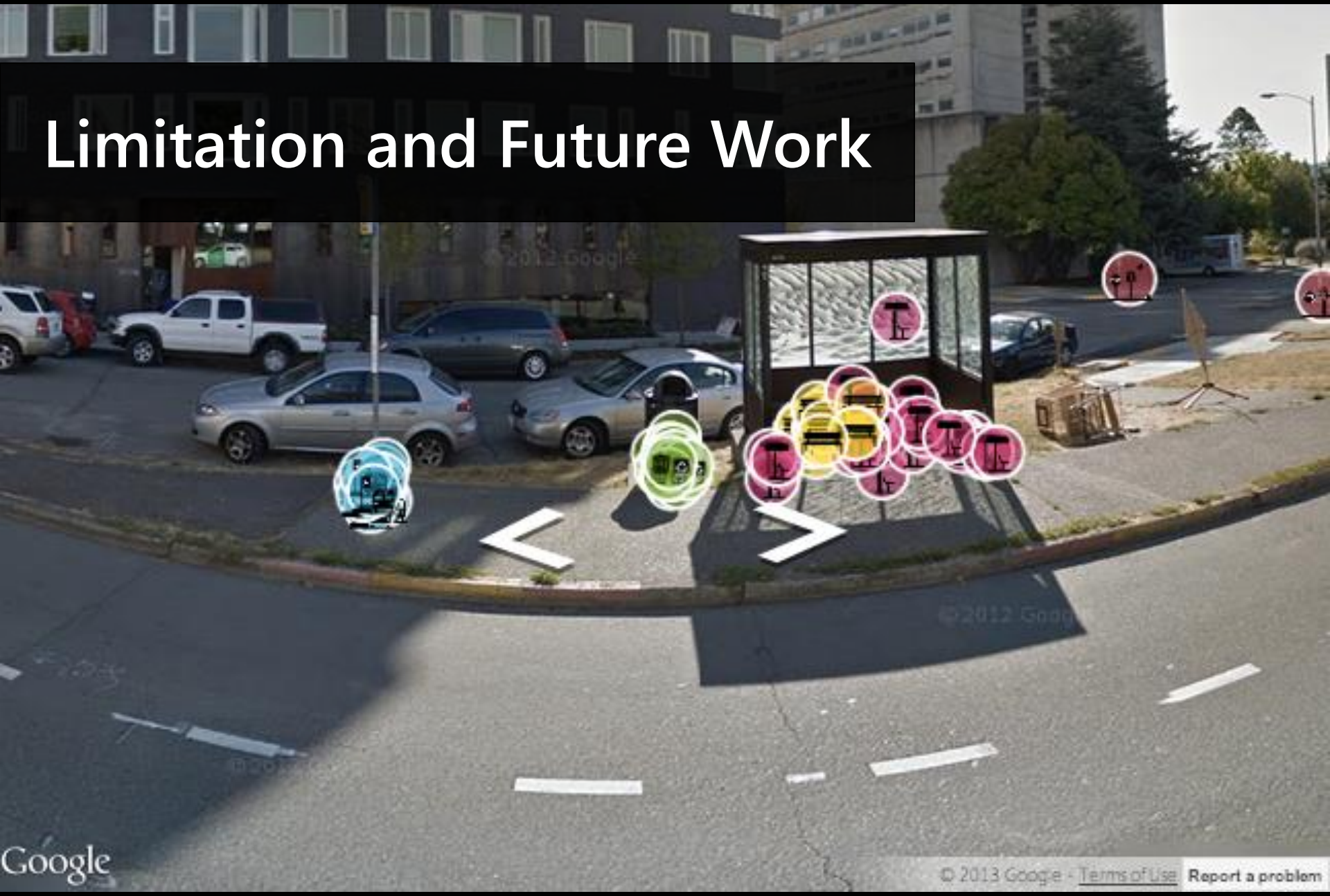

Overall Accuracy
100%
90%
80%
70%
60%
50%
Average Accuracy (%)
82.50%
85.90%
86.60%
87.30%
Stderr: 0.5%
1 Turker
3 Turkers
5 Turkers
7 Turkers
Number of Turkers in a Group



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
Google
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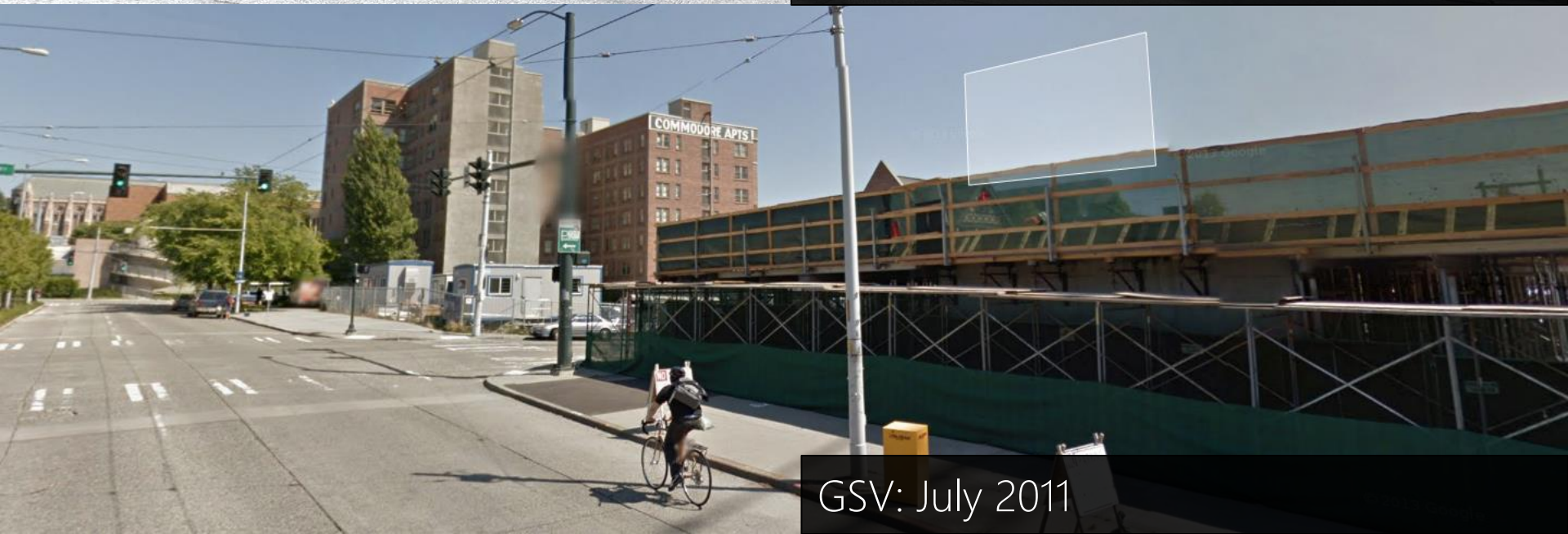
Report a problem

Image Age

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

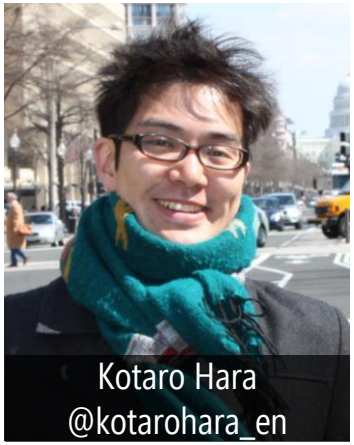
Turkers can find bus stop landmarks with **82.5%** accuracy from Google Street View

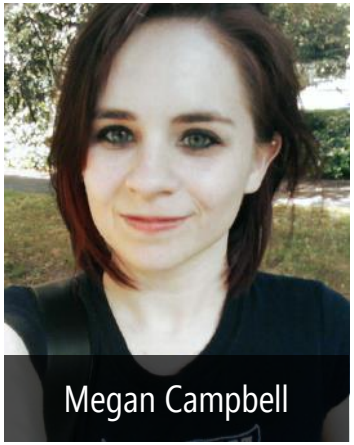
This work is supported by

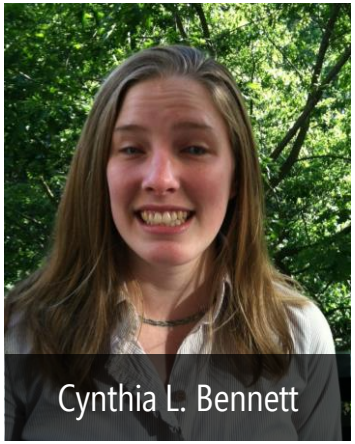
Google
Faculty Research Award

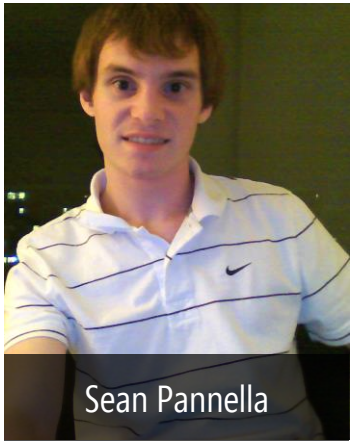
NSF

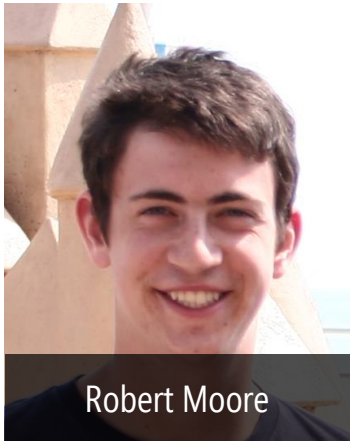
at&t

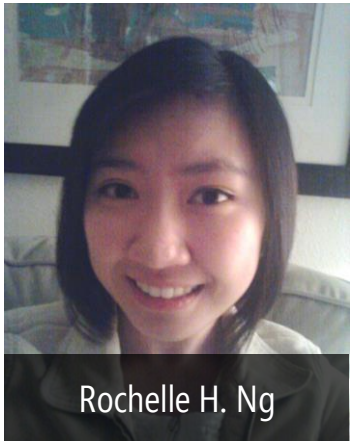












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UNIVERSITY OF MARYLAND

HCIL

makeability lab

dub

UNIVERSITY of WASHINGTON

Questions?

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

Kotaro Hara, @kotarohara_en

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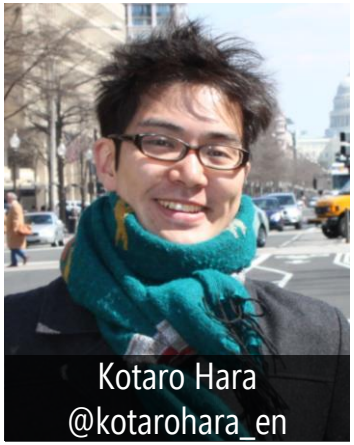
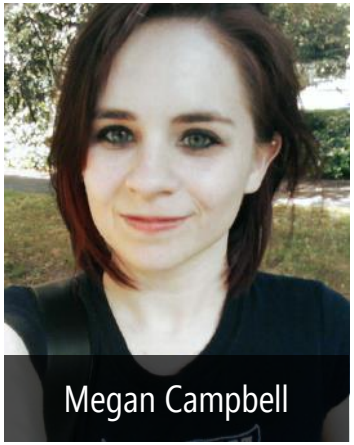
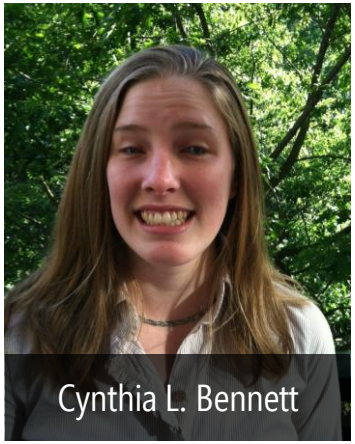
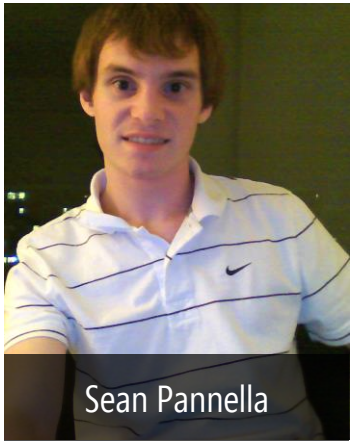
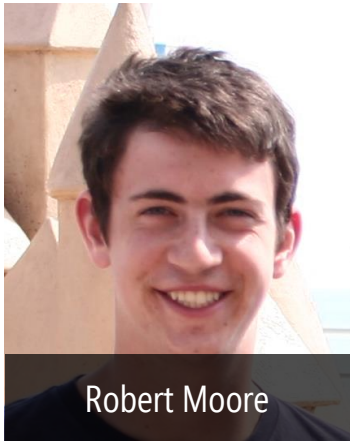
COMPUTER SCIENCE UNIVERSITY OF MARYLAND
HCIL
makeability lab
dub
UNIVERSITY of WASHINGTON

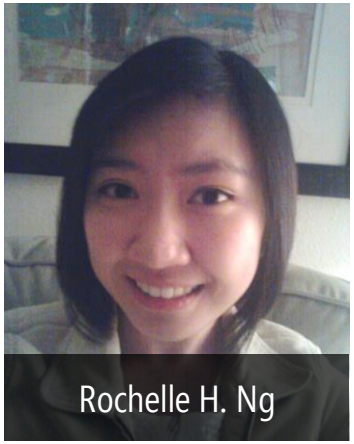












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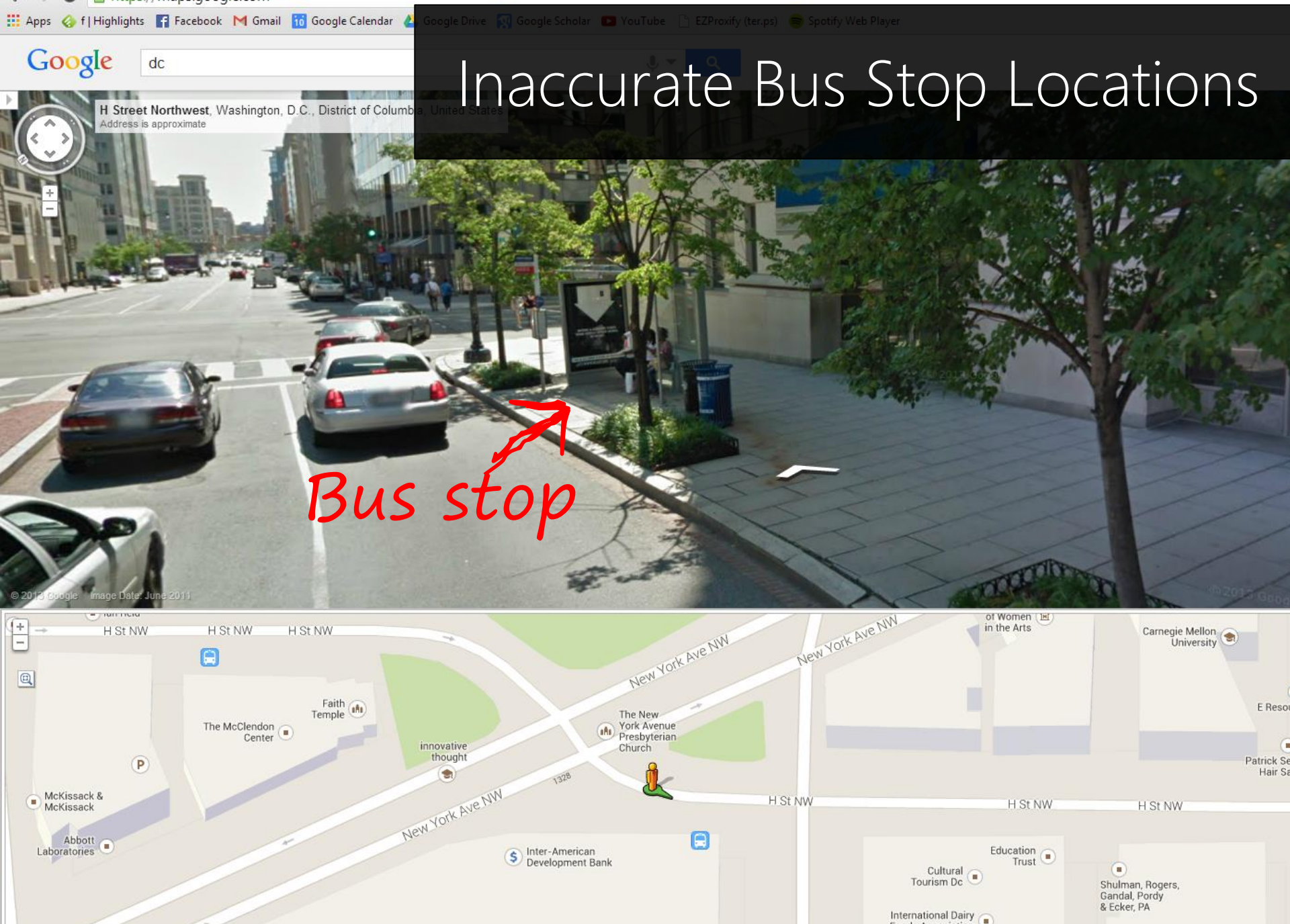
Inaccurate Bus Stop Locations

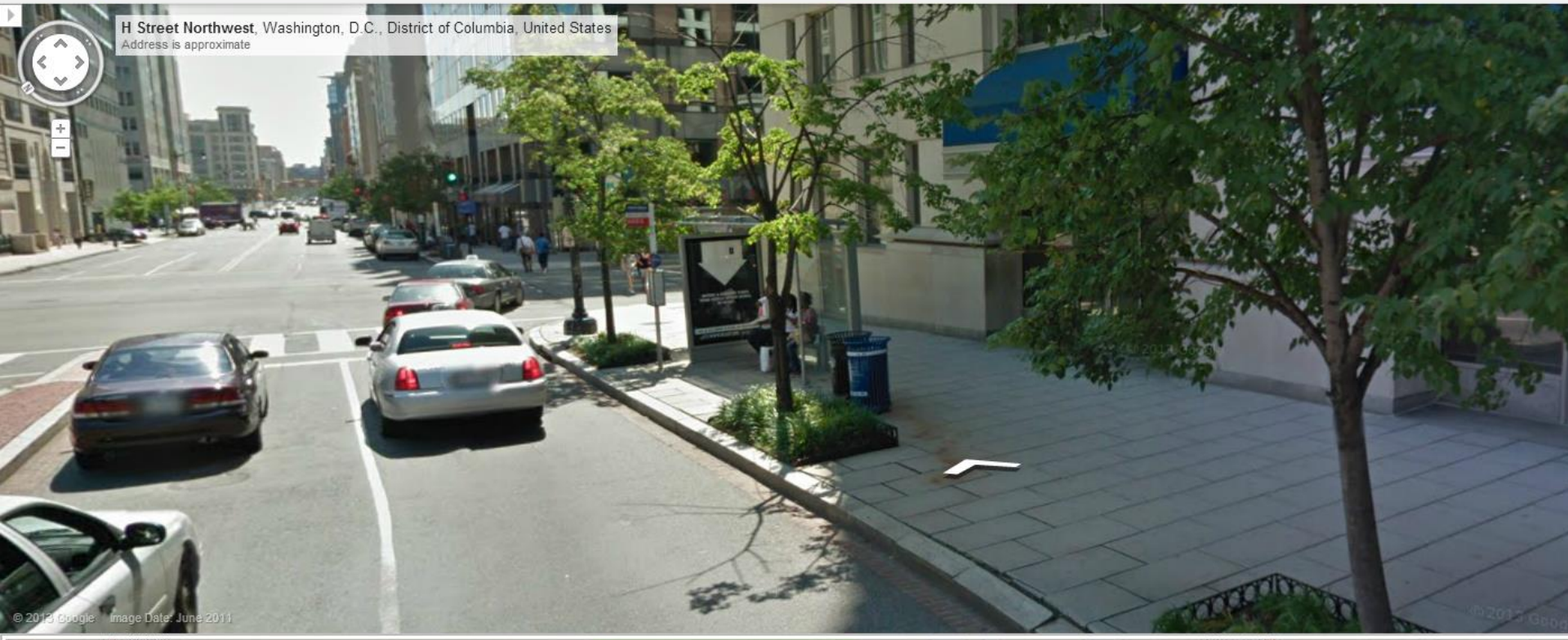


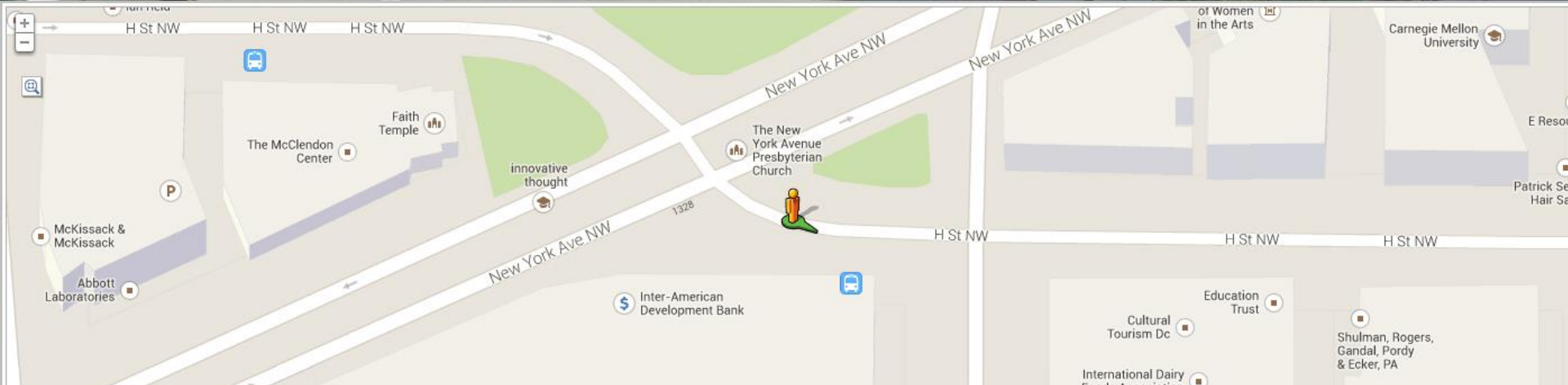
dc - Google Maps

https://maps.google.com

Apps | Highlights | Facebook | Gmail | Google Calendar | Google Drive | Google Scholar | YouTube | EZProxify (ter.ps) | Spotify Web Player

Google dc





We collect bus stop locations from Google's Transit data,

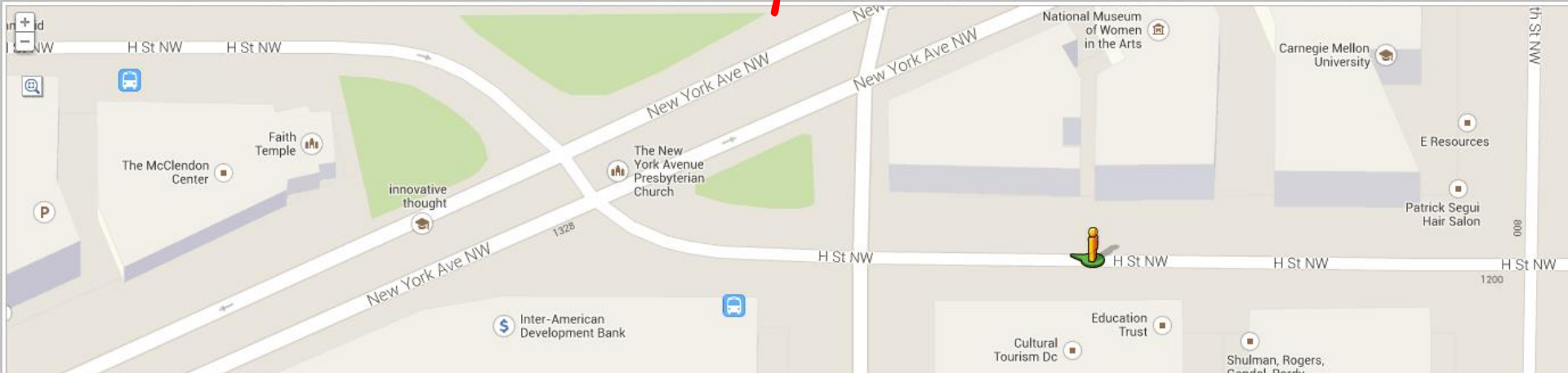
and automatically drop turkers to nearby locations.

dc - Google Maps

https://maps.google.com

Apps | f | Highlights | Facebook | Gmail | Google Calendar | Google Drive | Google Scholar | YouTube | EZProxify (ter.ps) | Spotify Web Player

Google dc



dc - Google Maps

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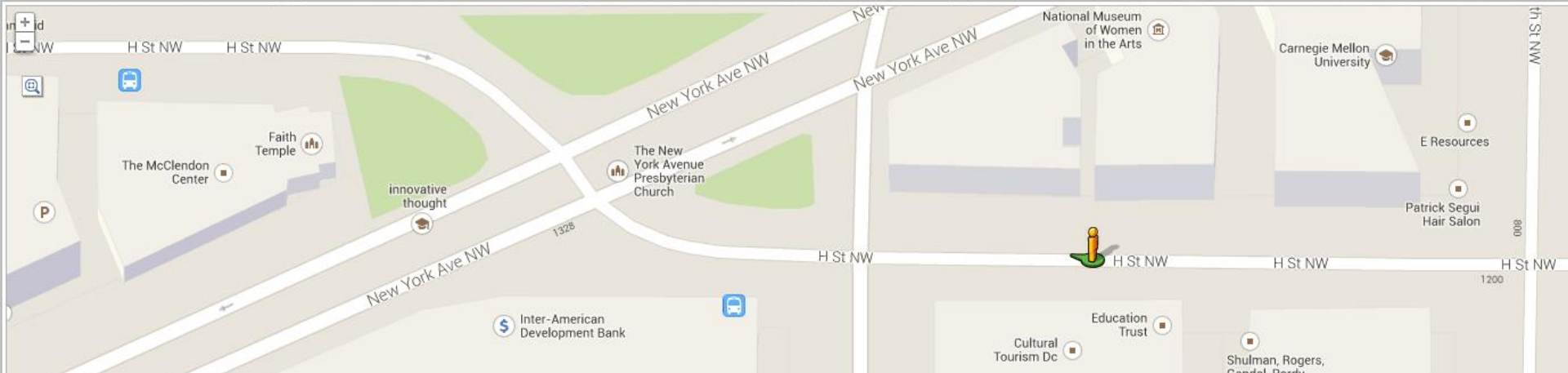
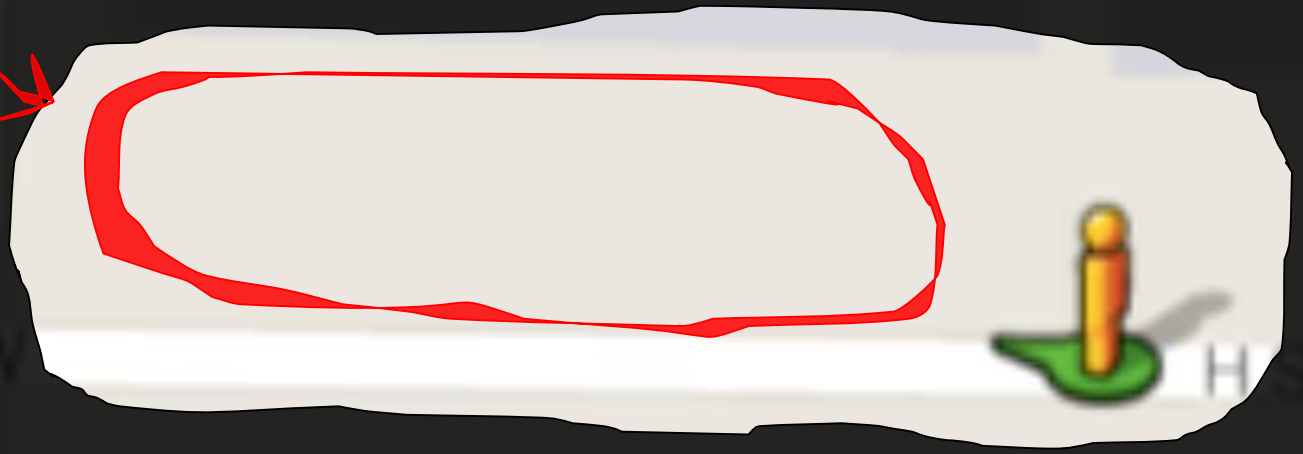
Google dc

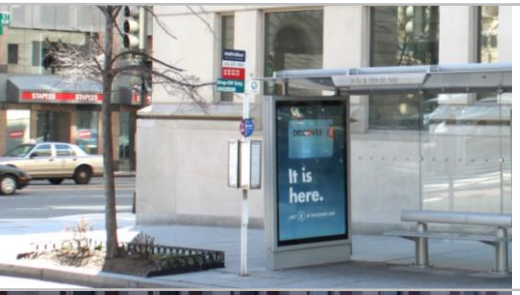


Sometimes bus stop locations are missing

We cannot automatically situate turkers in these cases



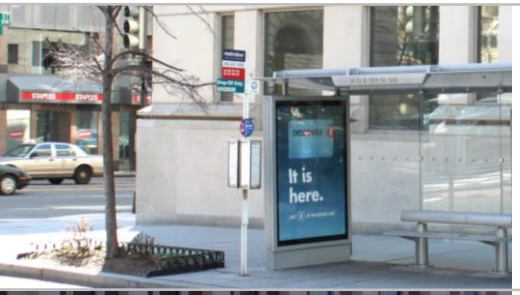
Bus Stop Signs

	# Bus Stop Signs in **Physical Audit Data**			# Bus Stop Signs in **GSV Images**			
	R1	R2	R3	R1	R2	R3	
	1	1	1	1	1	1	
	1	1	1	1	1	1	
	1	1	1	1	1	2	
⋮						⋮	

Krippendorff's α = 0.937

α = 0.761

Bus Stop Signs

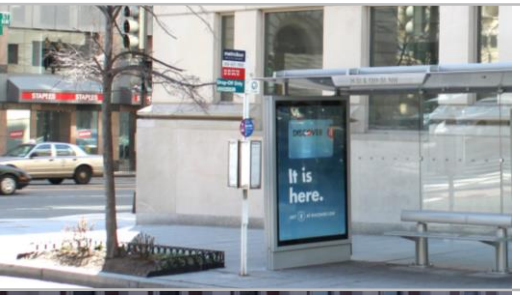
	# Bus Stop Signs in **Physical Audit Data**			# Bus Stop Signs in **GSV Images**			
	R1	R2	R3	R1	R2	R3	
	1	1	1	1	1	1	
	1	1	1	1	1	1	
	1	1	1	1	1	2	
⋮						⋮	

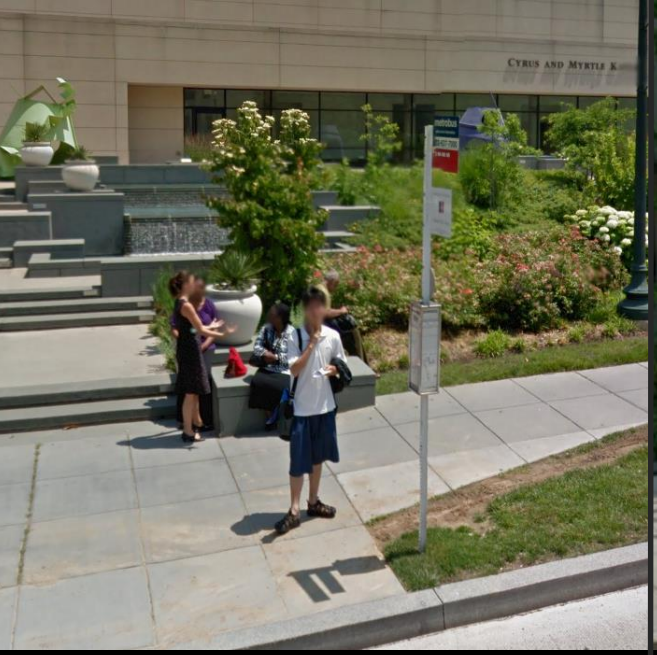
Krippendorff's α = 0.937

α = 0.761

Alpha below 0.8 is not satisfactory

Take 2

	# Bus Stop Signs in **Physical Audit Data**			# Bus Stop Signs in **GSV Images**			
	R1	R2	R3	R1	R2	R3	
	1	1	1	1	1	1	
	1	1	1	1	1	1	
	1	1	1	1	1	1	
⋮							⋮
	α = 0.972			α = 0.916			



Bus Stop Sign

Bus Stop Shelter

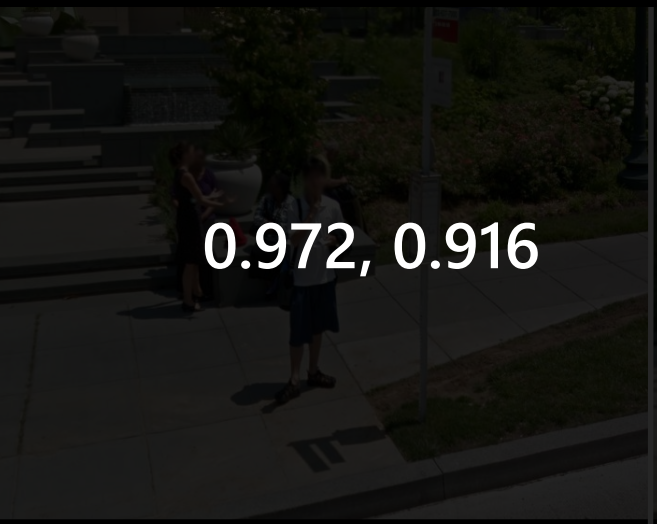
Bench

Trash Can

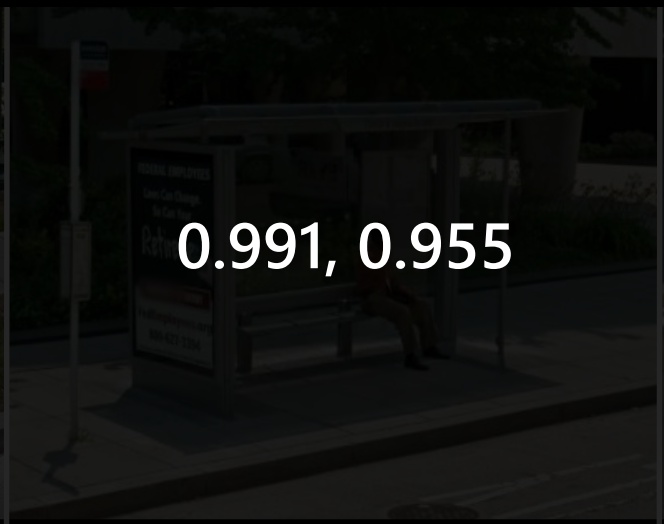
Newspaper Box

Traffic Sign

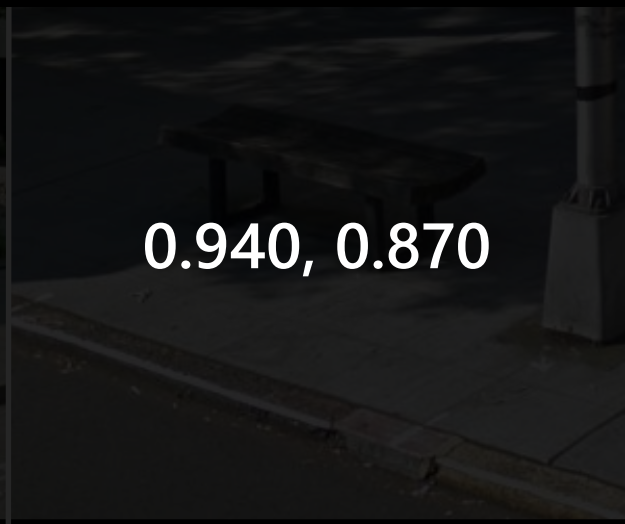
(α Physical Audit, α GSV)



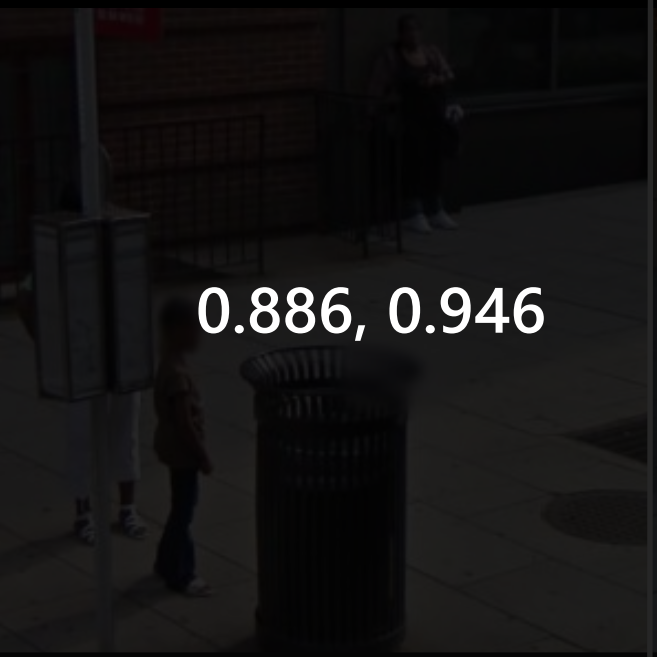
Bus Stop Sign



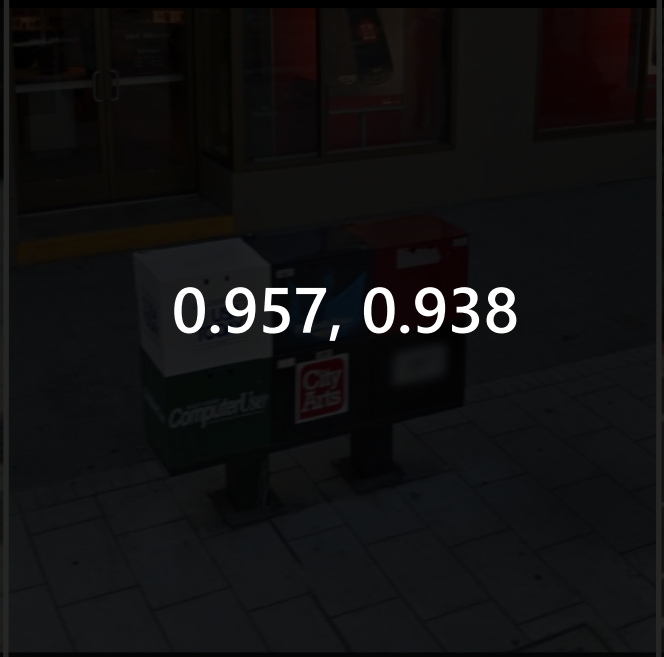
Bus Stop Shelter



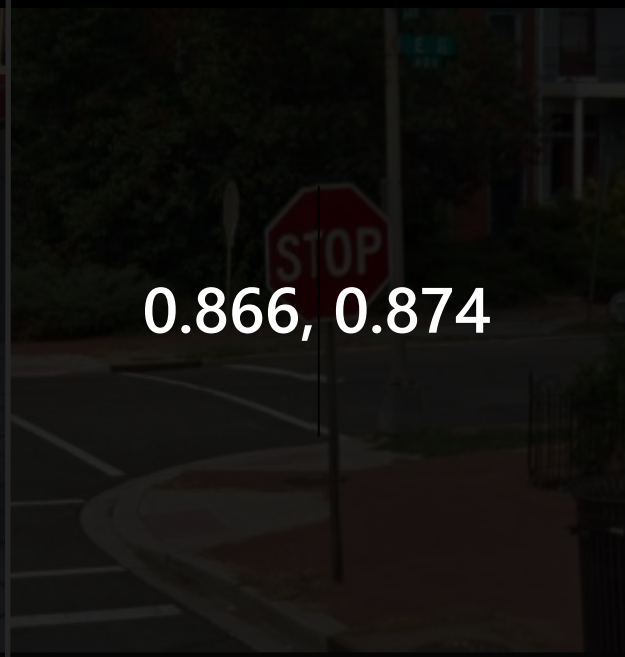
Bench



Trash Can



Newspaper Box



Traffic Sign

Result

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