Project Sidewalk: A Web-based Crowdsourcing Tool for Collecting Sidewalk Accessibility Data **at Scale**

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DESIGN USE BUILD

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30.6

million U.S. adults have a mobility impairment

Source: US Census, 2010

15.2

million use an assistive aid

Source: US Census, 2010


CHANEL
CHANEL
CHANEL
CHANEL
ONE WAY
NO PARKING
DIESEL


NO CURB RAMPS
CHANEL
ONE WAY
DIESEL


PHYSICAL OBSTACLES


SURFACE PROBLEMS


FedEx
INCOMPLETE SIDEWALKS

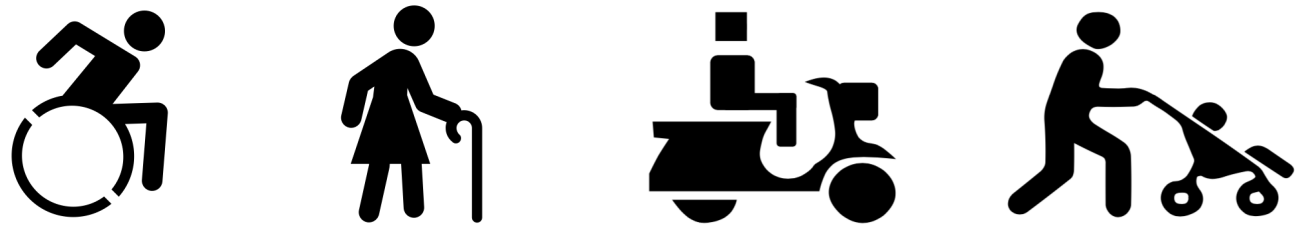

PHYSICAL OBSTACLES
NO CURB RAMP
SURFACE DEGRADATION

The National Council on Disability noted that there is **no comprehensive information** on "the degree to which sidewalks are accessible" in cities.

National Council on Disability, 2007
The impact of the Americans with Disabilities Act: Assessing the progress toward achieving the goals of the ADA

MOTIVATION

KEY STAKEHOLDERS



People with Mobility Impairments

MOTIVATION

KEY STAKEHOLDERS

Caregivers

.gov

Government Officials

e.g., *DOTs

MOTIVATION

WHY IS ACCESSIBILITY DATA COLLECTION HARD?

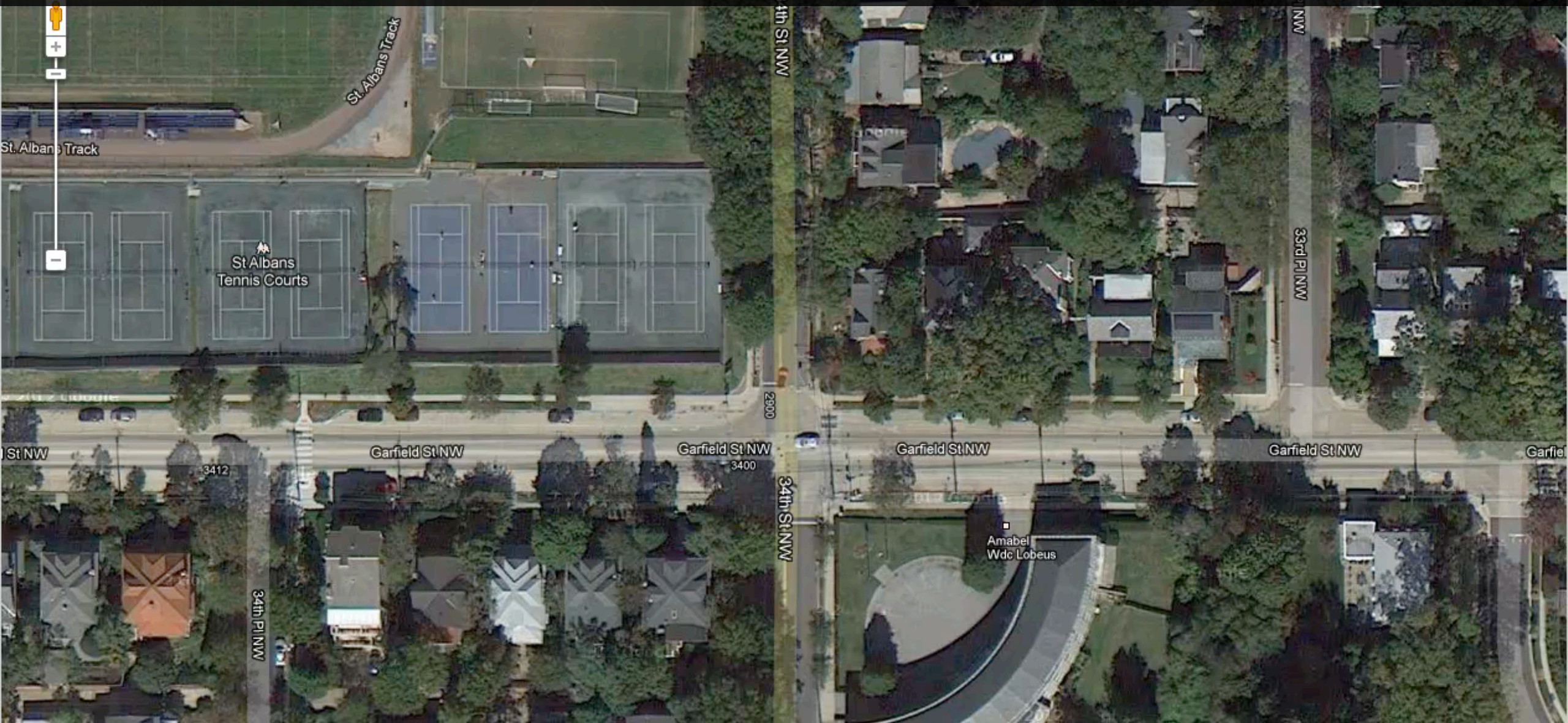
Slow, Manual, and Laborious

Huge Cost

Localized

PAST WORK SINCE 2012

Studying the state of street-level accessibility using Google Street View



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Categories and Subject Descriptors

K.4.2 [**Computer and Society**]: Social Issues-Assistive technologies for persons with disabilities

Keywords

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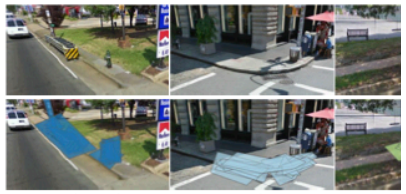

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Improving Public Transit Accessib
Crowdsourcing Bus Stop Landmark Loca

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Tohme: Detecting Curb Ramps in
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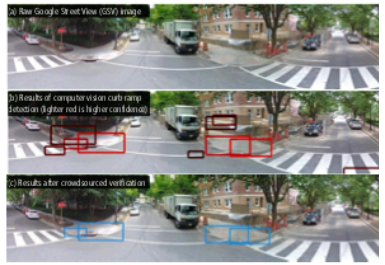

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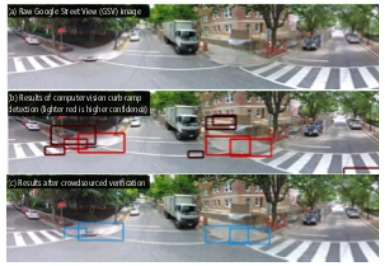

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Small Geographic Regions

Specialized populations

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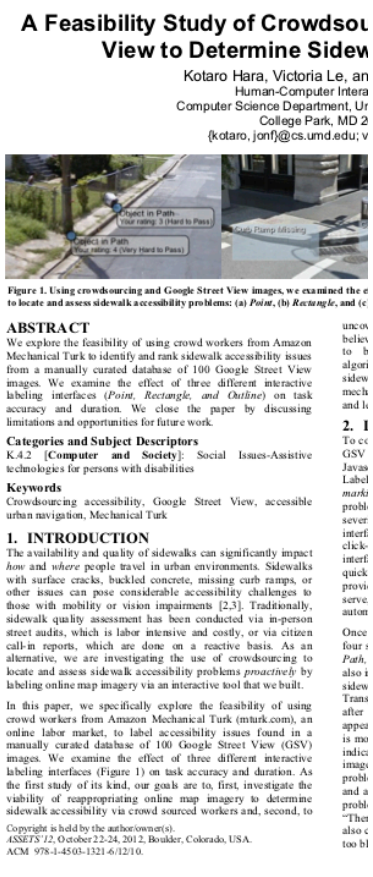

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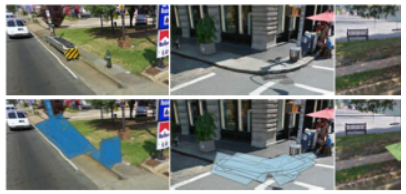

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Department of Computer Science
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ABSTRACT
Low-vision and blind bus riders often rely on known physical landmarks to help locate and verify bus stop locations (*e.g.*, by searching for a shelter, bench, newspaper bin). However, there are currently few, if any, methods to determine this information *a priori* via computational tools or services. In this paper, we introduce and evaluate a new scalable method for collecting bus stop location and landmark descriptions by combining online crowdsourcing and Google Street View (GSV). We conduct and report on three studies in particular: (i) a formative interview study of 18 people with visual impairments to inform the design of our crowdsourcing tool; (ii) a comparative study examining differences between physical bus stop audit data and audits conducted virtually with GSV; and (iii) an online study of 153 crowd workers on Amazon Mechanical Turk to examine the feasibility of crowdsourcing bus stop audits using our custom tool with GSV. Our findings reemphasize the importance of landmarks in non-visual navigation, demonstrate that GSV is a viable bus stop audit dataset, and show that minimally trained crowd workers can find and identify bus stop landmarks with 82.5% accuracy across 150 bus stop locations (87.3% with simple quality control).

Categories and Subject Descriptors
H.5 [**Information Interfaces and Presentation**]: User Interfaces; K.4.2 [**Social Issues**]: Assistive tech for persons with disabilities

General Terms
Measurement, Design, Experimentation, Human Factors

Keywords
Crowdsourcing accessibility; accessible bus stops; Google Street View; Mechanical Turk; low-vision and blind users

1. INTRODUCTION
For people who are blind or low-vision, public transportation is vital for independent travel [1,7,25,32]—particularly because their visual impairment often prevents driving. In previous formative work, we interviewed six blind adults about accessibility challenges in using public transportation [2]. We found that while buses were frequently a preferred mode of transit, determining the exact location of a bus stop was a major challenge [*ibid*, p. 3249]. Strategies for finding bus stops included asking other pedestrians for information (if available) or locating known landmarks such as bus stop signs, shelters, or other physical objects (*e.g.*, benches).

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Tohme: Detecting Curb Ramps in
Crowdsourcing, Computer Visio

Kotaro Hara[1,2], Jin Sun, Robert Moore[1,2],
[1]Makeability Lab | [2]Human Computer
Computer Science Department, Universit
{kotaro, jinsun, dwj, jonf}@cs.umd.e

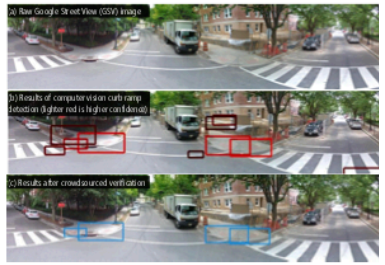

Figure 1: In this paper, we present *Tohme*, a scalable system for semi-automaticall imagery using computer vision, machine learning, and crowdsourcing. The images

ABSTRACT
Building on recent prior work that combines Google Street View (GSV) and crowdsourcing to remotely collect information on physical world accessibility, we present the first "smart" system, *Tohme*, that combines machine learning, computer vision (CV), and custom crowd interfaces to find curb ramps remotely in GSV scenes. Tohme consists of two workflows, a human labeling pipeline and a CV pipeline with human verification, which are scheduled dynamically based on predicted performance. Using 1,086 GSV scenes (street intersections) from four North American cities and data from 403 crowd workers, we show that Tohme performs similarly in detecting curb ramps compared to a manual labeling approach alone (F-measure: 84% *vs.* 86% baseline) but at a 13% reduction in time cost. Our work contributes the first CV-based curb ramp detection system, a custom machine-learning based workflow controller, a validation of GSV as a viable curb ramp data source, and a detailed examination of why curb ramp detection is a hard problem along with steps forward.

UIST'14, October 05 - 08 2014, Honolulu, HI, USA.

http://dx.doi.org/10.1145/2642918.2647403

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[1] Toh

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

KOTARO HARA, University of Maryland, College Park
SHIRI AZENKOT, Cornell Tech
MEGAN CAMPBELL and CYNTHIA L. BENNETT, University of Washington
VICKI LE, SEAN PANNELLA, and ROBERT MOORE, University of Maryland, College Park
KELLY MINCKLER and ROCHELLE H. NG, University of Washington
JON E. FROEHLICH, University of Maryland, College Park

Low-vision and blind bus riders often rely on known physical landmarks to help locate and verify bus stop locations (e.g., by searching for an expected shelter, bench, or newspaper bin). However, there are currently few, if any, methods to determine this information *a priori* via computational tools or services. In this article, we introduce and evaluate a new scalable method for collecting bus stop location and landmark descriptions by combining online crowdsourcing and Google Street View (GSV). We conduct and report on three studies: (i) a formative interview study of 18 people with visual impairments to inform the design of our crowdsourcing tool, (ii) a comparative study examining differences between physical bus stop audit data and audits conducted virtually with GSV, and (iii) an online study of 153 crowd workers on Amazon Mechanical Turk to examine the feasibility of crowdsourcing bus stop audits using our custom tool with GSV. Our findings reemphasize the importance of landmarks in nonvisual navigation, demonstrate that GSV is a viable bus stop audit dataset, and show that minimally trained crowd workers can find and identify bus stop landmarks with 82.5% accuracy across 150 bus stop locations (87.3% with simple quality control).

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General Terms: Measurement, Design, Experimentation, Human Factors

Additional Key Words and Phrases: Crowdsourcing accessibility, accessible bus stops, Google Street View, Mechanical Turk, low-vision and blind users, remote data collection, bus stop auditing

ACM Reference Format:
Kotaro Hara, Shiri Azenkot, Megan Campbell, Cynthia L. Bennett, Vicki Le, Sean Pannella, Robert Moore, Kelly Minckler, Rochelle H. Ng, and Jon E. Froehlich. 2015. Improving public transit accessibility for blind riders by crowdsourcing bus stop landmark locations with Google Street View: An extended analysis. ACM Trans. Access. Comput. 6, 2, Article 5 (March 2015), 23 pages.
DOI: http://dx.doi.org/10.1145/2717513

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A preliminary version of this article appeared in the Proceedings of the 15th ACM SIGACCESS International Conference on Computers and Accessibility, October 21–23, 2013.
Authors' addresses: K. Hara, V. Le, S. Pannella, R. Moore, and J. E. Froehlich, Department of Computer Science, University of Maryland, College Park, 20742 MD; S. Azenkot, Jacobs Technion-Cornell Institute, Cornell Tech, 111 8th Ave. New York NY 10011; M. Campbell, C. L. Bennett, K. Minckler, and R. H. Ng, Computer Science Department, University of Washington, 185 W Stevens Way NE, Seattle, WA 98195.

DOI: http://dx.doi.org/10.1145/2717513

See: Hara *et al.*, 2012; Hara *et al.*, 2013; Hara *et al.*, 2014; Hara, *et al.*, 2015

NO public deployments

How do we enable and sustain **large-scale** **data collection** of sidewalk accessibility across **diverse** **users**?

PROJECT SIDEWALK DEPLOYMENT STUDY

KEY RESEARCH QUESTIONS

User Behavior

Data Accuracy

Data Utility

PROJECT SIDEWALK DEPLOYMENT STUDY

KEY RESEARCH QUESTIONS

User Behavior

RQ1 What are the **behavioral differences** between paid crowd workers and volunteers?

Data Accuracy

Data Utility

PROJECT SIDEWALK DEPLOYMENT STUDY

KEY RESEARCH QUESTIONS

User Behavior

RQ1 What are the **behavioral differences** between paid crowd workers and volunteers?

Data Accuracy

RQ2 What are the **labeling quality differences** between paid crowd workers and volunteers and the **common mistakes** made?

Data Utility

PROJECT SIDEWALK DEPLOYMENT STUDY

KEY RESEARCH QUESTIONS

User Behavior

RQ1 What are the **behavioral differences** between paid crowd workers and volunteers?

Data Accuracy

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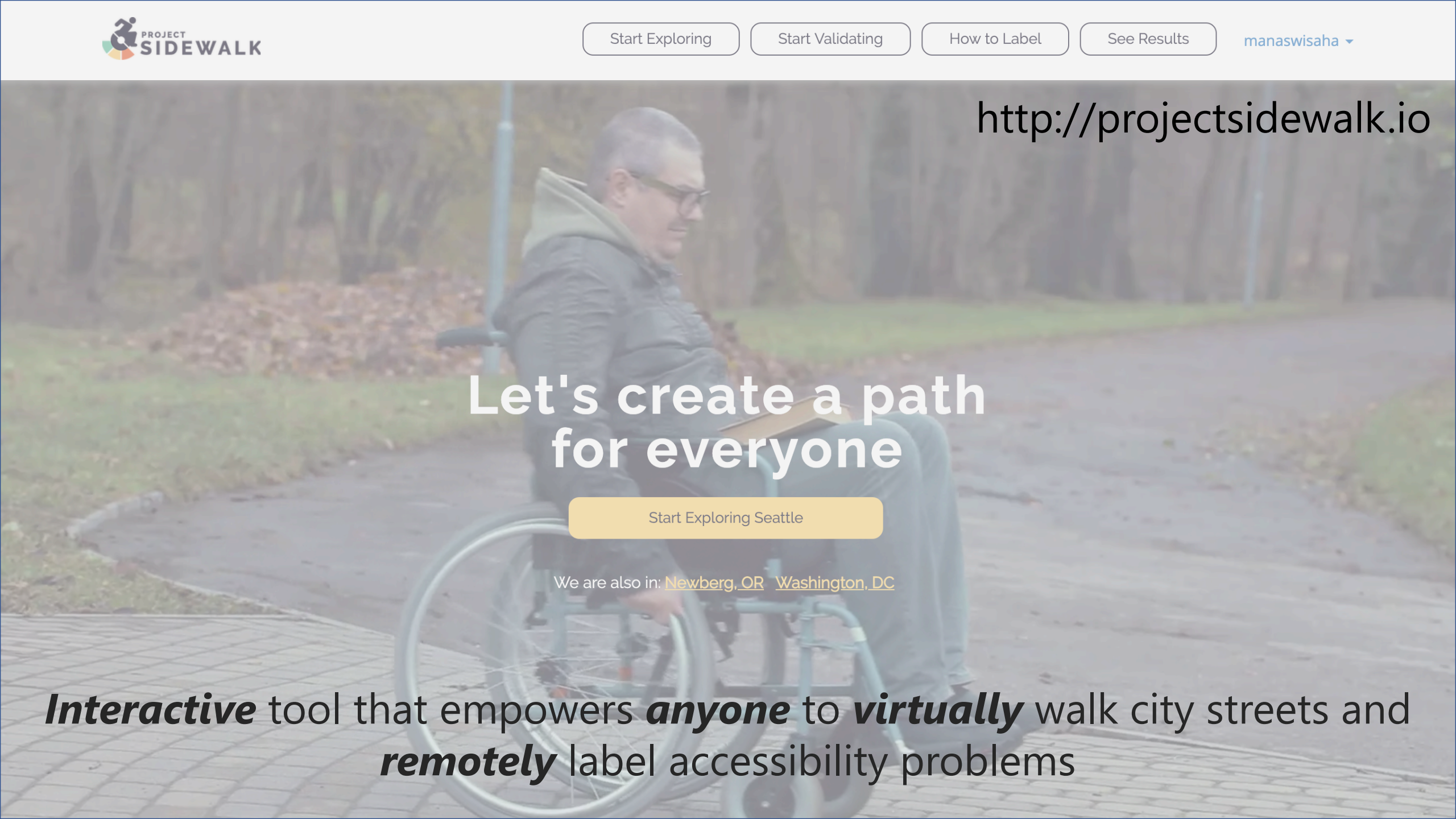
Data Utility

RQ3 What are the **perceptions of utility** of crowdsourced accessibility data and concerns of **key stakeholder groups**?

PROJECT SIDEWALK

HTTP://PROJECTSIDEWALK.IO



Interactive tool that empowers ***anyone*** to ***virtually*** walk city streets and ***remotely*** label accessibility problems

TOOL WALKTHROUGH

Find and label the following

Explore | Curb Ramp | Missing Curb Ramp | Obstacle in Path | Surface Problem | Other

Zoom In | Zoom Out | Undo | Redo

Current Neighborhood
Fort Stanton, D.C.

Sound

Jump

Feedback

Audit 1000ft of Fort Stanton

Your mission is to audit 1000ft of Fort Stanton and find all the accessibility features that affect mobility impaired travelers!

OK

TOOL WALKTHROUGH

Find and label the following

Explore | Curb Ramp | Missing Curb Ramp | Obstacle in Path | Surface Problem | Other

Zoom In | Zoom Out | Undo | Redo

Current Neighborhood

Fort McNair, D.C.

0.0 miles | 0 labels

Current Mission

Audit 1000ft of this neighborhood

15% complete

2 curb ramps

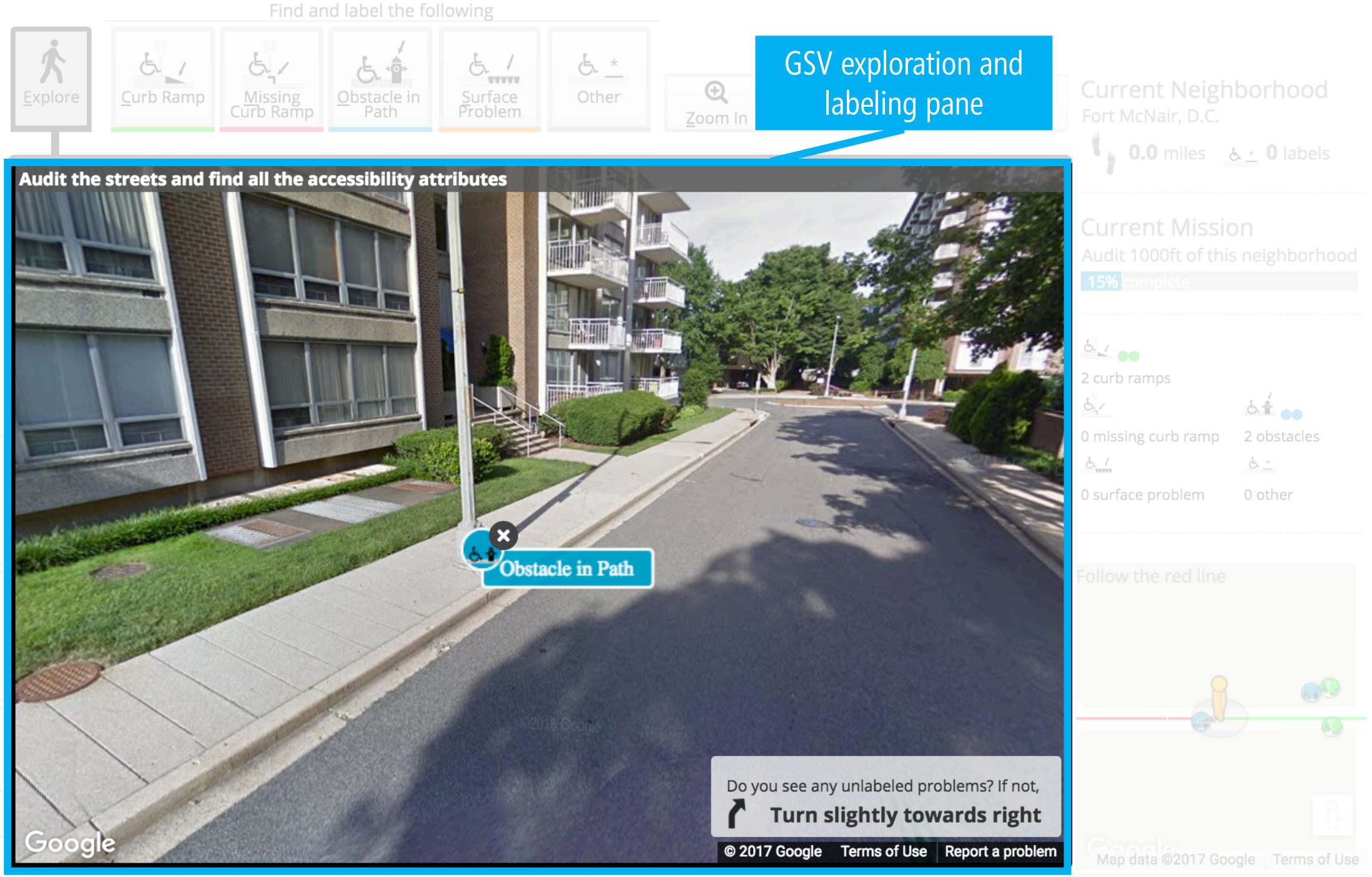
0 missing curb ramp

2 obstacles

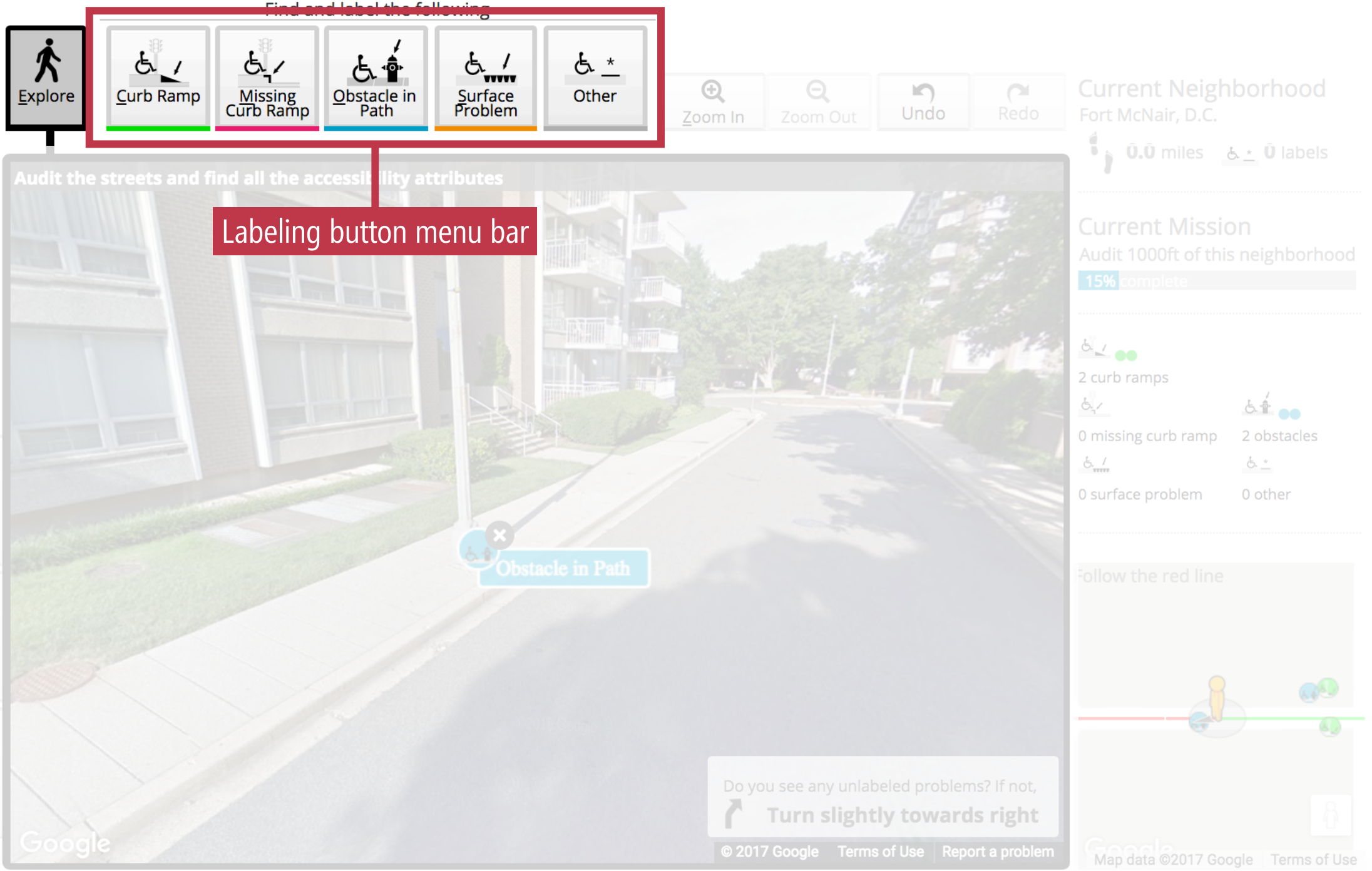
0 surface problem

0 other

TOOL WALKTHROUGH



TOOL WALKTHROUGH



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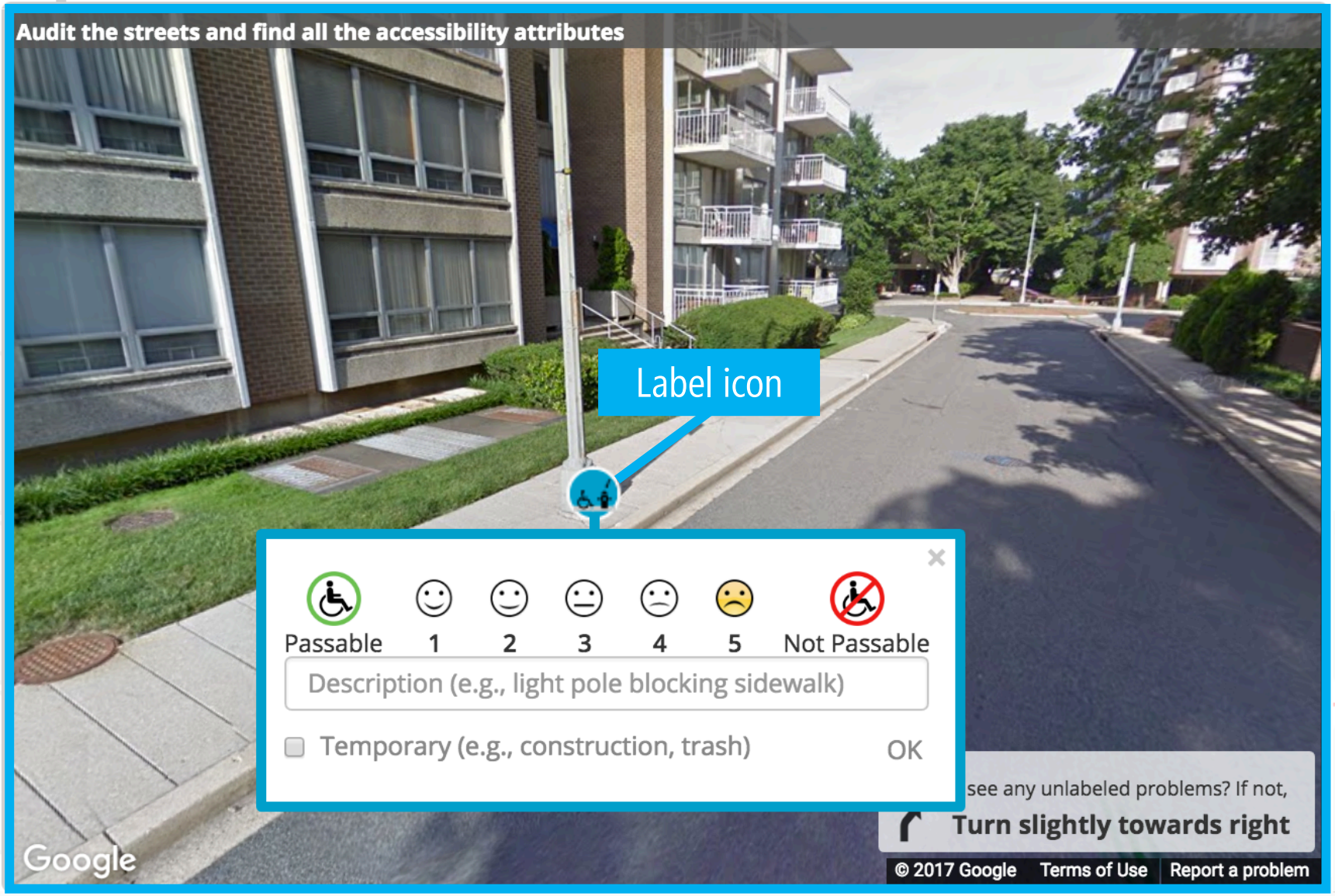

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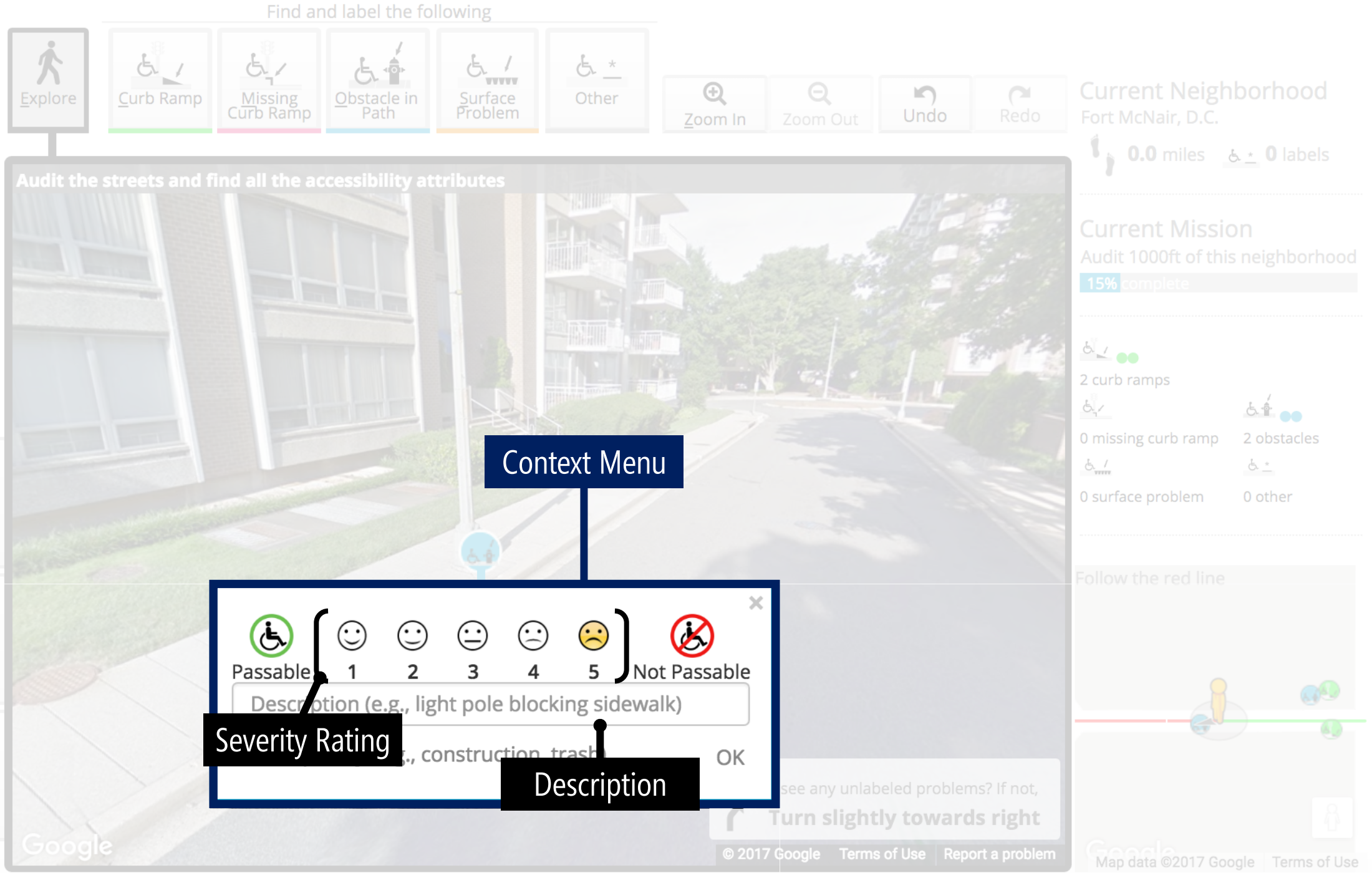

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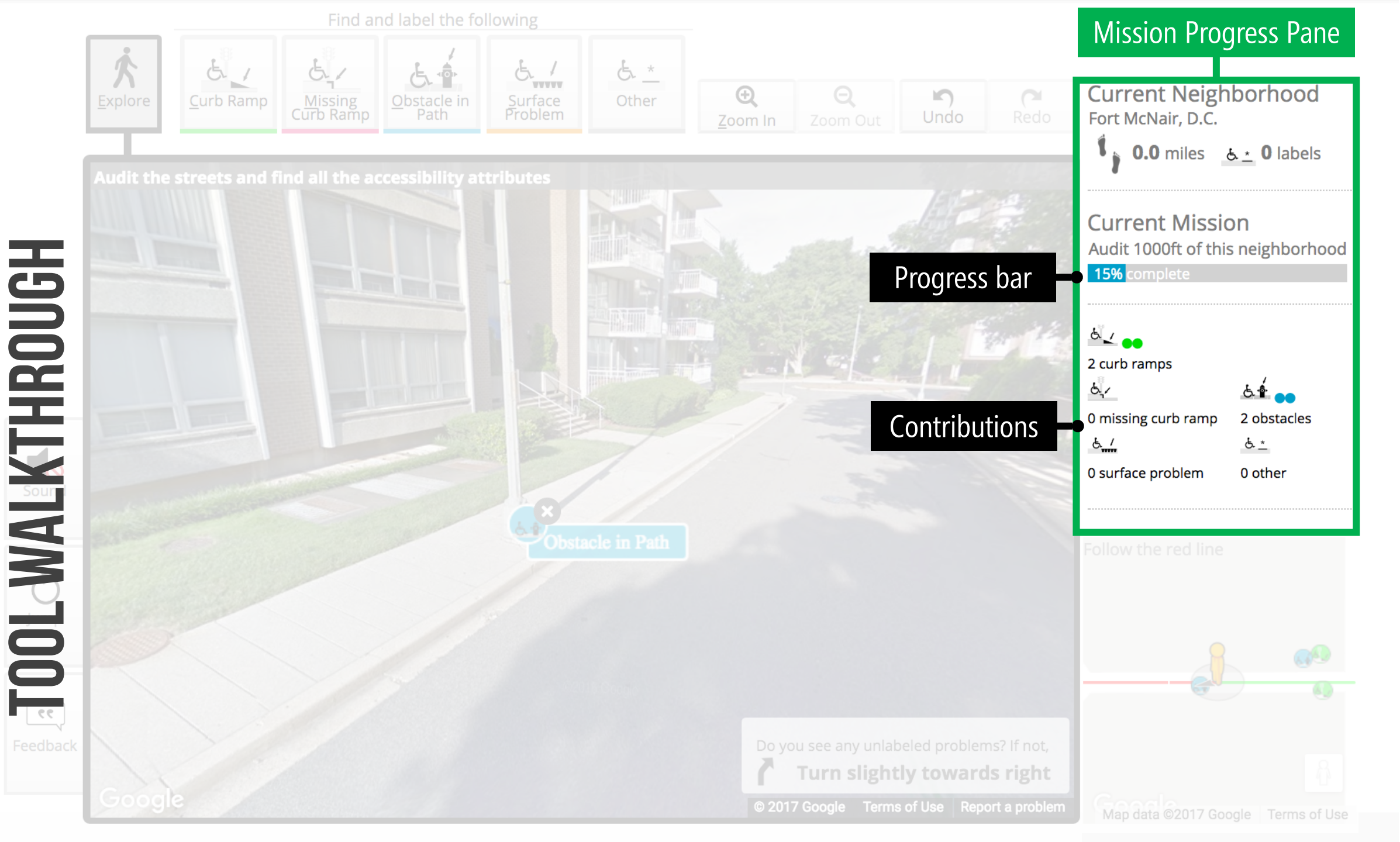

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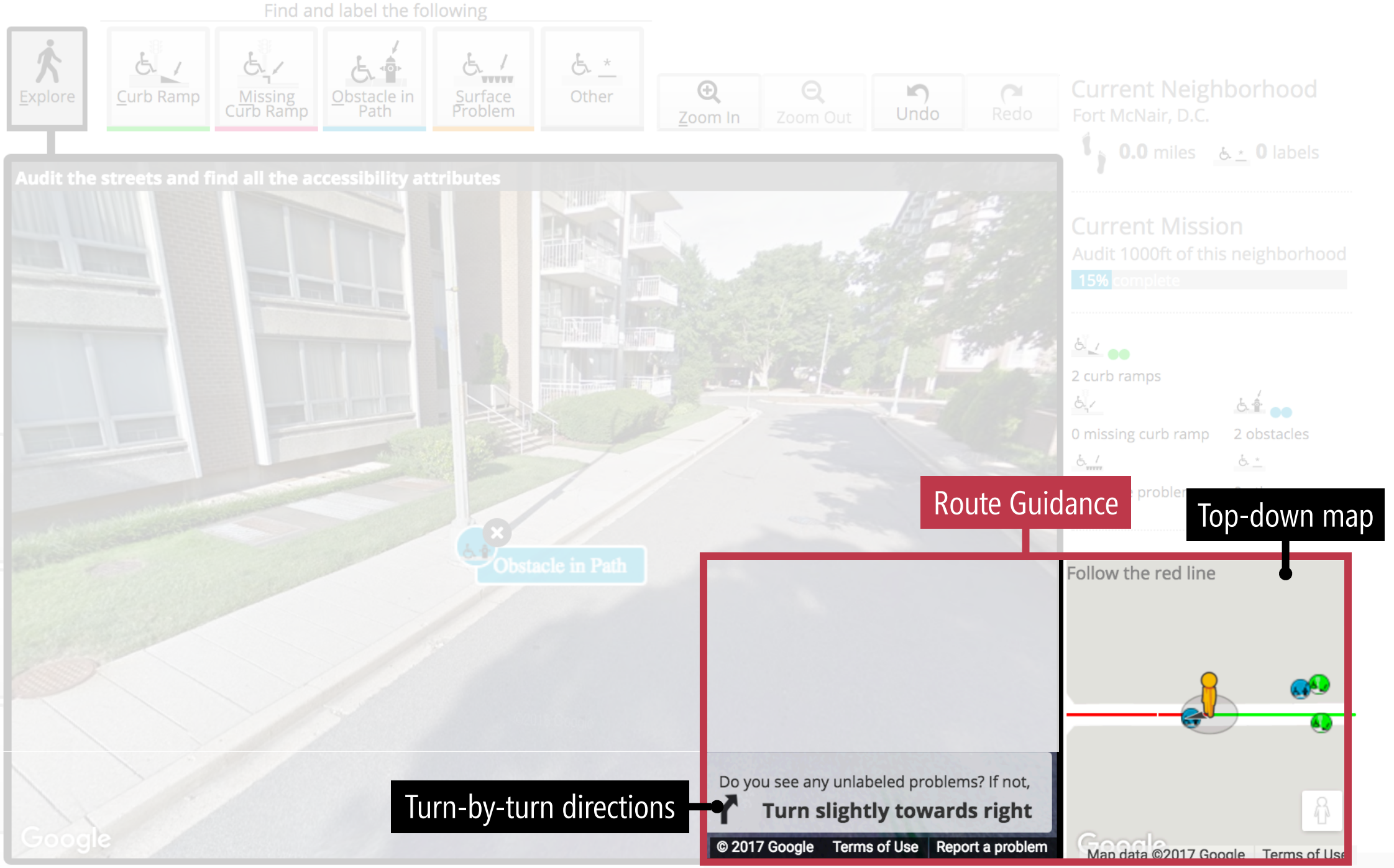


PROJECT SIDEWALK SYSTEM

INTERACTIVE TUTORIAL

Find and label the following

Explore | Curb Ramp | Missing Curb Ramp | Obstacle in Path | Surface Problem | No Sidewalk | Other | Zoom In | Zoom Out

Current Neighborhood
Woodridge, D.C.
0.0 miles
0 labels

Current Mission
Complete the onboarding tutorial!
0% complete

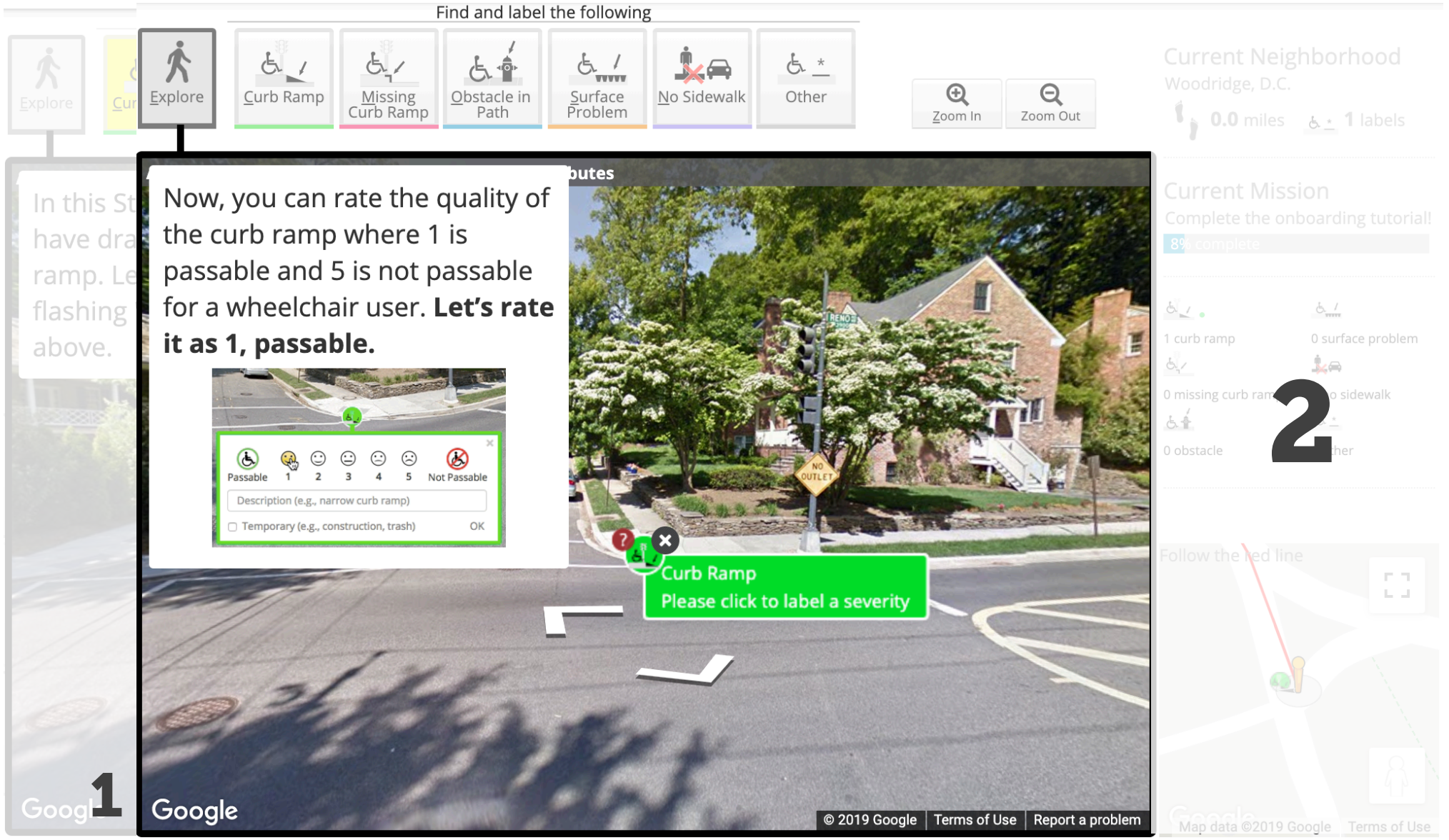
0 curb ramp
0 surface problem
0 missing curb ramp
0 no sidewalk
0 obstacle
0 other

1

Follow the red line

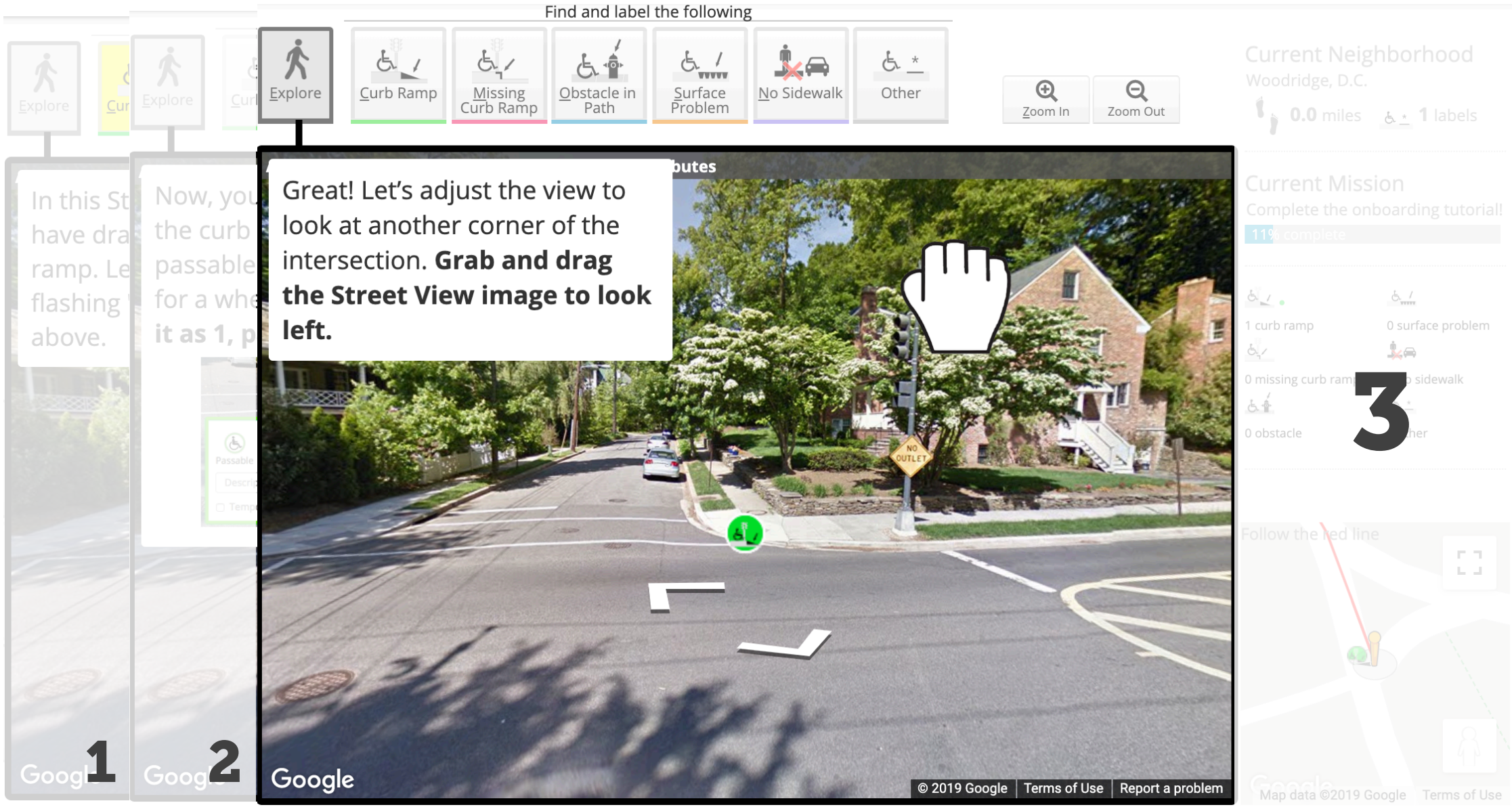
PROJECT SIDEWALK SYSTEM

INTERACTIVE TUTORIAL



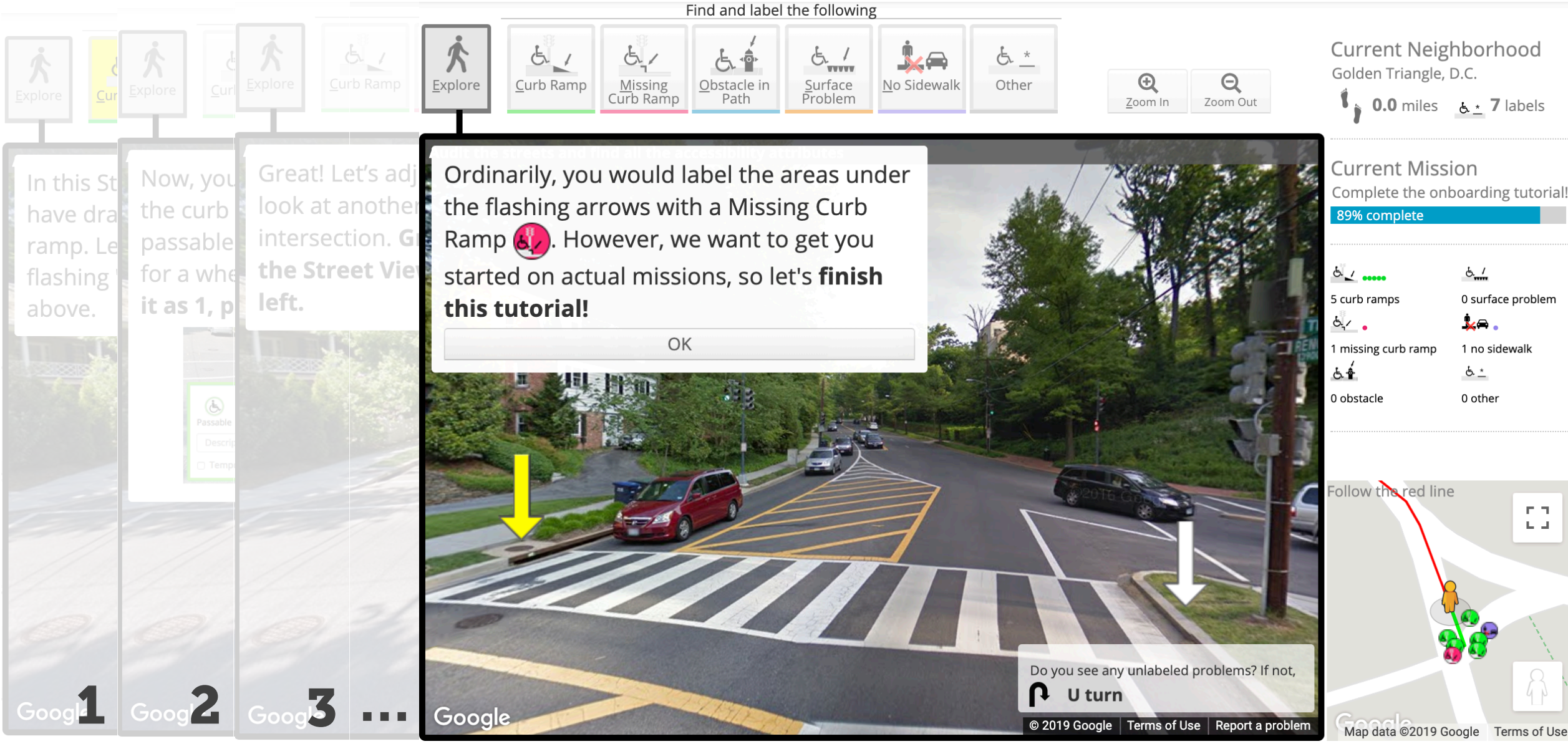
PROJECT SIDEWALK SYSTEM

INTERACTIVE TUTORIAL



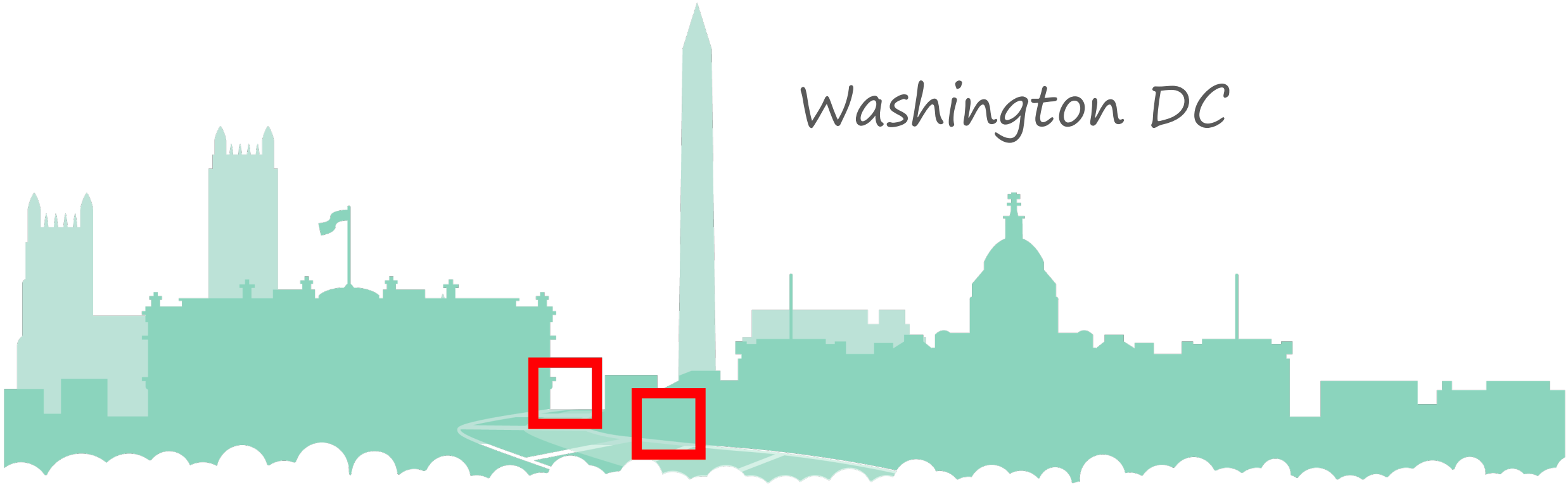
PROJECT SIDEWALK SYSTEM

INTERACTIVE TUTORIAL



PROJECT SIDEWALK SYSTEM

DEPLOYMENT STUDY



18-month deployment ~ Fall **2016** - Spring **2018**

DEPLOYMENT STUDY

DATA COLLECTED

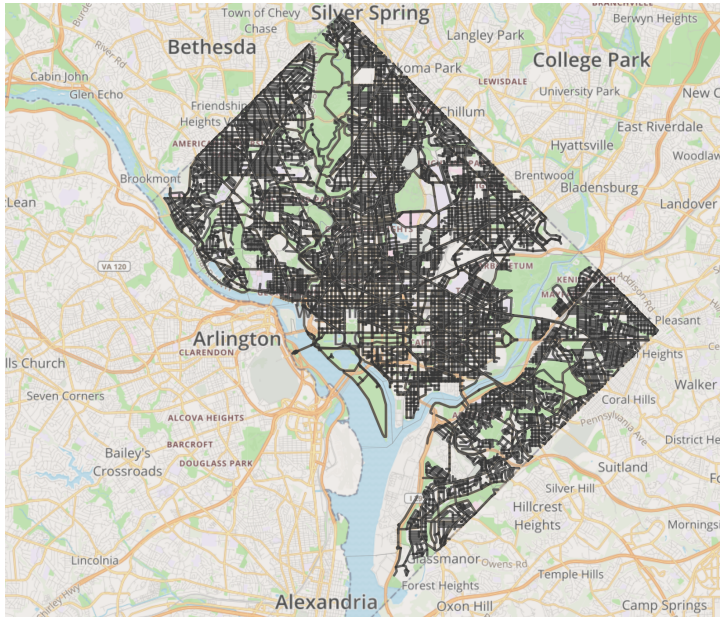
Fall 2016 - Spring 2018

PROJECT SIDEWALK
HTTP://PROJECTSIDEWALK.IO

797

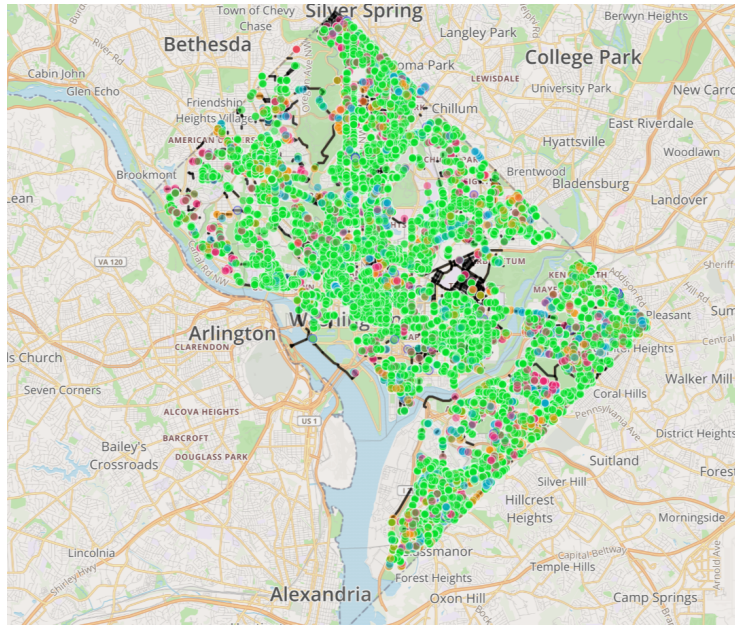
USERS

Volunteers | Turkers



2941

MILES



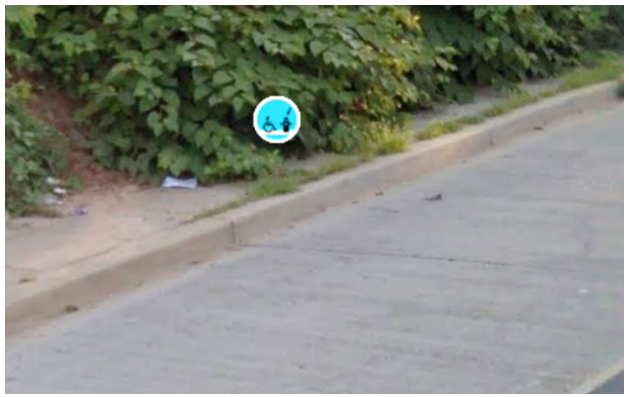
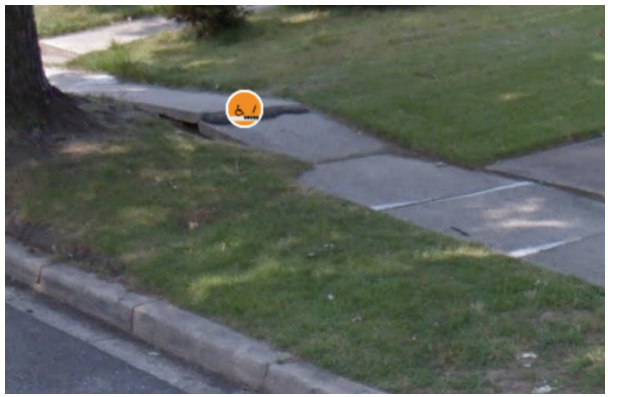
205,385

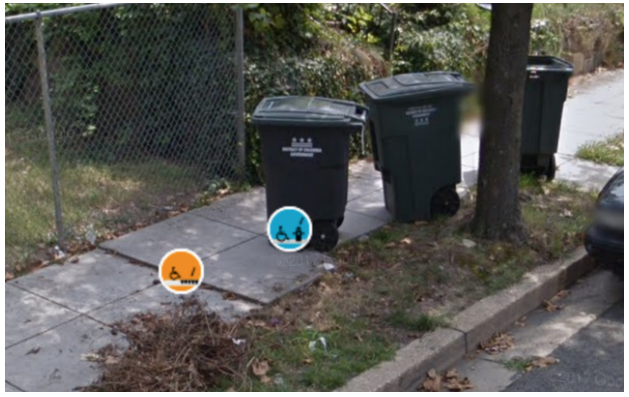
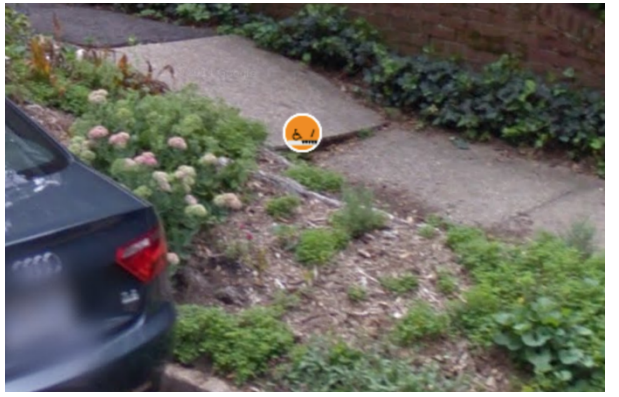
LABELS

DEPLOYMENT STUDY

LABEL EXAMPLES



142,835 Curb Ramps	18,719 Missing Curb Ramps	21,736 Obstacles	8309 Surface Problems

DEPLOYMENT STUDY

HOW ACCURATELY DID USERS PERFORM?

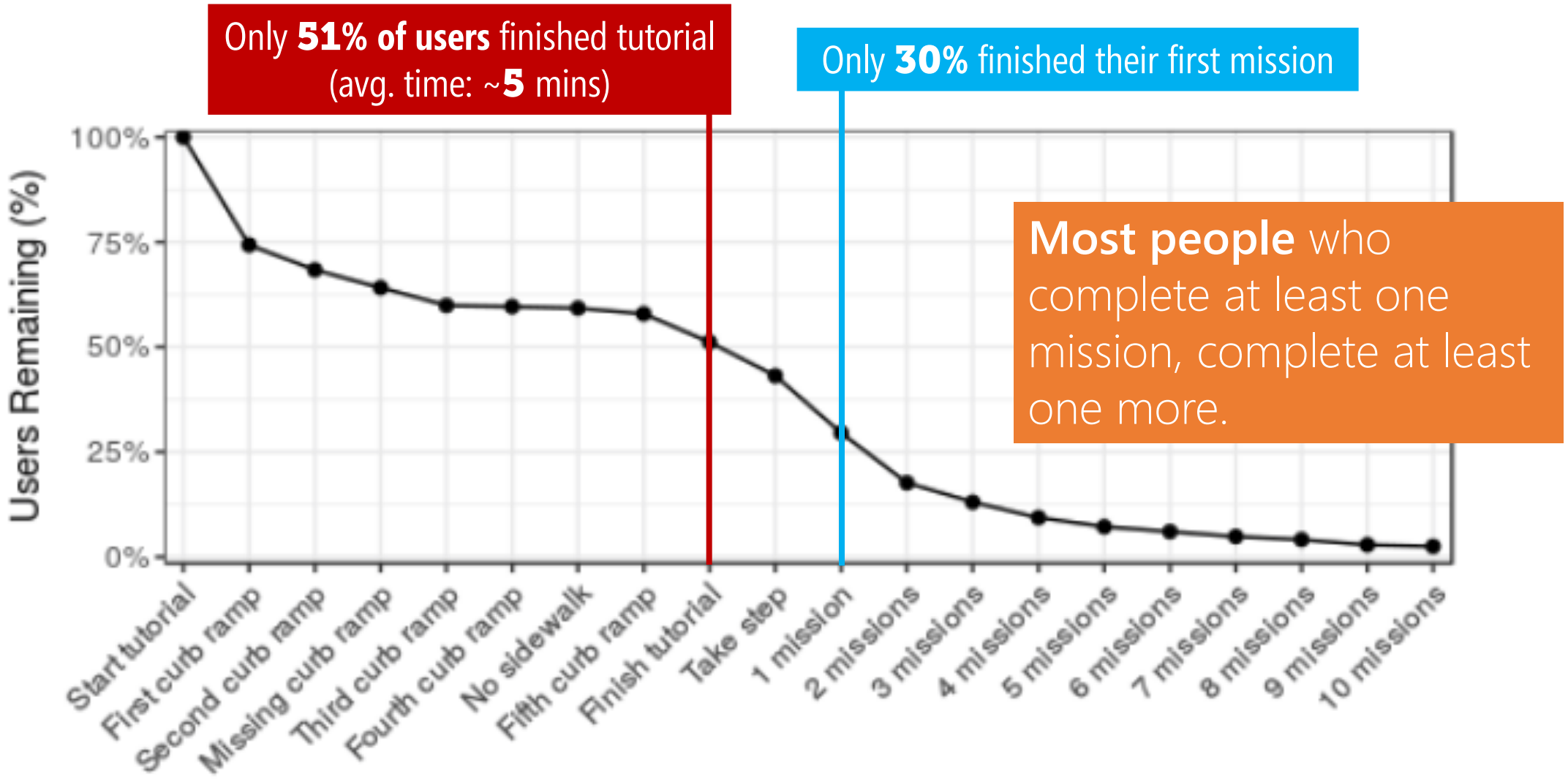
~70%

*raw accuracy across **all** user groups

*Calculated on a subset of the dataset

DEPLOYMENT STUDY

HOW ENGAGED WERE THE USERS?



PROJECT SIDEWALK DEPLOYMENT STUDY

KEY RESEARCH QUESTIONS

RQ1 What are the **behavioral differences** between paid crowd workers and volunteers?

RQ2 What are the **labeling quality differences** between paid crowd workers and volunteers and the **common mistakes** made?

RQ3 What are the **perceptions of utility** of crowdsourced accessibility data and concerns of **key stakeholder groups**?

PROJECT SIDEWALK DEPLOYMENT STUDY

USER GROUPS

Anonymous Users

Registered Users

Volunteers

amazon mechanical turk

Paid crowdworkers (Turkers)

RQ1: USER BEHAVIOR RESULTS

DID ALL USER GROUPS BEHAVE THE SAME WAY?

Registered users

completed more **missions**
contributed **more labels**
audited **faster**
spent **most time** on Project Sidewalk

} than anonymous users

Turkers did **more work** and were more **persistent** than both

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RQ2: DATA VALIDATION STUDY

DID ALL USER GROUPS LABEL THE SAME WAY?

44 miles of ground truth data by **3** researchers

From mix of **50** registered and **16** anonymous user routes

Across **four** quadrants and different land-use zones of DC

62 of **172** DC neighborhoods

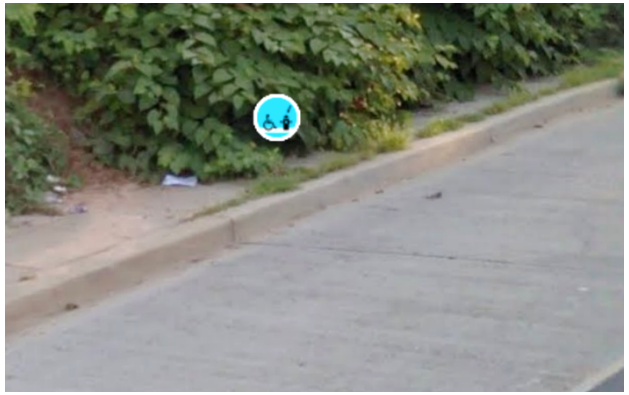
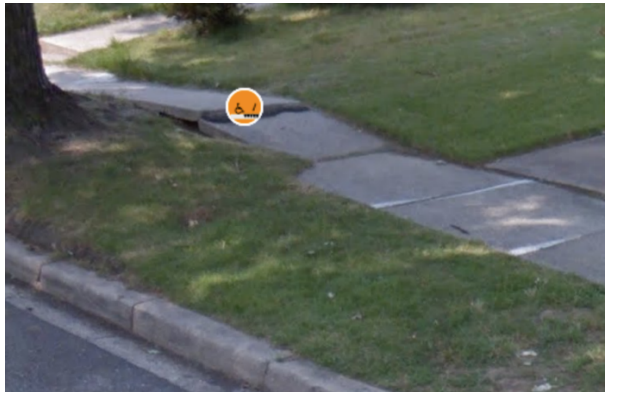
Clustered labels from single user then across users

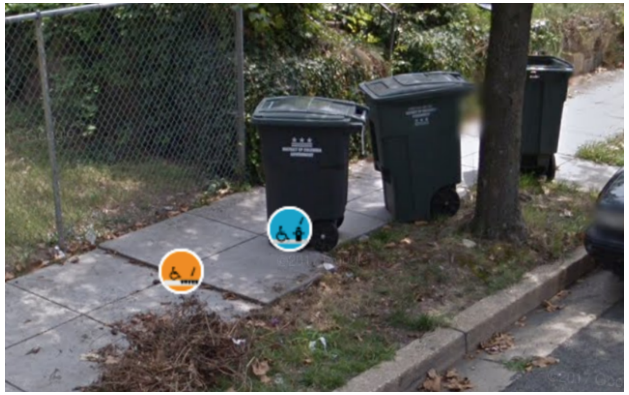
RQ2: DATA VALIDATION STUDY

DATA VALIDATION STUDY: DATASET

4617 label clusters




3212 Curb Ramps | **87** Missing Curb Ramps | **295** obstacles | **1023** Surface Problems

DATA VALIDATION STUDY: METRICS

Precision Measures correctness of an applied label

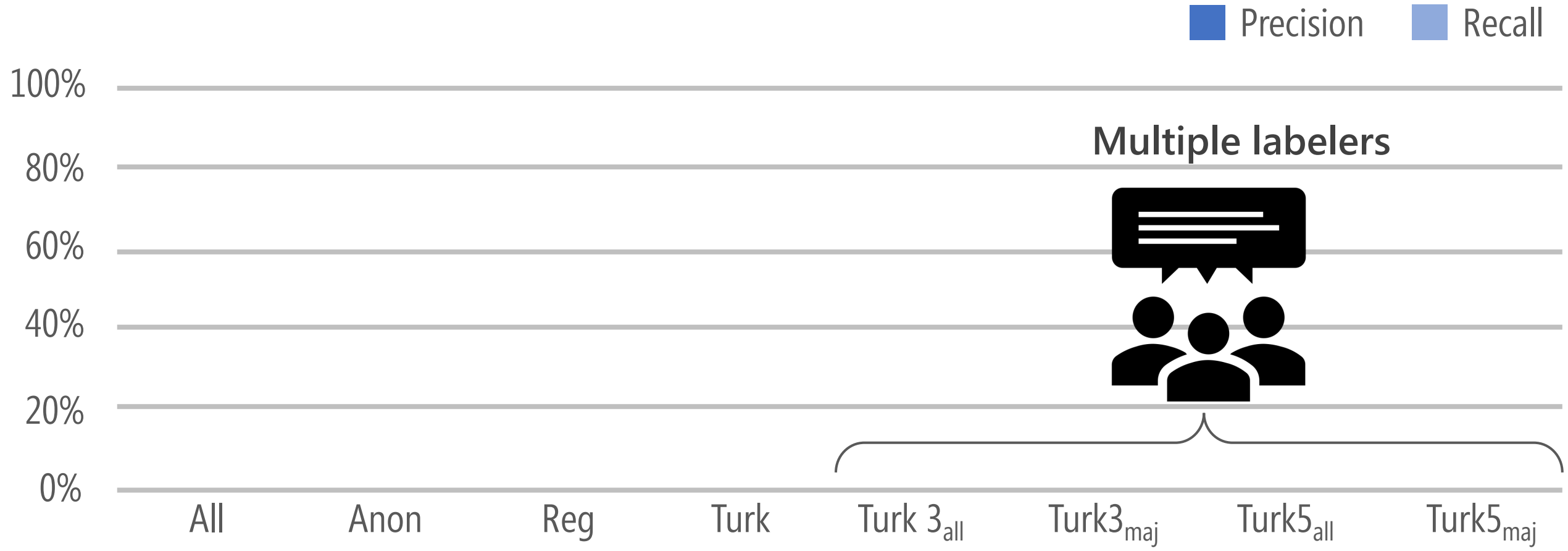
Recall Measures %age of correctly identified issues

False Positive

False Negative

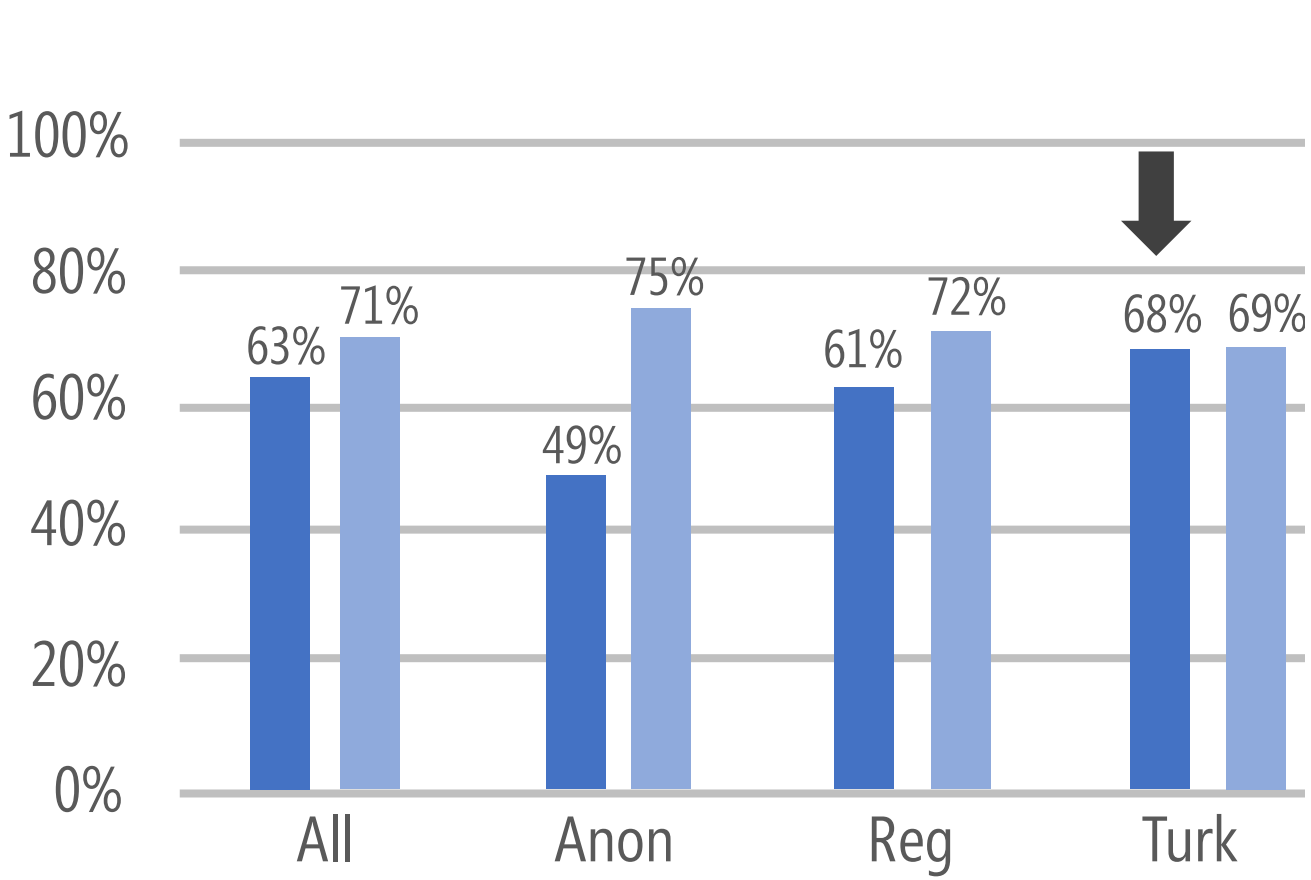
RQ2: DATA VALIDATION STUDY

HOW ACCURATELY DID USERS PERFORM?



RQ2: DATA VALIDATION STUDY

HOW ACCURATELY DID USERS PERFORM?



Turkers found significantly **more issues** with **similar precision**

RQ2: DATA VALIDATION STUDY

WHAT ARE THE HARDEST LABEL TYPES?

Missing Curb Ramps

20.5% precision | **69.3%** recall

Confusion with what justifies as a missing curb ramp

RQ2: DATA VALIDATION STUDY

WHAT ARE THE HARDEST LABEL TYPES?

Hard to find
Requires diligent exploration
Often confused with each other

Surface problems | Obstacles in Path

72.6% precision | **47.5%** precision

27.1% recall | **39.9%** recall

RQ2: QUALITATIVE ANALYSIS OF ERRORS

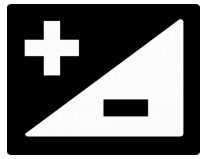
WHAT ARE THE COMMON LABELING MISTAKES?

RQ2: QUALITATIVE ANALYSIS OF ERRORS

WHAT ARE THE COMMON LABELING MISTAKES?

54

False positives



54

False negatives

432

total error samples analyzed

RQ2: QUALITATIVE ANALYSIS OF ERRORS

WHAT ARE THE COMMON LABELING MISTAKES?

Randomly sampled 54 false positives and 54 false negatives for each label type (432 total error samples analyzed)

Curb Ramps

44.4% driveway transition

22.2% driveways

66.7% - driveways

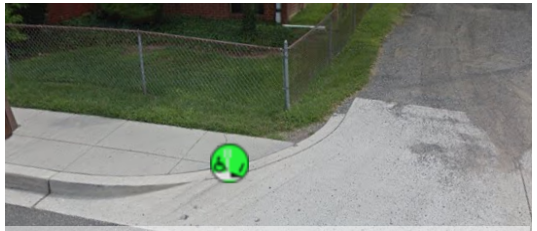
14.8% random

RQ2

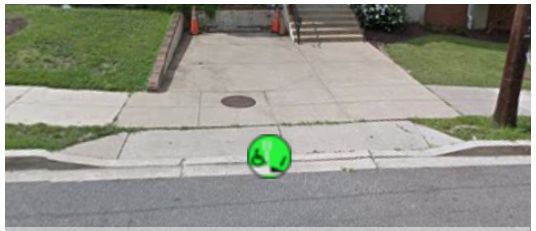
WHAT ARE THE COMMON LABELING MISTAKES?

Randomly sampled 54 false positives and 54 false negatives for each label type (432 total error samples analyzed)

Curb Ramps



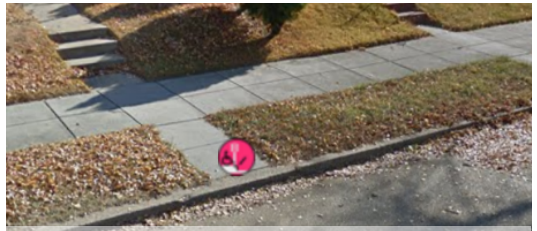
44.4% driveway transition



22.2% driveways

14.8% random

Missing Curb Ramps



29.6% house-to-curb

25.9% no pedestrian route

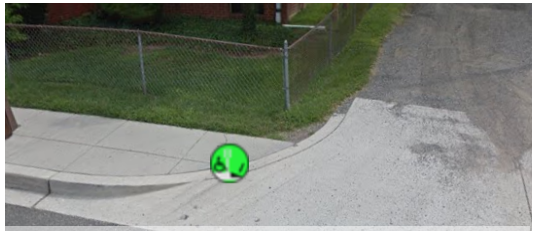
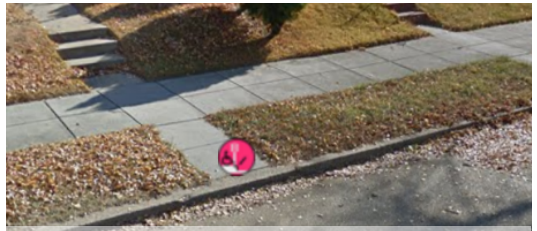
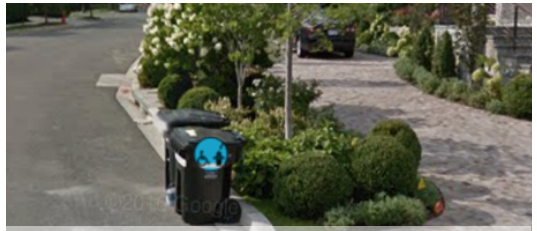
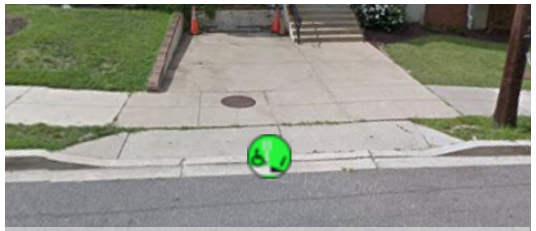
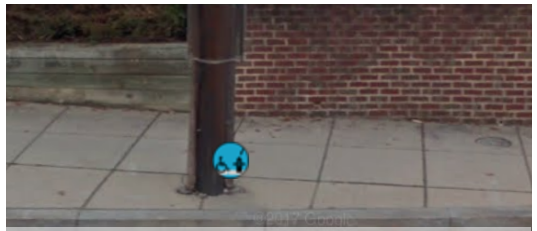
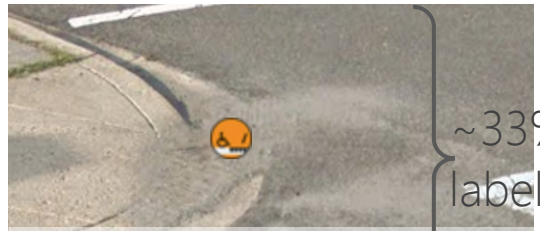
24.1% curb ramp exists

~30% extended residential walkways

RQ2: QUALITATIVE ANALYSIS OF ERRORS

WHAT ARE THE COMMON LABELING MISTAKES?

Randomly sampled 54 false positives and 54 false negatives for each label type (432 total error samples analyzed)

Curb Ramps	Missing Curb Ramps	Obstacles	Surface Problems
 **44.4%** driveway transition	 **29.6%** house-to-curb	 **42.6%** not on pedestrian route	 **46.2%** not on pedestrian route
 **22.2%** driveways	 **25.9%** no pedestrian route	 **37.0%** space to avoid obstacle	 **32.7%** incorrect label type
 **14.8%** random	 **24.1%** curb ramp exists	 **9.3%** wrong label type	 **11%** normal sidewalk tiling

~50% not on pedestrian route

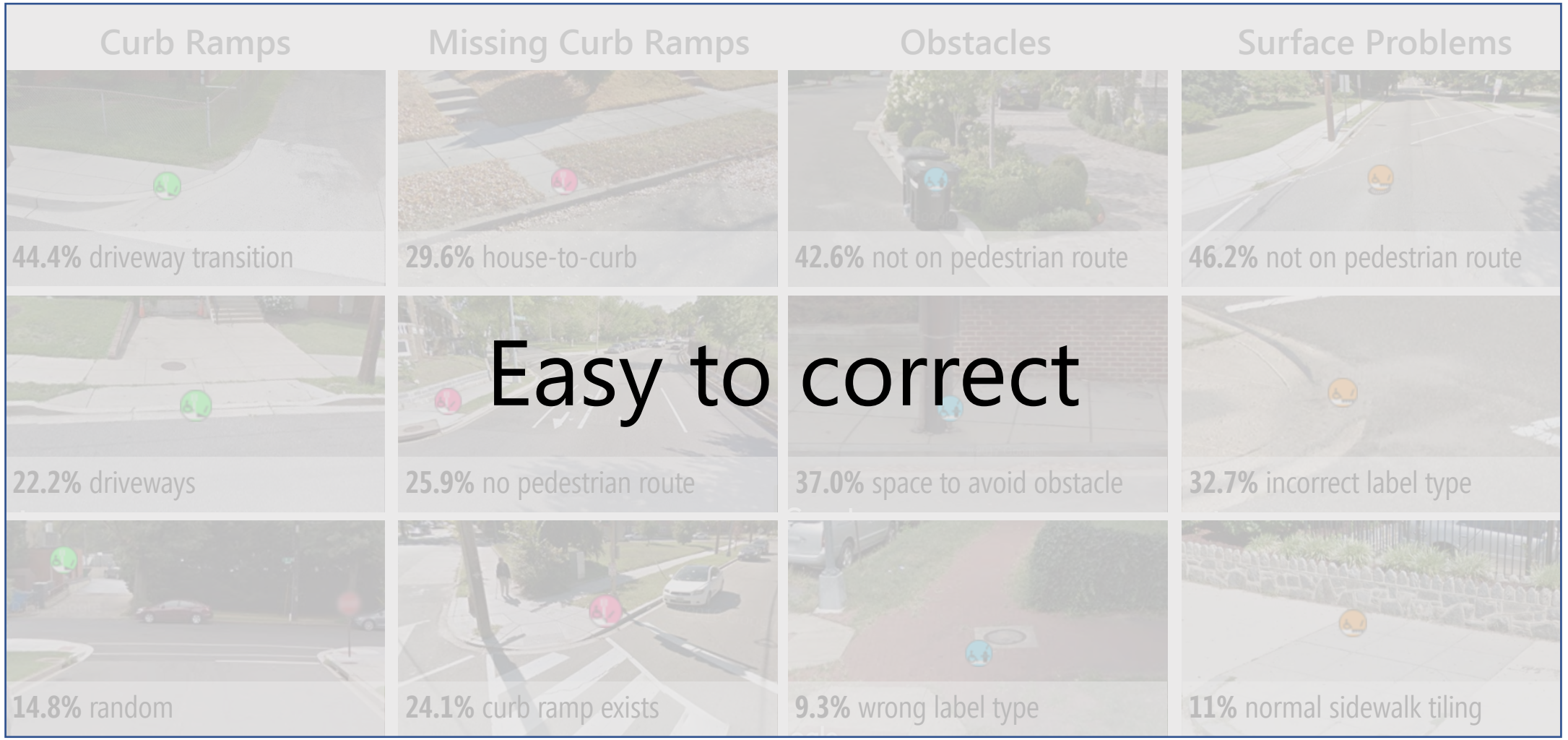
~33% wrong label type

~9% wrong label type

RQ2: QUALITATIVE ANALYSIS OF ERRORS

WHAT ARE THE COMMON LABELING MISTAKES?

Randomly sampled 54 false positives and 54 false negatives for each label type (432 total error samples analyzed)



PROJECT SIDEWALK DEPLOYMENT STUDY

KEY RESEARCH QUESTIONS

RQ1 What are the **behavioral differences** between paid crowd workers and volunteers?

RQ2 What are the **labeling quality differences** between paid crowd workers and volunteers and the **common mistakes** made?

RQ3 What are the **perceptions of utility** of crowdsourced accessibility data and concerns of **key stakeholder groups**?

PROJECT SIDEWALK DEPLOYMENT STUDY

KEY RESEARCH QUESTIONS

RQ1 Are there **behavioral and labeling quality differences** between paid crowd workers and volunteers?

RQ2 What are the **common labeling mistakes**?

RQ3 What are the **perceptions of utility** of crowdsourced accessibility data and concerns of **key stakeholder groups**?

RQ3: INTERVIEW STUDY

WHAT ARE THE STAKEHOLDERS' PERCEPTIONS AND CONCERNS?

N=14 across **3** stakeholder groups: **MI, CVG, GOV**

Perceived Value

Usability

Design Suggestions

Concerns

RQ3: INTERVIEW STUDY

WHAT ARE THE STAKEHOLDERS' PERCEPTIONS AND CONCERNS?

N=14 across **3** stakeholder groups

Perceived Value

Usability

Design Suggestions

Concerns

RQ3: INTERVIEW STUDY

WHAT ARE THE STAKEHOLDERS' PERCEPTIONS AND CONCERNS?

Perceived Value

Enabled rapid data collection

Gathered diverse perspectives about accessibility

Helped engage citizens in thinking about urban design

RQ3: INTERVIEW STUDY

WHAT ARE THE STAKEHOLDERS' PERCEPTIONS AND CONCERNS?

Perceived Value

> *It's really good for a starting point. This is a first observation, and when you send somebody out in the field, they can see those observations and pick up more information. It's just neat!*
>
> -G4

RQ3: INTERVIEW STUDY

WHAT ARE THE STAKEHOLDERS' PERCEPTIONS AND CONCERNS?

Concerns

Data age i.e., outdated GSV imagery or labels

Data reliability

Conflicted data

RQ3: INTERVIEW STUDY

WHAT ARE THE STAKEHOLDERS' PERCEPTIONS AND CONCERNS?

Concerns

> *I would have more confidence if different people did it, did the same street.*
>
> -G4

RQ3: INTERVIEW STUDY

WHAT ARE THE STAKEHOLDERS' PERCEPTIONS AND CONCERNS?

Concerns

> *My concern as a user [is that] someone said this was accessible and I got there and it wasn't accessible, because everyone has different opinions on accessibility.*
>
> -MI1

What **next**?

ONGOING AND FUTURE WORK

MORE CITIES!

Newberg, OR

40%
Newberg mapped

43
miles covered

5,167
labels

ONGOING AND FUTURE WORK

MORE CITIES!

Seattle, WA

28%

Seattle mapped

515

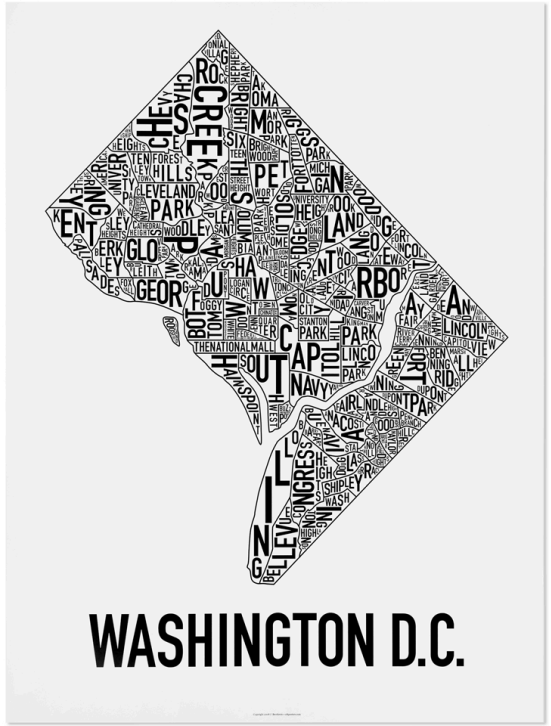
miles covered

57,317

labels

ONGOING AND FUTURE WORK

MODELING ACCESSIBILITY



vs

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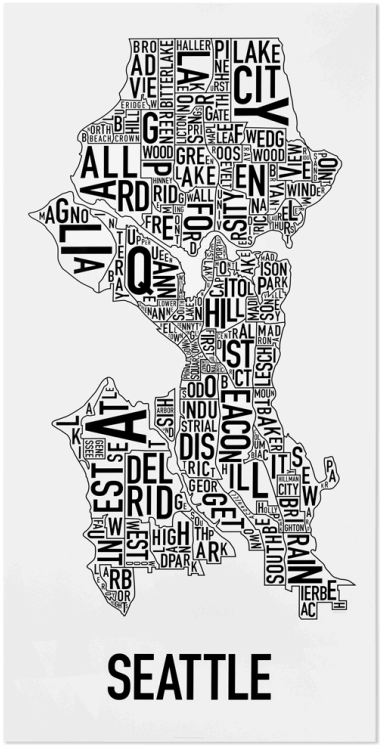
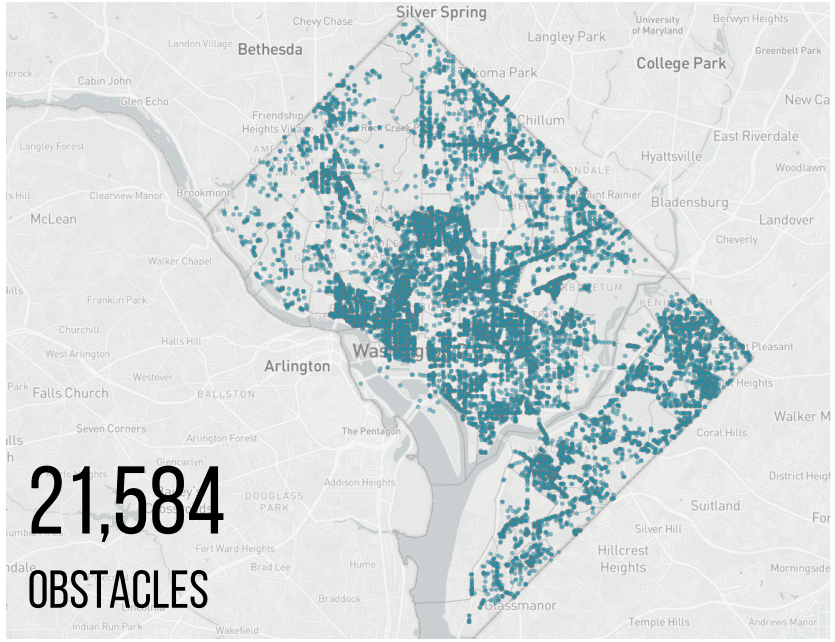


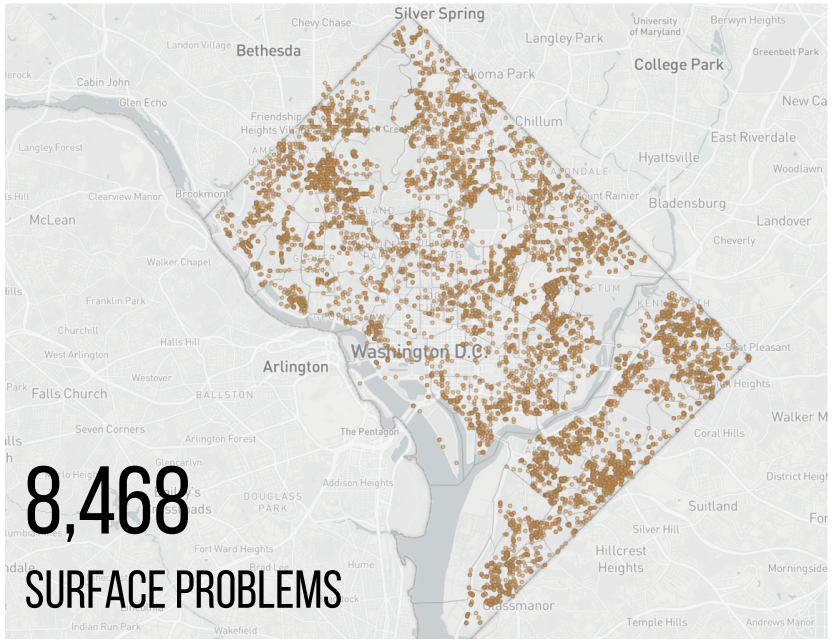
How do we compare accessibility across cities?

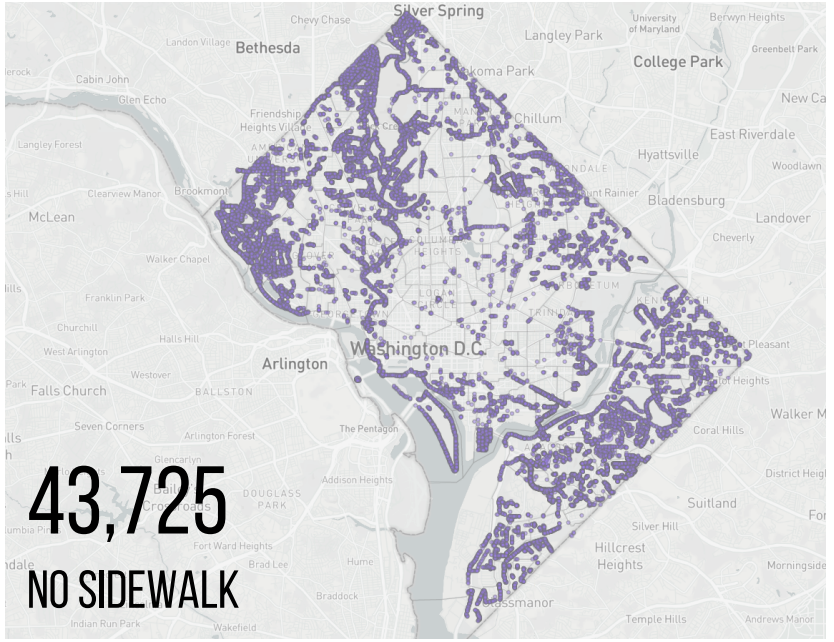
What are the correlates to accessibility?

ONGOING AND FUTURE WORK

VISUALIZING ACCESSIBILITY







What are the (in)accessible areas of the city?

ONGOING AND FUTURE WORK

AUTOMATING DATA COLLECTION USING COMPUTER VISION

Is this a **Curb Ramp**?

Is this an **Obstacle in Path**?

ONGOING AND FUTURE WORK

VALIDATION INTERFACES

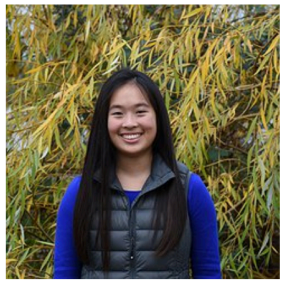
ACKNOWLEDGEMENTS

PROJECT SIDEWALK TEAM

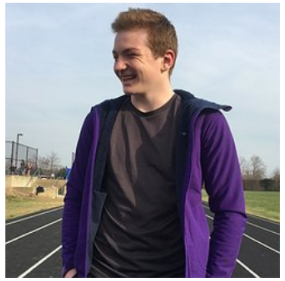
Manaswi Saha

Michael Saugstad

Hanuma Teja Maddali



Aileen Zeng



Ryan Holland

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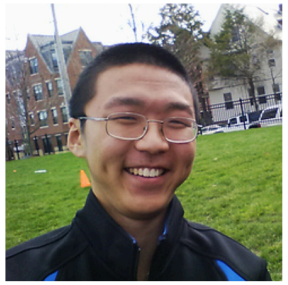

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Help make the world more accessible for everyone!

Join us. Contact manaswi@cs.uw.edu manaswisaha

https://github.com/ProjectSidewalk http://projectsidewalk.io/api

PROJECT SIDEWALK

HTTP://PROJECTSIDEWALK.IO

Any Questions?

MAKEABILITY LAB

DESIGN USE BUILD

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