UnlockedMaps: Visualizing Real-Time Accessibility of Urban Rail Transit Using a Web-Based Map

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ABSTRACT

Current web-based maps do not provide visibility into real-time elevator outages at urban rail transit stations, disenfranchising commuters (e.g., wheelchair users) who rely on functioning elevators at transit stations. In this paper, we demonstrate UnlockedMaps, an open-source and open-data web-based map that visualizes the real-time accessibility of urban rail transit stations in six North American cities, assisting users in making informed decisions regarding their commute. Specifically, UnlockedMaps uses a map to display transit stations, prominently highlighting their real-time accessibility status (accessible with functioning elevators, accessible but experiencing at least one elevator outage, or not-accessible) and surrounding accessible restaurants and restrooms. UnlockedMaps is the first system to collect elevator outage data from 2,336 transit stations over 23 months and make it publicly available via an API. We report on results from our pilot user studies with five stakeholder groups: (1) people with mobility disabilities; (2) pregnant people; (3) cyclists/stroller users/commuters with heavy equipment; (4) members of disability advocacy groups; and (5) civic hackers.

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CCS CONCEPTS

• **Human-centered computing → Accessibility systems and tools**; **Visualization toolkits**; **User interface toolkits**.

KEYWORDS

web-based maps, accessibility, transit, open data, elevator outages

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1 BACKGROUND & INTRODUCTION

Urban rail transit (e.g., subway, light rail, train) plays a pivotal role in the everyday lives of commuters [2, 27, 29]. According to a report by the United States (US) Department of Commerce [6], over four million people in the US utilized at least one form of urban rail transit in 2019 to commute to work. This number only accounts for people in the US who commuted for work-related purposes; therefore, a much higher number of urban rail transit commuters is imaginable when considering other countries and commuting purposes. Among these commuters are also people with mobility disabilities who constitute 13.7% of the population of the US [7] and can only utilize rail transit if the transit stations are wheelchair accessible (e.g., equipped with elevators).

Web-based maps (e.g., Google Maps [12]) are the most frequent method of map dissemination [9, 20], allowing organizations and individuals to share data effectively and efficiently [9, 10]. Several researchers have utilized web-based maps to provide insights into

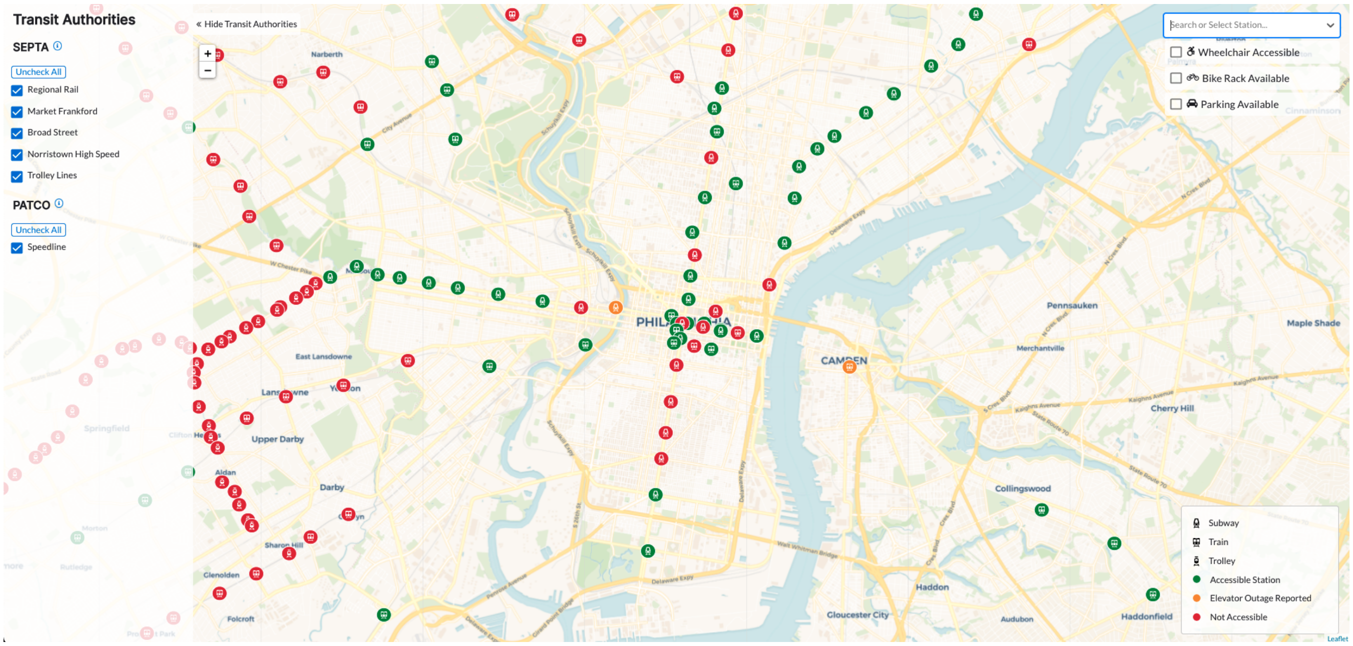

Figure 1: The *map page* of UnlockedMaps’ user interface (UI) showing transit stations in Philadelphia. *Filtering options for station-related attributes* are displayed at the top-right corner, *filtering options for transit authorities* are at the left corner, and *map legend* is at the bottom-right corner of the page. Accessible stations are shown using icons with a green background, inaccessible stations with a red background, and stations experiencing an elevator outage with an orange background.

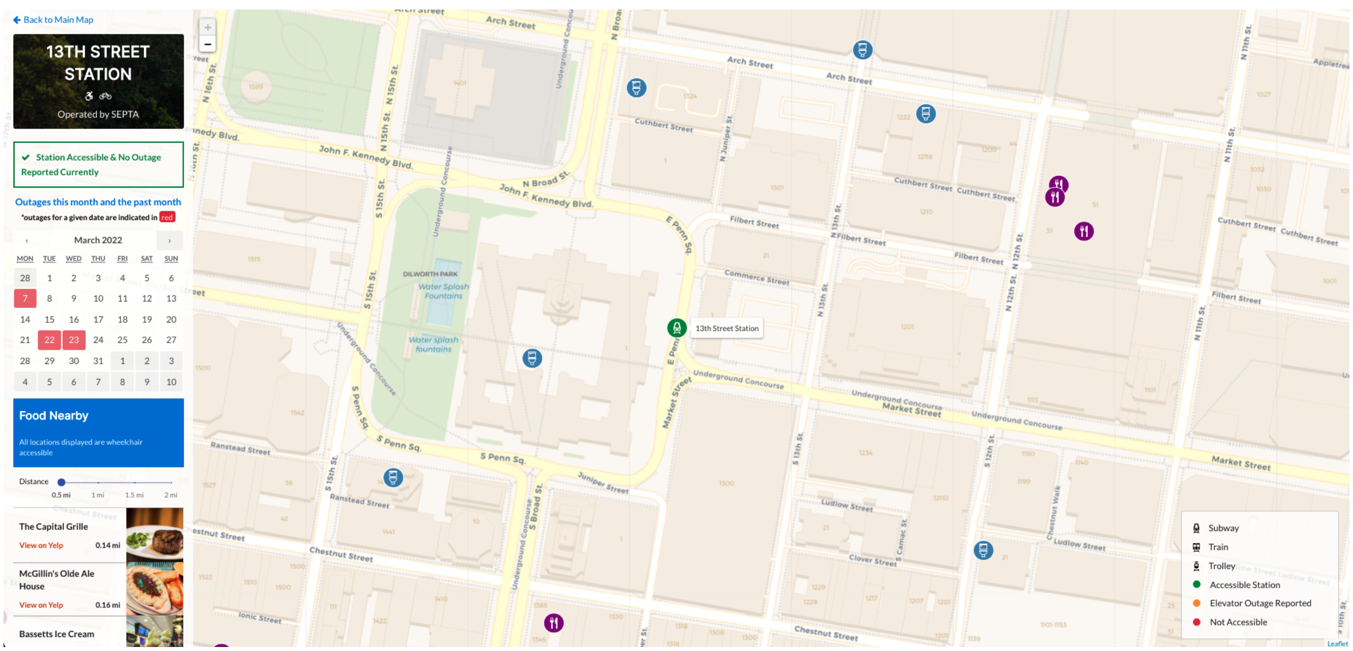

Figure 2: The *station page* of UnlockedMaps’ UI showing the “13th Street Station” in Philadelphia. *Elevator outage history* and *Food Nearby* are displayed on the left sidebar. Accessible restaurants are shown using icons with a purple background and accessible restrooms icons have a blue background.

urban accessibility [4, 5, 11, 16, 17, 22, 24]. Although these tools are plausible solutions for visualizing accessibility using web-based maps, no prior work has visualized the real-time accessibility of urban rail transit stations. Our work is the first to do so. (We define "real-time accessibility" as real-time elevator outages and nearby accessible restaurants and restrooms.)

Additionally, while transit authorities communicate information on *active* elevator outages through their websites, they do not provide the data on *past* elevator outages to the public. The lack of exposure to this data can affect the reliability assessment of transit stations and reduce public transparency into the inequities faced by disabled commuters, potentially occluding avenues for disability advocates to drive policy changes. Our work follows similar data collection approaches and strategies used by existing tools [4, 5, 11, 22] to gather the data on transit stations and elevator outages from transit authorities and release it publicly in a *universal* format via an Application Programming Interface (API).

To assist users in making informed decisions about their commute, we developed UnlockedMaps—an open-source and open-data web-based map. Unlike existing mapping solutions (e.g., Google Maps), UnlockedMaps allows users to visualize urban rail transit stations by their real-time accessibility status: (1) *accessible with functioning elevators*; (2) *accessible but experiencing at least one elevator outage*; and (3) *not-accessible* (Figure 1). Additionally, using UnlockedMaps, users can view accessible restaurants and restrooms in the vicinity of transit stations. We recorded elevator outages over 23 months from 2,336 transit stations (≈ 1.9 years), enabling users to assess the reliability of transit stations. We made this data publicly available via an API, providing transparency into the elevator outage data. To the best of our knowledge, UnlockedMaps is the only system that has collected and publicly released data on elevator outages in multiple cities.

To assess the usability and user-friendliness of UnlockedMaps, we conducted user studies with 34 participants, each representing at least one of five stakeholder groups: (1) people with mobility disabilities; (2) pregnant people; (3) cyclists/stroller users/commuters with heavy equipment; (4) members of disability advocacy groups; and (5) civic hackers.

Our contributions include (1) UnlockedMaps, an open-source and open-data web-based map that visualizes the real-time accessibility of urban rail transit stations in six North American cities available at https://unlockedmaps.com; (2) data on elevator outages collected from 2,336 transit stations in six North American cities over 23 months (≈1.9 years); and (3) empirical results from our pilot studies with 34 participants from five stakeholder groups.

2 DATA COLLECTION

We collected information on transit stations (name, longitude, latitude, wheelchair accessibility, bike rack availability, parking availability) and elevator outages at those stations (outage time, station information, elevator location, and advisory message) by scraping the websites of transit authorities. Although crowdsourcing is a plausible method of collecting data [1, 23], the websites of transit authorities served as a reliable and sufficient source for our needs. Our system automatically collects the station data quarterly (every three months) and the elevator outages data every hour for each of the six North American cities. As of the date of this writing, our automated script collected information on 1,061,375 elevator outages over the past 23 months. All our data is publicly available via two API endpoints: (1) https://api.unlockedmaps.com/v1/stations; and (2) https://api.unlockedmaps.com/v1/outages.

3 USER INTERFACE (UI)

To visualize the real-time accessibility of urban rail transit, we created a website (https://unlockedmaps.com) using `OpenStreetMap` [3] to display transit stations on a map by their real-time accessibility status: (1) *accessible with functioning elevators*; (2) *accessible but experiencing at least one elevator outage*; and (3) *not-accessible*. Our website has two main components: (1) *map page* (Figure 1); and (2) *station page* (Figure 2).

3.1 Map Page

Our map page comprises three sections: (1) *filtering options for station-related attributes* (name, wheelchair accessibility, bike rack availability, and parking availability); (2) *filtering options for transit authorities*; and (3) *map legend*. Users can filter stations by: (1) *searching for or selecting the desired station*; (2) *wheelchair accessibility*; (3) *bike rack availability*; (4) *parking availability*; and (5) *transit line and authority*. Transit authorities are displayed using a collapsible menu displaying transit lines grouped by their respective transit authorities (shown in Figure 1).

3.2 Station Page

The *station page* displays the information about a transit station (shown in Figure 2), including elevator outage history and accessible restrooms and restaurants nearby. We displayed the recent (current and past month) elevator outage history on the *station page* to provide transparency into the reliability of transit stations. We did not show the elevator outage history for inaccessible stations. We collected the data on accessible restaurants and restrooms using the Yelp and Refuge Restrooms API [21], respectively. Additionally, we added a distance slider that enables users to specify a search radius for accessible restaurants, ranging from 0.5 miles to 2 miles.

4 PILOT STUDIES

We reviewed the guidelines on evaluation strategies for artifact-based research [13, 15, 19, 28] and employed approaches similar to prior work [11, 22] to evaluate the usability and user-friendliness of UnlockedMaps.

4.1 Participants & Procedure

We recruited 34 participants (M=33.9 years, SD=11.5; see Appendix A Tables 1 and 2). We compensated participants with a $20 Amazon gift card for 45 minutes of their time. Participants took part in our online user study without supervision. Each user study session had three stages: (1) *Video Tutorial*; (2) *Interacting with UnlockedMaps* (participants interacted with UnlockedMaps for at least 20 minutes, using all the features shown in the tutorial video); and (3) *Post-Interaction Questionnaire* (participants provided subjective ratings, assessing the usability and user-friendliness of UnlockedMaps).

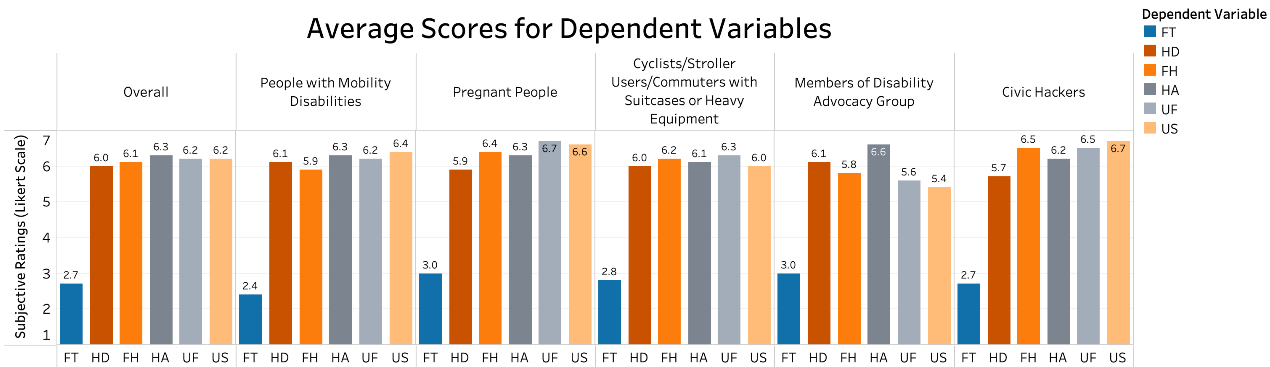

Figure 3: Average scores for each dependent variable used in our analysis across each stakeholder group. Likert scale ranged from 1-7 (higher is better except for FT where lower is better). ***UF=User-friendliness, FH=Feature Helpfulness, US=Usefulness for people in the same demographic, HD=Data Helpfulness for Developers, HA=Data Helpfulness for Advocates,* and *FT=Fatigue.***

4.2 Analysis & Results

We used *Stakeholder Group* (SG) as our independent variable with the following levels: {people with mobility disabilities, pregnant people, cyclists/stroller users/commuters with heavy equipment, members of disability advocacy groups, civic hackers}. Our dependent variables were *User-friendliness* (UF), *Feature Helpfulness* (FH), *Usefulness for People in the Same Demographic* (US), *Data Helpfulness for Developers* (HD), *Data Helpfulness for Advocates* (HA), and *Fatigue* (FT), all of which were Likert responses (ranging from 1 [worst] to 7 [best], except for FT for which lower was better). We treated our dependent variables as "ordinal approximation of continuous variables" [14, 18, 25, 30] and used Linear Models (LM) [8, 26] to analyze these factors.

None of our dependent variables (UF, FH, US, HD, HA, and FT) had a significant main effect ($p \approx .233$, $p \approx .506$, $p \approx .167$, $p \approx .964$, $p \approx .897$, $p \approx .979$, and $p \approx .123$, respectively) on SG. (Because our goal was to investigate if the usability of UnlockedMaps varied across the different stakeholder groups, a null statistical result here is noteworthy.) Overall, our participants' average ratings were high for UF (M=6.2, SD=0.9), FH (M=6.1, SD=1.0), US (M=6.2, SD=1.2), HD (M=6.0, SD=1.3), and HA (M=6.3, SD=1.1), and low for FT (M=2.7, SD=2.2). Figure 3 shows the average scores of our dependent variables across each stakeholder group.

5 DISCUSSION & CONCLUSION

In this work, we developed UnlockedMaps, an open-source and open-data web-based map that displays the real-time accessibility status of urban rail transit stations in six North American cities. Additionally, UnlockedMaps enables users to view accessible restaurants and restrooms near stations. To provide transparency into the elevator outage history and assist users in assessing the reliability of functioning elevators at transit stations, we made elevator outage data collected from 2,336 transit stations over 23 months publicly available through our API. Additionally, we conducted user studies to assess the usability and user-friendliness of UnlockedMaps, finding that all our stakeholder groups found UnlockedMaps user-friendly and beneficial for their individualized needs.

For the past 23 months (≈1.9 years), UnlockedMaps has collected data on elevator outages from transit stations in six North American cities to show the real-time accessibility status of transit stations. Various individuals, including social scientists, community leaders, urban planners, and advocates, can utilize our data cross-disciplinarily to explore matters beyond accessibility. For example, researchers and advocates can use our data to identify pressure points in the urban transit system that cause strain on surrounding communities and compare the disparity in urban transit access among neighborhoods. Additionally, they can use the stations' data to gather granular insights into the infrastructure of cities. Similarly, our data can be instrumental in driving policy changes for commuters with and without disabilities.

We plan on deploying UnlockedMaps to more cities within and outside of the US and conducting longitudinal studies with UnlockedMaps users to identify usage patterns and areas of improvement. Additionally, we note that we record the elevator outages hourly. Therefore, the visualized data can be outdated. We're working on increasing our computing resources to collect the data more frequently. We plan on engaging with the ASSETS commuting during the demonstration of our tool to solicit feedback on future work and improvements. We hope that our publicly-available elevator outage data will assist commuters and researchers in assessing the reliability of transit stations and advocates and policymakers in driving change to improve the accessibility of urban rail transit. We also hope that by open-sourcing our code for UnlockedMaps, civic hackers and developers can utilize our work to create more tools for urban rail commuters.

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A PARTICIPANTS

Table 1: Participants, their gender identification (column "G"), age, city, and demographic group. "I?" identifies if we conducted a follow-up interview with the participant. Under the *Gender* column, *M* = *Male, F* = *Female, NB* = *Non-binary,* and "-" signifies that the participant preferred not to disclose.

	G	Age	I?	City	Demographic Group
P1	M	26	No	Chicago, IL	People with mobility disabilities
P2	W	30	No	New York, NY	Pregnant people
P3	M	31	Yes	Chicago, IL	Members of disability advocacy group
P4	W	24	No	New York, NY	Civic hackers
P5	M	30	No	New York, NY	Members of disability advocacy group
P6	M	43	No	New York, NY	People with mobility disabilities
P7	W	33	No	Bay Area, CA	Pregnant people
P8	W	29	No	Philadelphia, PA	Pregnant people
P9	M	27	No	Chicago, IL	Civic hackers
P10	NB	39	Yes	Seattle, WA	Cyclists/Stroller users/Commuters with suitcases or heavy equipment, Members of disability advocacy group
P11	W	24	No	Toronto, ON	Pregnant people
P12	M	73	No	Seattle, WA	Members of disability advocacy group
P13	M	20	No	Bay Area, CA	Cyclists/Stroller users/Commuters with suitcases or heavy equipment
P14	M	19	No	Philadelphia, PA	Cyclists/Stroller users/Commuters with suitcases or heavy equipment
P15	W	28	No	New York, NY	People with mobility disabilities
P16	M	48	No	Bay Area, CA	Cyclists/Stroller users/Commuters with suitcases or heavy equipment, Members of disability advocacy group, Civic hackers
P17	M	26	No	Toronto, ON	Cyclists/Stroller users/Commuters with suitcases or heavy equipment
P18	M	45	No	Chicago, IL	Cyclists/Stroller users/Commuters with suitcases or heavy equipment
P19	W	35	No	Seattle, WA	Pregnant people
P20	W	30	No	Chicago, IL	Pregnant people
P21	W	32	Yes	Toronto, ON	People with mobility disabilities
P22	NB	53	Yes	Philadelphia, PA	People with mobility disabilities, Members of disability advocacy group
P23	W	30	No	Toronto, ON	Civic hackers
P24	W	52	No	Chicago, IL	Cyclists/Stroller users/Commuters with suitcases or heavy equipment
P25	NB	22	No	Seattle, WA	People with mobility disabilities
P26	W	30	No	Philadelphia, PA	People with mobility disabilities
P27	W	35	No	Philadelphia, PA	Pregnant people
P28	M	40	Yes	Bay Area, CA	People with mobility disabilities
P29	-	37	No	Philadelphia, PA	Cyclists/Stroller users/Commuters with suitcases or heavy equipment, Civic hackers
P30	W	34	Yes	Seattle, WA	Cyclists/Stroller users/Commuters with suitcases or heavy equipment, Civic hackers
P31	NB	30	No	Toronto, ON	Cyclists/Stroller users/Commuters with suitcases or heavy equipment, Members of disability advocacy group
P32	M	18	No	Seattle, WA	Cyclists/Stroller users/Commuters with suitcases or heavy equipment
P33	W	29	No	New York, NY	People with mobility disabilities
P34	M	52	No	Chicago, IL	People with mobility disabilities, Cyclists/Stroller users/Commuters with suitcases or heavy equipment, Members of disability advocacy group

B DEMOGRAPHIC BREAKDOWN

Table 2: Demographic breakdown for our $N = 34$ participants across the stakeholder groups and cities. N is the total number of participants and % is the percentage compared to the total number of participants. For the "overall" column, the % is shown as "-," naturally assuming it to be 100. *BAY* represents Bay Area, CA, *CHI* represents Chicago, IL, *NYC* represents New York, NY, *PHI* represents Philadelphia, PA, *SEA* represents Seattle, WA, and *TOR* represents Toronto, ON. Participants were allowed to self-identify as members of multiple stakeholders, if applicable.

	Overall		***BAY***		***CHI***		***NYC***		***PHI***		***SEA***		***TOR***	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Overall	34	-	4	11.8	7	20.6	6	17.6	6	17.6	6	17.6	5	14.7
People with Mobility Disabilities	10	-	1	10.0	2	20.0	3	30.0	2	20.0	1	10.0	1	10.0
Pregnant People	7	-	1	14.3	1	14.3	1	14.3	2	28.6	1	14.3	1	14.3
Cyclists / Stroller users / Commuters with Suitcases or Heavy Equipment	12	-	2	16.7	3	25.0	0	0.0	2	16.7	3	25.0	2	16.7
Members of Disability Advocacy Groups	8	-	1	12.5	2	25.0	1	12.5	1	12.5	2	25.0	1	12.5
Civic Hackers	6	-	1	16.7	1	16.7	1	16.7	1	16.7	1	16.7	1	16.7