Towards an Inclusive Urban Environment: A Participatory Approach for Collecting Spatial Accessibility Data in Zurich

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Abstract

The unprecedented rate of urbanization, along with the increase in the aging and disabled populations, bring about an increasing demand for public services and an inclusive urban environment that allows easy access to those facilities. Spatial Accessibility is a measure to assess how inclusive a city is and how easily public facilities can be reached from a specific location through movement in physical space or built environment.

A detailed geodata source of accessibility features is needed for reliable spatial accessibility assessment, such as sidewalk width, surface type, and incline. However, such data are not readily available due to the huge implication costs. Remote crowdsourcing data collection using Street View Imagery, so-called 'virtual audits' have been introduced as a valid, cost-efficient tool for accessibility data enrichment at scales compared to conventional methods because it enables involving more participants, saving more time by avoiding field visits and covering a larger area.

Therefore, in our pilot project, ZuriACT: Zurich Accessible CiTy, with the help of digital tools that allow for virtual inspections and measurements of accessibility features, we want to contribute to collecting and enriching accessibility information in the city of Zurich embedded in a citizen science project that will have both scientific and social impacts.

With the help of additional accessibility data produced in this project, the issues of an inclusive urban environment can be demonstrated by mapping the potential spatial inequalities in access to public facilities for disabled or restricted people in terms of mobility. Thus, this project provides helpful insight into implementing policy interventions for overcoming accessibility biases to ensure equitable services, particularly for people with disabilities, and contributes to creating an inclusive and sustainable urban environment. It goes without saying that an inclusive city is beneficial and impacts the quality of life of not only the population groups mentioned above but also the society at large.

2012 ACM Subject Classification Social and professional topics

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1 Introduction

It is projected that by 2050, about 70 percent of the world's population will live in urban environments, 15 percent of them will live with disabilities [10]. Moreover, the prediction shows that by 2050, the number of older people will reach 2 billion worldwide [12]. The unprecedented rate of urbanization, along with the increase in the aging and disabled populations, bring about an increasing demand for public services and access to those facilities. Depending on the infrastructure and design, the urban environment and physical

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space can facilitate or impede the mobility and accessibility of the aforementioned population groups and consequently affect their active social and physical participation in society as well as their quality of life [11]. Besides, promoting accessible built environments such as easy-access buildings and barrier-free sidewalks is a key element for sustainable and inclusive cities and is of high societal importance. But how can we measure the inclusivity of a city? Spatial accessibility, traditionally defined as the "potential of opportunities for interaction" [7] and more concretely understood as how easily destinations such as services (e.g., medical centers, grocery stores, and banks), friends, or places of social interaction can be reached from a certain location through movement in physical space, is one of the measures which is also a crucial factor for supporting active and healthy aging and mobility.

A comprehensive geodata source of accessibility features is a prerequisite for accurate spatial accessibility assessment and therefore, urban inclusivity measurement. Examples of accessibility features, i.e., spatial features impeding or facilitating accessibility, are sidewalk inclination, crossings, and ramps. Accessibility features are crucial to disabled and mobility-restricted persons' navigation and mobility. Still, they are usually not offered by commercial geodata providers [13] and are mostly not readily available in existing open-access geographic information databases such as Open Street Map (OSM) [5]. Moreover, existing routing services and digital maps, such as Google Maps and OSM, fail to provide practical guidance for the above-mentioned persons' navigation due to the lack of relevant information on the needs of these user groups, which results in incomplete routing results or results that may not always reflect real-world conditions [6].

Different data collection methods have been applied to address this data gap issue and support the mobility of persons with disabilities (e.g., wheelchair users, visually impaired persons), which are traditionally conducted on the field applying on-field surveys [13], sensors (e.g., Global Positioning System) [16, 9], or a wide range of mobile applications (e.g., Vespucci [20], Go Map!! [4], and StreetComplete [21]). However, during the last few years, with the widespread use of the Internet, remote data collection using Street View Imagery (SVI), so-called 'virtual audits' has emerged as a valid alternative to expensive and time-consuming field visits [17]. The most famous and popular service for providing SVI worldwide is Google Street View (GSV) which is a basis for most virtual audits [14, 17, 15]. Virtual auditing allows users to remotely and manually measure and collect accessibility features by virtually walking in the city using the SVIs.

Collecting and maintaining detailed and up-to-date geographical information on accessibility is a considerably laborious, time-consuming, and expensive process. Hence, public partners usually avoid investing in such costly data collection [13]. Applying collaborative technologies such as citizen science helps address this challenge. Compared to the physical-based traditional methods, the virtual audit tools are easy-to-use, time and cost-efficient, and suitable for collaborative data collection, allowing the participants, particularly those who do not have the opportunity to do field visits for data collection, comfortably and safely collect detailed data at a larger scale wherever and whenever they want.

As mentioned earlier, publicly available geographical data sources such as OSM lack a considerable amount of accessibility information. For example, based on a recent study, only 2.3 percent of the OSM footpath data in Zurich include the inclination or steepness [3]. Besides, to the best of our knowledge, there has been no comprehensive geodatabase or data collection of accessibility information for the city of Zurich. Also, the city has launched no participatory data collection campaign in that regard.

Therefore, in our participatory project titled: ZuriACT (Zurich Accessible CiTy), for the first time, with the help of virtual audits, we want to take the initiative and contribute to providing a systematic and enriched dataset of the accessibility features in the selected study

Figure 1 Study area: District 1 of the city of Zurich.

area of District 1 of the city of Zurich embedded in a citizen science project. District 1 of the city of Zurich (see Fig. 1) has been selected as the study area due to its topographical and geographic characteristics such as inclined streets, various public facilities (e.g., shopping streets, touristic attractions, main train station), a significant number of commuter populations, and centrality.

Also, we aim to contribute to a better understanding of spatial accessibility and its potential biases in the urban environment by providing an enriched accessibility database that can bring about essential information for reliable accessibility measurements, thereby equipping policymakers and urban planners with helpful insights into a more sustainable and inclusive environment for society, particularly persons with disabilities. Moreover, generating further new data can significantly contribute to scientific gaps in the accessibility analysis domain that have not been addressed so far due to a lack of appropriate, comprehensive open geographical data.

2 Method

2.1 Recruitment and Participants

A range of different marketing options will be used to inform citizens about the ZuriACT project idea, including the organization's websites (e.g., The City of Zurich, the organizations for people with disability, University of Zurich), e-newsletters, social media (e.g., LinkedIn, and Twitter), and distributing flyer in the study area. The communication and recruitment of citizens will also be conducted through the university webpage, where citizens can find further information about the project, as well as contact information and register for the study.

After screening the registered people based on the inclusion criteria, eligible participants will be contacted via email and asked to sign a consent form, including information about the study objectives and procedure, expected contribution, and participant compensation. Upon receipt of the informed consent, participants will be contacted to schedule meetings for different parts of the project, including focus group discussions and training sessions for data collection.

A total of 80–100 will be recruited for the study. As for eligibility criteria, participants must be cognitively healthy (assessed based on self-report) adults aged 18 and above, and belong to at least one of the population groups below:

1. Community-dwelling older adults aged 65 and above
2. Persons with situation mobility restrictions, such as parents with pushchairs
3. Mobility-disabled persons (e.g., wheelchair users)

2.2 Focus Groups

Our citizen science project focuses on co-creation, aiming to maximize the level of citizens' involvement in most or all stages of the project, including project design, data collection, and implementation [18]. To this end, we apply methods and tools for co-producing knowledge, such as focus group discussions [19]. In workshops, we bring together academics, citizens, and public and private partners to discuss the project's objective and contents, including initial ideation and data collection specifications. This helps gain experience from various perspectives and learn about the needs, knowledge, demand, and interests of different people involved in the project, laying the basis to adapt the project planning in a way that could be beneficial to all. An example of a similar initiative is the 'MIND Inclusion' project by Martínez-Molina et al. (2020), which focused on providing co-created accessible cognitive design tools for people with intellectual disabilities [8].

2.3 Spatial Accessibility Data Collection

We will use the Project Sidewalk tool for virtual audits by citizens. Project Sidewalk allows for collecting accessibility data at a large scale by anyone with an Internet connection and a web browser through GSV images. Examples of data that can be collected using this tool are "curb ramp", "missing curb ramp", "surface problems", "no sidewalk", "Obstacles in path", and "Others" [15]. Besides, it offers an excellent citizen science platform that allows laypersons to collect accessibility data comfortably via interactive onboarding and mission-based tasks. However, it lacks tools for collecting accessibility features that require measurements, such as sidewalk incline or width. Moreover, Project Sidewalk highly depends on GSV images which are sometimes outdated or do not cover the entire street network of the study area.

To address the data collection gaps using Project Sidewalk, we will use the Infra3D web-based tool [2], which is based on up-to-date and complete 3D SVI data "Strassenraum 3D" taken from car-mounted cameras from the entire city of Zurich developed by the Swiss company iNovitas [1] and also offers measurement tools. The "Strassenraum 3D" data has a higher and finer temporal resolution and spatial coverage than GSV and is updated every two years. The 3D images embedded in the infra3D web-based tool have been taken from an equipped vehicle and include all public roads (excluding motorways) and the whole tram network of Zurich city and selected cycle paths and squares. However, since Infra3D lacks a well-designed citizen science platform like Project Sidewalk, it might be challenging for laypeople and citizens to contribute to data collection using this tool. Therefore, to address this issue, we will involve persons with expertise in geographical data for virtual auditing using this tool.

During the data collection, through online forums or on-site social events, we ask participants to provide feedback or exchange information regarding their data collection experiences. The data collection will continue until obtaining the total coverage of the accessibility features in District 1. However, using the above-mentioned web tools, there will still be data gaps in the areas that were not reachable by the vehicle, such as stairs or narrow alleys or where GSVs are missing. Therefore, our virtual data collection will be limited to the areas traversed by the car or covered by GSV images using Infra3D or Project Sidewalk, respectively. To fill this void, the accessibility features will have to be collected via on-site field surveys with the help of research assistants. This can happen by using the most commonly used smartphone apps for enriching and editing OSM data, such as "Vespucci" or "Go Map!!" which enables on-site accessibility data collection. The on-site data collection can also help verify the data derived remotely from virtual audits.

2.4 Discussion and Conclusion

In this project, we aim to contribute to filling the spatial accessibility data gap on sidewalks in Zurich with and for citizens by providing a systematic collection and enrichment of accessibility features utilizing digital tools, and virtual audits. The participatory design of this project involving citizens, researchers, and public partners allows for collecting and enriching a vast amount of detailed accessibility information across a larger geographical area during a shorter period, which not only contributes to considerable savings in time and resources compared to conventional data collection methods but also provides additional descriptive and spatial data to address crucial research and practical questions about the mobility and spatial accessibility of disabled people and how to realize an inclusive urban environment.

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Navigation Challenges in Urban Areas for Persons with Mobility Restrictions

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Abstract

The Sustainable Development Goals (SDGs) promote making the world better for everyone, with a focus on creating cities that are inclusive and sustainable, as outlined in SDG 11. Spatial accessibility plays a pivotal role in fostering age-friendly and inclusive urban environments. However, there is still a lack of complete data on accessibility essential for providing mobility services to individuals with restricted mobility, mainly due to the high costs. While some participatory initiatives like OpenStreetMap (OSM) have made progress in this area, there is still a significant gap in data about sidewalk accessibility.

To address this gap, we used a citizen science approach to gather information and improve our understanding of sidewalk accessibility in District 1 of Zurich. Eighteen individuals from diverse population groups took part in our study. Using the Project Sidewalk web tool (PRSW), participants collected sidewalk features like curb ramps and surface problems by virtually inspecting street view images.

In this paper, we present preliminary results derived from participatory data collection. The findings show the variances in accessibility labels concerning their frequency, spatial distribution, and severity levels attributed by participants. Furthermore, we provide insights into the accuracy of the data, verified through validation by experts in geographical knowledge using PRSW.

Our approach allowed for broader participation and diverse perspectives in collecting sidewalk accessibility data. We believe that the provided dataset has the potential to address unanswered questions about spatial accessibility. For instance, the distribution of accessibility within specific population groups or across a city can be explored. This information can help policymakers develop interventions that tackle accessibility inequalities and ensure equitable access, especially for those with mobility impairments.

2012 ACM Subject Classification Social and professional topics

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1 Introduction

The Sustainable Development Goals (SDGs) outlined in the United Nations' 2030 Agenda are dedicated to making the world a better place for all. In consonance with the past ten years of the SDGs, the World Health Organization (WHO) declared the United Nations Decade of Healthy Aging (2021-2030), focusing on the fast-growing aging population with a primary objective of enhancing their quality of life by fostering the creation of age-friendly cities and environments as a pivotal action area [11]. This endeavor resonates with SDG 11, which strives to make "cities and human settlements inclusive, safe, resilient, and sustainable". An essential factor and measure for an age-friendly, sustainable, and smart city is spatial accessibility, particularly for pedestrians [10]. Spatial accessibility refers to how easily public facilities can be reached from a specific location through movement in physical space [1].

The built environment can impose challenges, leading to bias and inequality in the accessibility and mobility of population groups with varying needs and capacities. For example, barriers such as steep sidewalks, poor surface conditions, and narrow pathway can significantly impede their physical movement, potentially isolating persons with mobility impairment from social engagement and participation. Such exclusion, in turn, adversely affects their physical and mental health, such as depression [13], thus imposing additional societal costs.

Digital transformation and advanced technologies hold the potential to address these issues by providing assistive navigation tools and opportunities for individuals with mobility limitations to overcome built environment barriers and enhance mobility and social inclusion [6, 2, 8]. However, most existing tools, such as digital maps and navigation services, are mainly designed for the general population and often fall short of delivering practical guidance for disabled people in terms of mobility. This inadequacy arises from the inherent bias in accessibility data and the absence of relevant information tailored to the specific needs of particular groups, such as sidewalk inclinations, pedestrian crossings, and ramps [9, 1]. Consequently, existing tools frequently yield incomplete or inaccurate routing results that do not always align with real-world conditions [5].

To address this challenge effectively, the first step is to provide the required database containing comprehensive accessibility information [10]. To this end, in our pilot citizen science project ZuriACT: Zurich Accessible CiTy [1], we employed a digital web tool for District 1 in Zurich, Switzerland, that allows for virtual inspections and measurements of sidewalk accessibility labels based on street view images (SVIs). In contrast to in-situ measurements, which are labor and time-intensive, the usage of SVIs allows for a scalable data collection, enabling individuals with mobility restrictions to comfortably and safely assess sidewalk features [4, 1]. Our project contributes to developing an enriched dataset of accessibility information on sidewalks. We believe the generated dataset within our study can be leveraged to provide more reliable spatial accessibility assessments and a basis for practical solutions such as personalized navigation services beneficial to mobility-restricted and impaired persons.

2 Method

In our study, we applied the citizen science approach. Citizen science entails collaboration between members of the general public and scientists. There are different types of citizen science projects depending on the level of members of public involvement, namely contributory, collaborative, and co-created projects [3]. Our participatory project emphasizes co-creation, striving to engage members of the public throughout all project phases, such as design and data collection. This approach enabled us to gain insights from diverse viewpoints and understand the needs, experiences, and interests of various population groups participating in the project. Furthermore, this foundational understanding informed adjustments to project planning aimed at benefiting all stakeholders.

To this end, we applied methods and tools for co-producing knowledge, such as focus group discussions and employing participatory digital tools for data collection. The Project Sidewalk web tool (PRSW) [7] was used for data collection in the study area of District 1 of Zurich. PRSW has a well-designed citizen science platform with an on-boarding tutorial that makes the data collection training process more intuitive and, consequently, makes the data collection easier for laypeople. Participants were asked to collect labels, i.e., point data, on *curb ramp*, *missing curb ramp*, *obstacles in path*, *no sidewalk*, *surface problem*, *crosswalk*, *occlusion*, *other* and *pedestrian signal*, along with the corresponding severity level rated from 1 to 5, i.e., fully accessible to fully inaccessible, and label tags providing more details about the collected label.

After participants completed data collection, five researcher assistants (RAs) contributed to the data validation. Each label type was validated at least by two RAs who had expertise in geographical information and were trained in correctly labeling and validating data using the PRSW.

The analysis and visualization of the data were conducted using the software R, version 4.3.3.

2.1 Participants

Participants were recruited from April 2023 to March 2024, using various outreach methods, including the university disability office mailing lists, contacting non-profit organizations, poster campaigns, and flyer distributions in the study area. Registration for participation remained open throughout the data collection period, allowing interested individuals to join at their convenience. Participants were required to be cognitively healthy (assessed based on self-report) adults aged 18 and above and live in Switzerland. A total of 21 participants (N=21) enrolled in the data collection, from which four persons (N=4) withdrew without contributing any data. Seventeen persons (N=17, 13 females), with ages ranging from 27 to 81 (mean: 46.4 years, standard deviation: 20.3 years), actively contributed to the data collection process. The diverse group of data collection participants included older adults without age-related mobility restrictions (N=3), adults with situational mobility restrictions (e.g., parents with pushchairs or caregivers) (N=3), and persons with mobility impairments (N=6). Additionally, five participants (N=5), named as group *others* without mobility impairment or restriction, contributed to the data collection by adopting the perspective of wheelchair users. All participants signed the informed consent form. Every procedure was performed according to the Declaration of Helsinki.

2.2 Data collection

Data collection training workshops were implemented online and on-site, where the PRSW was introduced to the participants, giving them the opportunity to familiarize themselves with the tool in a guided environment. Five participants from all population groups participated in the data collection training workshops either online (N=2) or on-site (N=3). For participants who wanted to learn the data collection independently (N=16, including the three persons who withdrew from the data collection afterward), we organized a short meet and greet session to get to know the participants in person and share the access information to the

(a) **(b)**

Figure 1 Spatial accessibility label data collected in District 1, (a) point data and (b) heatmap.

data collection tool in a privacy-protected way. Depending on our participants' preferences, the 15-minute sessions were held online (N=9) or on-site (N=7). All participants received the PRSW tool overview and labeling guidelines and could contact us with any questions. We assigned data collection tasks to participants so that each participant could contribute to collecting data in a specific neighborhood of District 1. Interested participants received a second data collection task, preceded by personalized feedback on their performance in the initial task. This allowed us to ensure that every neighborhood of District 1 was assessed by individuals from different population groups. The data collection ran from August 2023 to April 2024.

3 Results

In this section, we present preliminary findings based on data collected by our participants. It is worth mentioning that the data presented here is raw and will undergo further filtering and preprocessing following expert validation.

Participants collected 9136 raw labels in total, with each participant spending an average of 354 minutes on the data collection. Figure 1 shows the distribution and the density of data per label type. The *obstacle in path* was the most frequently collected label, followed by *surface problem*, *curb ramp*, *crosswalk*, *pedestrian signal*, *no sidewalk*, *missing curb ramp*, *other*, and *occlusion*.

The spatial distribution of *surface problem* labels, as shown in Figure 1a, reveals a concentration within Zurich's historic old town, particularly in the central part of District 1, near the river. The heatmap generated by the 2D Kernel density method [12] exhibits comparable patterns in the distribution density of all labels combined, indicating that they are primarily clustered around the old town and the central part of the District (Figure 1b). Similarly, instances of *no sidewalk* were frequently collected in these areas (Figure 1a). Notably, the spatial patterns of *curb ramp* and *crosswalk* labels exhibit alignment. Participants occasionally placed *pedestrian signal* labels alongside the previously mentioned labels. Beyond the typical *curb ramp* labels placement at pedestrian crossings, a notable number of *curb ramp* labels were collected on a street on the east side of the river, which effectively divides District 1 into two parts. In contrast, *missing curb ramp*, *obstacle*, *other*, and *occlusion* labels seem to be distributed equally within District 1.

Moreover, Figures 1a and 1b illustrate the spatial distribution and density of the collected accessibility labels and highlight sidewalk segments lacking these labels. Unavailable SVIs for these segments often cause this deficiency.

An examination of the severity levels across various labels, as shown in Figure 2, reveals that over 75% of *curb ramps* and *crosswalks* are fully accessible, indicated by a severity level of 1. Notably, there are no inaccessible *curb ramps* or *crosswalks* within the study area. Conversely, *obstacle in path*, followed by *no sidewalk*, *missing curb ramp*, and *other*, exhibit the highest percentage of severity level rated as 5, suggesting inaccessibility along those routes imposed by these labels.

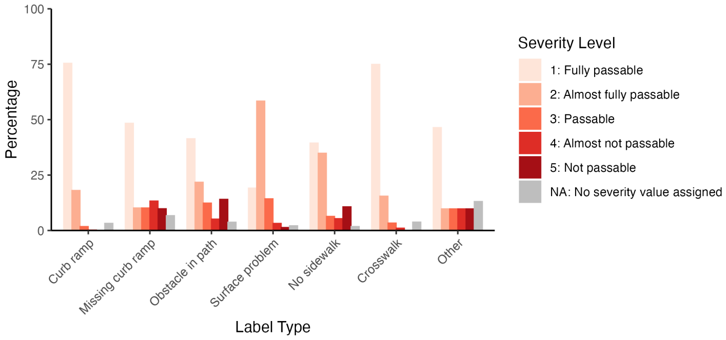

Figure 2 Percentage of severity levels assigned per spatial accessibility label type.

Figure 3 shows the distribution of labels per population group. As the map shows, among different population groups, participants with situational mobility restrictions, such as caregivers, contributed the most to the data collection, followed by mobility-impaired individuals, older adults, and others. In our future study, our objective is to delve deeper into this dataset to understand how the gathered data diverges across diverse population groups when viewed from various perspectives, i.e., varying perceived severity for the same feature labeled by different individuals. Through this investigation, we aim to gain valuable insights into the impact of spatial accessibility features on individuals' mobility.

Figure 4 shows the validation results per spatial accessibility label type conducted by RAs and participants. The highest agreement percentage belongs to *crosswalks* (92%) followed by *curb ramp* and *pedestrian signal* (81%), *occlusion* (79%), *surface problem* (65%), *no sidewalk* (49%), *other* (36%), *obstacle in path* (31%), and *missing curb ramp* (23%).

4 Discussion

Spatial analysis of the accessibility label types reveals some interesting results. As Figure 1a depicts, *surface problem* labels are mostly located in the old town of Zurich, characterized by historic cobblestone streets. Correspondingly, *no sidewalk* labels are more prevalent in this area as certain streets within the old town have been designated as pedestrian zones, restricting motorized traffic in this area. The location of such zones can be identified by analyzing the spatial distribution of the label *no sidewalk*, which participants often placed in exactly these areas. The alignment of the spatial patterns of *curb ramp* and *crosswalk* labels leads to the conclusion that pedestrian crossings are generally accessible for different

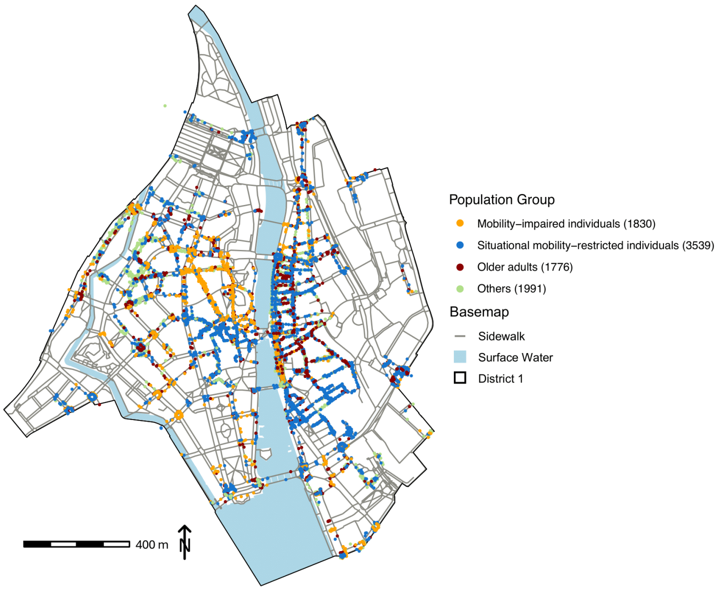

Figure 3 Spatial accessibility labels per population group.

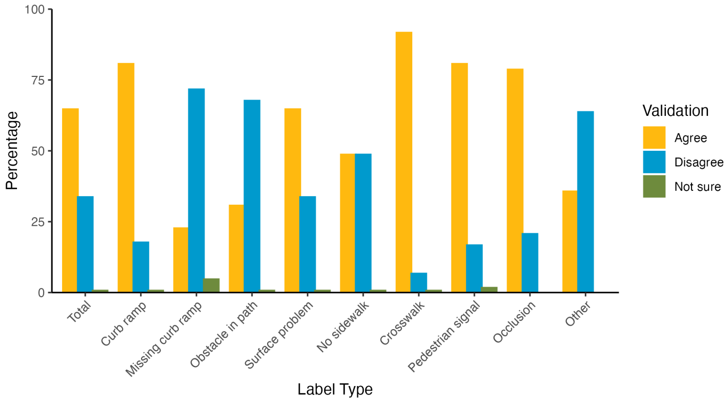

Figure 4 Validation percentage per spatial accessibility label type.

population groups. Besides the labels *curb ramp* and *crosswalks*, participants also collected *pedestrian signal* labels at locations where larger intersections frequented by public transport vehicles, bicycles, cars, and pedestrians are present. The above-mentioned *curb ramp* labels placed on the street on the east side of the river depict a curb, which is continuously lowered over several hundred meters with the exception of public transport stops.

The level of agreement fluctuates greatly across various label types, with categories such as *missing curb ramp*, *obstacle in path*, *other*, and *no sidewalk* displaying the least agreement. These disparities allow us to shed some light on potential ambiguities in the labeling guide, resulting in divergent interpretations and data collection practices among participants. For instance, participants extensively collected data on objects on the sidewalk, marking them with *obstacle in path* labels even though these objects leave enough space on the sidewalk to pass, i.e., they do not impede a person's mobility. Additionally, a small number of participants extensively collected *missing curb ramp* labels constantly along sidewalks, even where the curb was not supposed to be lowered, thus resulting in a low level of agreement. In subsequent data analysis, it will be of interest to determine whether performance improved, i.e., agreement increased after the personalized feedback participants received between the first and second data collection tasks.

The high number of 9136 collected labels can be explained by the overlap of users' data collection tasks, resulting in multiple users collecting the same label in the same area. Since the users are from different population groups, the collected data can be assigned to specific perceptions. In future analysis, we focus on the validation agreement of different population groups, allowing us to gain valuable insights into potential data collection patterns and accessibility perceptions of specific population groups, i.e., between individuals with and without mobility restrictions.

Furthermore, future efforts on accessibility data collection will rely on automated/semi-automated machine-learning approaches, where such validated data collected based on SVIs can serve as valuable input or training datasets, allowing data collection to be scaled in a larger area.

5 Conclusion

The preliminary results show that participants from different population groups successfully collected sidewalk accessibility labels using PRSW. These labels match real-world conditions and, therefore, hold great potential for accessibility assessments based on the labels collected from different perspectives within this citizen science project.

With the inclusion of additional data generated by this initiative, new and previously unexplored questions can be examined from various angles. For instance, researchers can investigate the influence of built environment factors on the diversity of accessibility or explore the distribution of accessibility within specific impairment groups or across a city. Furthermore, the provided data on sidewalk features can enhance existing datasets and serve as an additional input for navigation services. This improvement will help mobility-impaired individuals to navigate in unfamiliar environments more effectively.

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