# 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.

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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.

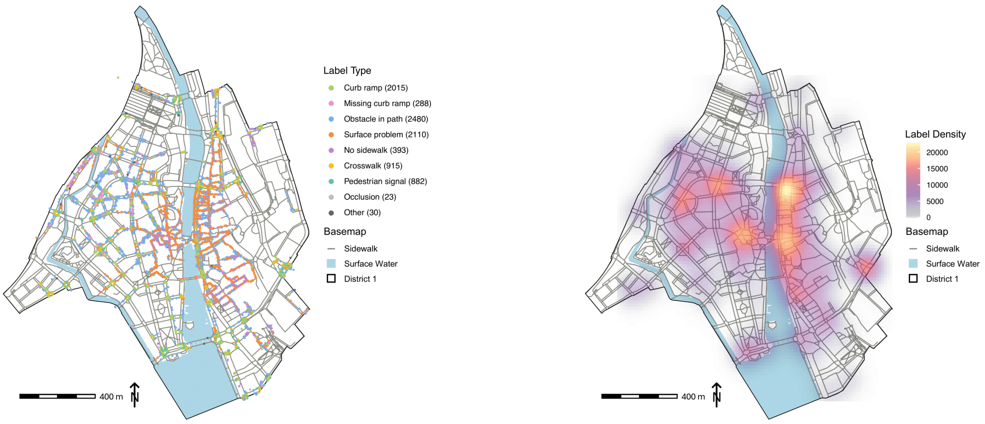
The analysis and visualization of the data were conducted using the software R, version 4.3.3.

## 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.

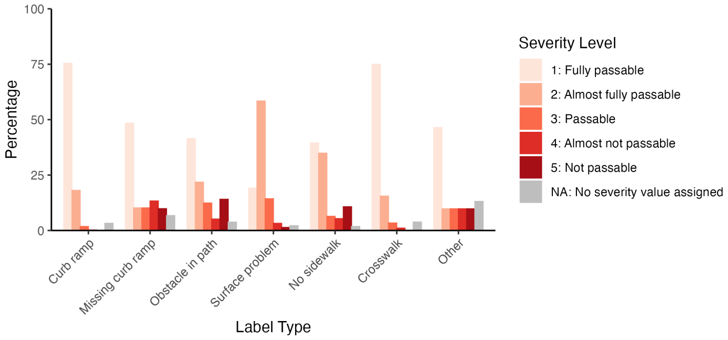


**Figure 2** Percentage of severity levels assigned per spatial accessibility label type.

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

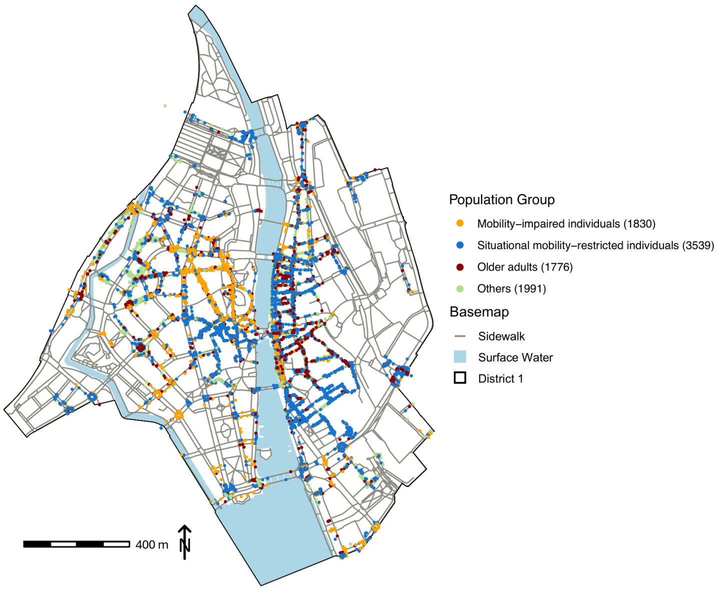


**Figure 3** Spatial accessibility labels per population group.

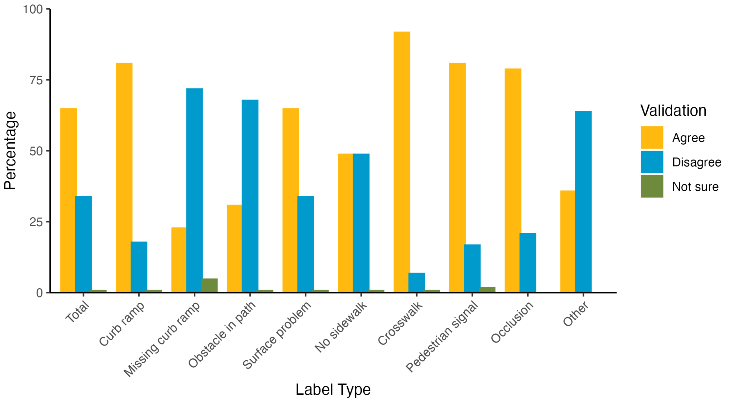


**Figure 4** Validation percentage per spatial accessibility label type.

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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