University of Zurich[UZH]

Overcoming Urban Obstacles: Barriers at Hotspots for Wheelchair Users in the City of Zurich

GEO 511 Master's Thesis

Author
Silvia Juen
17-642-471

Supervised by
Dr. Oliver Grübner
PD Dr. Michael von Rhein (michael.vonrhein@kispi.uzh.ch)

Faculty representative
Prof. Dr. Robert Weibel

30.06.2024
Department of Geography, University of Zurich

Abstract

Accessibility of public spaces for individuals with walking disabilities is an important concern in Switzerland's urban planning. This research investigates spatial accessibility in Zurich, focusing on the Lengg healthcare area and the transit route to Zurich Main Station. Gaps include inadequate application of universal design principles, lack of direct evaluations and continuous monitoring of existing standards, and absence of targeted Smart City strategies for wheelchair users in Zurich. The study emphasizes the need for inclusive urban planning and integrates Geographical Information Systems (GIS) to identify urban barriers. A comprehensive *Accessibility Standards for Public Spaces for Wheelchair Users* catalogue was developed and applied to systematically evaluate mobility barriers. Field data were collected using the Swisstopo app, capturing barriers like high curbs and narrow passages. Interviews with wheelchair users from the Mathilde Escher Foundation focussed on daily challenges and provided insights into the relevance of the results. Additionally, innovative Smart City solutions were explored, focusing on digital information systems and mobile apps for real-time accessibility information. Findings revealed significant obstacles, including insufficient sidewalk widths, poorly designed crossings and inadequate public transport facilities. These mobility barriers were categorized using a 2x2 matrix, Norm compliant or not to problematic or not, assessing compliance with accessibility standards and the actual impact on wheelchair users. Detailed maps visualized the identified barriers and helped in formulating targeted solutions. The analysis showed that while new constructions in Zurich meet accessibility standards, much of the existing infrastructure fails to do so, revealing a substantial gap in urban accessibility. The interpretation of the results indicates that despite efforts and regulations, the practical implementation is inconsistent, with significant barriers persisting in older parts of the city. A combination of conventional and Smart City solutions is proposed to enhance accessibility. Recommendations include widening sidewalks, improving curb edges and implementing digital information systems for real-time updates. This study contributes to creating inclusive urban spaces in Zurich by emphasizing the need for inclusive urban planning. It integrates Geographical Information Systems (GIS) to identify urban mobility barriers, ensuring public areas are accessible to all residents and visitors, particularly those depending on wheelchairs. By addressing these objectives, this research supports the broader goal of enhancing urban mobility and social inclusion for individuals with disabilities.

Keywords: Urban Accessibility, Mobility Obstacles, Wheelchair Users, Inclusive Urban Planning, Smart City Solutions, Geographical Information Systems (GIS)

Acknowledgments

I am proud to present this work to the inclined reader, whom I much encourage to continue reading, as this topic never ceased to fascinate me, even after more than a year of working on it. But without serious supervision, this project would not have come about either. Therefore, I would like to express my sincere gratitude to the following individuals who have been important in the completion of my master's thesis:

- **Dr. Oliver Grübner**, my university supervisor, for his guidance, valuable insights and unwavering support throughout this journey.
- **PD Dr. med. Michael von Rhein**, for his exceptional expertise and valuable contributions, which have been immensely helpful in shaping the content and direction of my research.
- **Prof. Dr. Robert Weibel**, for his profound expertise and direction, which have significantly influenced the quality and focus of my work.
- **Staff and people living in the Mathilde Escher Heim**, for their openness to collaborate and especially to the three interview partners who were willing to share their experiences, thus making a valuable content contribution to this work.

A heartfelt thank you to all my dear friends and family for their support of all sorts and for bearing (with) me whenever I stared absentmindedly from the ground, undecided how to best tackle the next hurdle. They have all been great supporters of mine, especially David Wehrli, for the countless discussions, tireless reviewing of my drafts and his emotional support. His insights and encouragement have been indispensable. I am also deeply grateful to my parents for their unwavering support and belief in me, providing the foundation for my academic endeavours. My friends have provided moral support and helpful feedback, which have been crucial in the completion of this thesis.

Your contributions and encouragement have been pivotal in bringing this work to fruition.

Thank you all for your unwavering support and invaluable contributions.

Contents

List of Figures

List of Tables

1 Introduction

The accessibility of public spaces for individuals with walking disabilities in Switzerland has recently come under intense scrutiny. A recent evaluation by the Convention on the Rights of Persons with Disabilities (CRPD) Committee highlighted significant deficiencies in Switzerland's efforts to meet its international commitments to concerning disability rights. This report criticized the lack of strategic planning and noted inadequate accessibility in critical areas such as public transportation and spaces. Additionally, it exposed discernible implementation gaps on national, cantonal and municipal levels, underlining the challenges in fully realizing these commitments (United Nations, 2019).

Despite the establishment of the "Equal Rights for Persons with Disabilities" legislation in 2004 (BehiG; SR 151.3), Furthermore, the adoption of the Sustainable Development Goals (SDGs) by the United Nations in 2015, which include specific standards for ensuring the inclusion and equality of persons with disabilities in areas such as education, employment, and accessibility, obligated Switzerland to adhere to these global standards (United Nations, 2019). Furthermore, the adoption of the Sustainable Development Goals (SDGs) by the United Nations in 2015, which include specific standards for ensuring the inclusion and equality of persons with disabilities in areas such as education, employment, and accessibility, obligated Switzerland to adhere to these global standards (Schweizerische Eidgenossenschaft, 2022). Several cantons, including Zurich, have recognized the need for improvement and initiated targeted action plans in 2022 to address these criticisms and bridge implementation gaps. These plans include enhancing the accessibility of bus and tram stops by 2023 and establishing a commission to improve communication and empower persons with disabilities to lead to self-determined lives (Regierungsrat Kanton Zürich, 2022).

Despite these initiatives, progress on equality measures has been slow since the CRPD's endorsement, prompting a reevaluation of advancements made. Although new constructions in Zurich are required to be barrier-free, it remains challenging to implement these standards in the already built parts of the city, presenting considerable difficulties. It is therefore important to identify where mobility barriers exist and where better standards and regulations should be established to create a more accessible environment (Regierungsrat Kanton Zürich, 2022). Public spaces, including sidewalks, parks and transit areas, often lack the necessary modifications to ensure accessibility, making it difficult for individuals with disabilities to navigate these areas safely and independently (Bennett, Lee Kirby and MacDonald, 2009).

Accessibility for healthcare facilities, in particular, must be prioritized as they serve a significant number of people with disabilities or impairments. Public hospitals, doctors' clinics and similar private facilities should provide barrier-free and independent access to their premises (Alzouby, Nusair and Taha, 2019). Consequently, the publicly accessible environment surrounding these facilities should also be free of barriers (United Nations, 2019).

A critical example of the need for accessible urban spaces is the area in Zurich Lengg. This area, currently undergoing significant planning and transformation, is surrounded by facilities such as the Balgrist Hospital, the Mathilde Escher Foundation and the Psychiatric University Hospital Zurich (Baudirektion Kanton Zürich, 2015). The transformation of the Lengg healthcare area underscores the importance of integrating accessibility into these developments from the outset. Given that Zurich is undergoing significant redevelopment, particularly in the Lengg healthcare area, this transformation provides a unique opportunity to integrate accessibility considerations into urban planning from the outset.

Focusing specifically on individuals with mobility impairments, particularly wheelchair users, allows this study to address more tangible and widespread challenges. The targeted approach facilitates a clearer assessment of the physical environment and the identification of specific obstacles that impair mobility. By addressing these mobility barriers, the study also aims to benefit other groups, such as the elderly and parents with strollers, thereby enhancing the overall inclusivity of urban spaces(United Nations, 2024).

This study looks at the remaining barriers in the Lengg healthcare area and its public transport links, aiming to find ways to improve access to essential facilities. Additionally, the study analyses the route to Zurich Main Station via the tram stops Balgrist and Bahnhofstrasse/HB, given the direct tram connection. This route is critical for understanding the accessibility challenges faced by wheelchair users and identifying improvements needed along this important transit corridor. A set of criteria, compiled in a catalogue based on current standards, will be jus applied and used to evaluate urban environments. Ultimately, this paper not only identifies areas needing attention but also proposes solutions, including the adaptation of Smart City initiatives, to help the city of Zurich become more inclusive. By addressing these objectives, the study contributes to the ongoing efforts to enhance accessibility in Zurich, ensuring that public spaces are welcoming and navigable for all residents and visitors, particularly those depending on wheelchairs.

1.1 Literature Review

1.1.1 Inclusive urban planning: promoting accessibility and participation in urban spaces

Accessibility in urban areas is a crucial aspect of urban planning. Given the diversity of urban residents and their varying needs, it is vital to ensure that urban spaces are designed and developed in a way that is accessible and usable for all (Pujiyanti, 2023). The term "accessibility" generally refers to straightforward access of primary public services like hospitals, libraries and police stations (Alzouby, Nusair and Taha, 2019). The concept of accessibility is based on the belief that all community facilities and services should be equally accessible to everyone (United Nations, 2024). The absence of accessibility can significantly impact the lives of all citizens (Nakarmi and Shrestha, 2022). Barrier-free urban planning benefits not only people with disabilities but also the wider community (Evcil, 2010; Nakarmi and Shrestha, 2022). Therefore, it is essential that urban planning incorporates the principles of accessibility to ensure that all citizens have unhindered access to public spaces (Huang, White and Langenheim, 2022).

Accessibility in Urban Planning: Definition and Spatial Accessibility

Accessibility in urban planning includes dimensions such as orientation, personal independence, mobility, integration, economic independence, transition and change (Filiz and Meshur, 2013). It is important to distinguish between accessibility and spatial accessibility. General accessibility includes factors such as transport, travel time, distance and cost (Penchansky and Thomas, 1981) ensuring all citizens have equal access to public facilities and services tailored to their individual needs and abilities (Darcy and Harris, 2003). On the other hand, Spatial accessibility focuses on the geographic distribution of places or services and their reachability (Allahbakhshi, 2023). Therefore, it merges the concept of accessibility and availability, describing the number and capacity of accessible services(Penchansky and Thomas, 1981). However, accessibility is subjective and based on individual perceptions. Therefore, perceived accessibility is crucial, as there can always be differences in understanding and interpretation (Pot, van Wee and Tillema, 2021).

The Role of Accessibility and Participation in Inclusive Urban Planning

Urban planning plays a crucial role in ensuring the accessibility of public spaces. Traditionally, disability was viewed through the medical model, which saw disability as an individual problem to be addressed through medical interventions (F Bromley, Matthews and Thomas, 2007; Kadir and Jamaludin, 2012). The social model, however, attributes disability to societal barriers, public prejudice, ignorance of rights and physical obstacles in the built environment (Meyers *et al.*, 2002; Evcil, 2010). Thus, disability is caused by the complex relationships between people and their environment, which includes cultural, social, political, climatic, topographical, technological and architectural elements (Meyers *et al.*, 2002; Basha, 2015).

The social model highlights that architectural barriers significantly contribute to the exclusion of persons with disabilities, impairing their well-being (Darcy and Harris, 2003). Moreover, Imrie and Hall (2001) argue that the policies, practices and values of professionals designing the built environment are key causes of these mobility barriers. Hence, prioritizing accessibility during the planning stage is crucial to minimize obstacles in public spaces, rather than expecting individuals to adapt, as the medical model suggests (Kadir and Jamaludin, 2012).

Prioritizing Inclusive planning and design for accessible urban futures

In modern urban landscapes, addressing the individual needs of residents is crucial for forming inclusive communities. As urbanization increases, creating inclusive environments has become a primary focus for urban planners, researchers and policymakers (Nam and Pardo, 2011; Huang, White and Langenheim, 2022). Future urban planning must address global challenges such as health, demographic shifts, and social inclusion, aiming to enhance mobility across diverse populations and encourage active participation from all community members (Huang, White and Langenheim, 2022).

An integral aspect of creating inclusive cities lies in the design of public spaces. Public spaces should be areas where all members of society can participate equally, as described by Basha (2015). Inclusive design aims to create these spaces to be accessible and usable for all, regardless of individual characteristics or circumstances. This means designing spaces that consider the needs of diverse populations, including older adults, people with disabilities, families with children, migrants and individuals from varied social and economic backgrounds (Matthews, 1995; Yılmaz, 2018). By doing so, public spaces can promote interaction among diverse population groups, strengthening community ties and contributing to a vibrant and diverse urban environment (Basha, 2015).

International frameworks and local initiatives

Various international initiatives, including the United Nations Agenda 2030 and Sustainable Development Goal (SDG) 11, support the objective of inclusive urban planning (Basha, 2015; Huang, White and Langenheim, 2022; United Nations, 2024). These frameworks emphasize the necessity of creating cities that promote growth and development based on justice and equality

(United Nations, 2024). It is crucial to recognize that the concept of inclusive cities encompasses a complex interrelationship of spatial, social and economic elements (Huang, White and Langenheim, 2022). Spatial inclusion necessitates access to essential infrastructure services, while social inclusion ensures equal rights and participation for all, including the most disadvantaged (Huang, White and Langenheim, 2022). Therefore, cities should be universally accessible and adopt inclusive strategies as advocated by Madanipour (2010).

Challenges in current urban design in Europe

Many European cities were historically designed without a focus on ensuring equal navigation and participation for all community members (Filiz and Meshur, 2013). These cities are usually designed for young, healthy, sporty and dynamic people (Yılmaz, 2018). Nevertheless, Inclusive urban design must facilitate the achievement of diverse objectives for all individuals, including those with disabilities (Darcy and Harris, 2003; Basha, 2015). Therefore, it is crucial to ensure that access to pedestrian and traffic areas is guaranteed (Basha, 2015). Unfortunately, the needs of people with disabilities, especially those with reduced mobility such as wheelchair users, are rarely considered (Velho, 2021). These people, including older people, pregnant women and parents with prams, make up an important part of society (Darcy and Harris, 2003; Stehlíková and Řezník, 2018; Yılmaz, 2018; Huang, White and Langenheim, 2022). Understanding and addressing the diverse needs of wheelchair users is critical to ensuring barrier-free mobility for all (Filiz and Meshur, 2013). This includes designing sidewalks, crossings and public transportation that are accessible to wheelchair users. By prioritizing the needs of wheelchair users, urban planners can tackle the most critical and visible barriers, setting a standard that benefits many people with various mobility issues. A specific focus on the needs of wheelchair users lays the groundwork for creating inclusive, equitable and navigable urban spaces for everyone (Darcy and Harris, 2003).

Mobility challenges for inclusion

Wheelchair users face significant challenges in urban environments, making them one of the most impacted groups by spatial obstacles (Matthews, 1995). Before planning, designing and renovating built environments to allow easy, independent and comfortable movement, it is important to understand that people in wheelchairs are not a homogeneous group and have different physical experiences (Filiz and Meshur, 2013). Therefore, urban development must support all people with movement impairment to access urban spaces and fully participate in public life, free from discrimination, social exclusion and physical barriers (Darcy and Harris, 2003; Basha, 2015; Yılmaz, 2018).

Creating an inclusive environment requires careful consideration of both physical and spatial aspects (Mahmoudi and Mazloomi, 2014). The combination of movement restrictions and architectural barriers, such as inaccessible public transport and the lack of alternative transportation options (Visnes Øksenholt and Aarhaug, 2018), significantly hampers the social participation of individuals with disabilities (Mahmoudi and Mazloomi, 2014; Velho, 2021) and can even lead to systemic discrimination (Basha, 2015). This can lead to people with disabilities feeling isolated and alone, which in turn can worsen their health (Mahmoudi and Mazloomi, 2014; Velho, 2021). Velho (2021) emphasises that efforts towards comprehensive accessibility should aim to create a future in which wheelchair users and all disabled passengers are neither rendered invisible nor forced to conspicuously assert their presence in a system designed without their needs in mind (Velho, 2021).

Enhancing social inclusion through inclusive design

Creating inclusive public spaces improves physical accessibility and enhances a sense of belonging, participation, and social cohesion. Inclusive public spaces promote interaction among diverse populations, strengthening community ties and contributing to a vibrant urban environment (Yılmaz, 2018). While some studies discuss the idea of a city for all, including universal design in general (Imrie and Hall, 2001; Lid and Solvang, 2016), others focus on identifying barriers in the built environment and overcoming them (Bickenbach *et al.*, 1999; Imrie and Hall, 2001; Castrodale and Crooks, 2010; Lid and Solvang, 2016). Addressing mobility issues, particularly for wheelchair users, remains crucial as external accessibility improves practical mobility needs (Wu *et al.*, 2022).

Experiences from countries like Sweden emphasize the importance of setting standards to accommodate people with disabilities (Shahraki, 2021). However, barriers and discrimination persist, hindering full participation on social life (Mahmoudi and Mazloomi, 2014). Research highlights disparities in urban planning regulations, with some regions, like Yogyakarta in Indonesia, only recently integrating measures to promote accessibility for all citizens (Pujiyanti, 2023). These insights underscore the ongoing global effort required to achieve genuinely inclusive cities that prioritize the needs of diverse population groups.

1.1.2 Geoographical Information Systems for Inclusive Urban Mobility

The creation of inclusive urban environments is a key aspect of social justice, particularly for individuals with mobility impairments. Zimmermann-Janschitz (2018) emphasizes the importance of Geographical Information Systems (GIS) in creating inclusive cities, outlining how this technology can identify and eliminate obstacles for individuals with mobility impairments.

GIS not only maps barrier-free access points but also develops navigation aids to assist individuals with disabilities in orientation and mobility (Zimmermann-Janschitz, 2018). Kocaman and Ozdemir (2020) extend this approach by demonstrating how GIS addresses contemporary challenges by focusing on the needs of individuals with mobility impairments.

Beale and Briggs (2002) developed a GIS-based system for calculating customized, barrier-free routes for wheelchair users. This system, along with other GIS techniques like dynamic segmentation and network analysis, helps analyse and quantify urban barriers. Alzouby, Nusair and Taha (2019) highlight that analysing accessibility through GIS facilitates the removal of mobility barriers and promotes social participation among individuals with mobility impairments. Furthermore, they integrate network analysis and multicriteria analysis to identify specific destinations based on distance, time and cost, drawing upon the work of Mavoa et al. (2012). Numerous other studies, including those by Lima et al. (2019), El Karim and Awawdeh (2020) and Qiu, Zhang and Cheng (2023), also use network analysis to improve accessibility.

Allahbakhshi, Huang and Weibel (2018) present various data collection methods, including field studies, sensors such as GPS and mobile applications. These methods provide precise data for analysing accessibility and support the planning of inclusive urban environments. Furthermore, (Huang, White and Langenheim, 2022) introduce the web application PedestrianCatch, which simulates pedestrian areas and offers evaluation approaches for urban scenarios. These approaches and methods demonstrate the technical potential of GIS technologies for creating inclusive urban environments and improving the quality of life for individuals with mobility impairments. However, they represent only a partial solution.

GIS and Accessibility: Bridging the Gap for Inclusive Urban Environments

Creating accessible urban environments is a central focus of urban planning and architecture. GIS provides a unique opportunity to analyse accessibility in urban areas by collecting, visualizing and analysing comprehensive spatial data (Langford *et al.*, 2008). Through the integration of GIS, planners and architects access precise data on accessibility patterns, barriers and obstacles, enabling them to develop and implement tailored measures for improvement (Huang, White and Langenheim, 2022). This technology represents an important advance in addressing the challenge of often not knowing where accessibility is lacking in urban environments (Mavoa *et al.*, 2012).

A more traditional method of identifying accessibility problems is manual inspection, involving physical measurement and assessment against applicable standards to determine if public facilities and urban areas meet accessibility standards for people with disabilities, including wheelchair users (Bennett, Lee Kirby and MacDonald, 2009). Despite increased awareness, studies such as Evcil (2010) show that many urban facilities still do not conform to accessibility standards. Architectural barriers significantly affect the quality of life of people with disabilities (Evcil, 2010).

Nakarmi and Shrestha (2022) highlight the critical need for accessibility assessments in urban areas, where mobility barriers are still a significant challenge. Their study in Nepal, based on United Nations guidelines of standards for urban environments, illustrates the need for concrete measures to improve accessibility (Nakarmi and Shrestha, 2022). Similarly, Bennett, Lee Kirby and MacDonald (2009) emphasize the importance of thorough manual verification of accessibility standards, particularly at intersections, where technical aids alone may not capture all relevant aspects of accessibility, as some aspects need to be considered on site to assess the level of difficulty for the user (Bennett, Lee Kirby and MacDonald, 2009).

1.1.3 Universal Design and the Integration of Global Standards with Local Adaptations for Accessibility

Universal design aims to create spaces and devices that can be utilized by a diverse range of users, regardless of their abilities or age. This concept promotes user-centred design, taking a holistic approach to address the needs of individuals with disabilities, including those arising from life changes (Esfandfard *et al.*, 2018). The diversity of norms and approaches reflects the varying cultural, legal and infrastructural contexts globally (Bennett, Lee Kirby and MacDonald, 2009).

Different countries have developed standards of accessibility for wheelchair users through extensive research. For example, Bennett, Lee Kirby and MacDonald (2009) emphasize the importance of guidelines for designing road crossings, recommending curb ramps to facilitate transitions from raised pavements to roads. The slope of these curb ramps is crucial for user-friendliness and functionality. Research shows that longer ramps with gentle slopes are easier for wheelchair users to navigate compared to shorter ramps with steep slopes (Sanford, Story and Jones, 1997).

Similarly, further research by Ferreira, Da and Sanches (2007) proposes specific standards for various aspects of accessibility, such as maximum curb heights and ramp gradients, to ensure safety and usability for wheelchair users. However, these standards can vary significantly between regions. For instance, North American standards, as discussed by Bennett, Lee Kirby and

MacDonald (2009), may not be directly applicable in other parts of the world due to differing infrastructural and legal contexts.

The challenges faced by individuals with disabilities also vary across different geographical regions. Esfandfard et al. (2018) observed that physical barriers significantly restrict the use of public spaces by individuals with disabilities in Tehran. Similarly, Shahraki (2021) found that cities in Iran were not adequately addressing the needs of people with disabilities.

In Malaysia, Kadir and Jamaludin (2012) highlighted the importance of making public buildings more accessible. They determined that specific modifications could enhance accessibility, emphasizing the necessity of designing both public spaces and buildings to be barrier-free (Kadir and Jamaludin, 2012).

Besides international standards, different countries have their own sets of accessibility guidelines. Stehlíková and Řezník (2018) note that in the USA, accessibility guidelines are typically available for each major city, while in the European Union, most countries have national schemes for presenting accessibility information. The Americans with Disabilities Act Accessibility Guidelines (ADAAG) in the USA exemplify a standard that may not necessarily be transferable to other countries due to differing national contexts (Bennett, Lee Kirby and MacDonald, 2009). Similarly, Australia and India have created specific standards for accessibility based on the universal design standards of the UN (Darcy and Harris, 2003; Nischith, Bhargava and Akshaya, 2018).

Switzerland, on the other hand, has developed its own comprehensive standards to ensure accessibility for people with disabilities, including wheelchair users. The Swiss standard SN 640 075: "Pedestrian Traffic: Barrier-Free Traffic Space" outlines detailed requirements for the design and construction of pathways and public spaces. This catalogue, developed by the federal government and the Swiss Association of Road and Traffic Experts (VSS), was significantly enhanced by the Fachstelle für Hindernisfreie Architektur, which provided essential insights and expertise. These principles and guidelines are based on extensive research into the requirements of people with disabilities in traffic areas, ensuring the design and implementation of barrier-free construction projects across Switzerland (Schweizerischer Verband der Strassen- und Verkehrsfachleute VSS, 2014). These adaptations highlight the necessity of developing accessibility guidelines that are context specific. By tailoring standards to local contexts while drawing on international research, urban environments can be made more inclusive and navigable for all individuals, regardless of their physical abilities (Mouratidis, 2021).

1.1.4 Understanding Urban Challenges for People with Disabilities

It is important to recognize that disability is not a marginal issue but a universal experience that manifests in various forms and degrees. Researchers like Bickenbach et al. (1999) emphasize that disability, particularly in the context of mobility limitations, affects the majority of individuals at some point in their lives, rather than being exclusive to specific groups.

Research indicates that the perspectives of people with disabilities are often overlooked, particularly in understanding their urban experiences. Lid and Solvang (2016) note that few studies examine the actual experiences of people with disabilities in urban settings and existing studies tend to focus on specific topics or disabilities rather than providing a comprehensive overview (Lid and Solvang, 2016).

The specific requirements of different user groups are frequently overlooked, as highlighted by Rodger et al. (2019). Electric wheelchairs are unsuitable for many environments considered barrier-free due to reliability and battery life limitations. Additionally, unfavourable gradients and restrictive access points to open spaces significantly limit the mobility of older adults and individuals with mobility impairments (Huang, White and Langenheim, 2022).

An interview with a wheelchair user illustrates the daily challenges they face, from the width of pavements to crossing railway tracks. The importance of these details and the diversity of barriers are often underestimated (Lid and Solvang, 2016).

Prioritizing Inclusion with Insights from Interviews

Urban planners and architects should prioritize the needs of individuals with mobility impairments, as recommended by Lid and Solvang (2016) This entails creating barrier-free infrastructure and offering information in accessible formats, ensuring that these measures are informed by the real-life experiences and needs of the affected individuals (Beale and Briggs, 2002).

A promising approach to identifying these needs is the use of qualitative interviews, as described by Lid and Solvang (2016). This approach facilitates direct dialogue at the relevant sites, leading to a deeper understanding of the challenges faced by individuals with disabilities. Similar methodologies have been used by other researchers to explore the experiences of wheelchair users in various urban environments (Matthews, 1995; Pyer and Tucker, 2017). Additionally, studies like as (Wu *et al.*, 2022) underline the ongoing need to eliminate barriers in urban environments for people in wheelchairs.

Creating a just and inclusive society requires a comprehensive approach based on in the lived experiences of people with disabilities. Access to services and facilities is another extensively studied area (Mouratidis, 2021). Meyers et al. (2002) report that individuals with disabilities encounter a range of personal, interpersonal and environmental barriers. While some barriers can be overcome, others will inevitably persist due to differing perceptions of what is achievable (Meyers *et al.*, 2002).

Identifying Physical and Social Barriers in Public Spaces

Numerous challenges have been identified by Evcil (2010). Despite existing legislation and regulations, there is often a lack of effective control mechanisms in the process of planning, leading to inadequate quality control of technical parameters during implementation (Basha, 2015).

In order to understand the specific issues faced by individuals with mobility impairments in urban environments, various studies have identified mobility barriers that impede access to public spaces and services. (Beale and Briggs, 2002) point out that obstacles such as stairs, high curbs and poor surface conditions significantly restrict mobility. The absence of lowered curbs and inadequate crossing points can result in longer travel routes, affecting not only wheelchair users but also those with other forms of mobility assistance. The quality of pavements is another critical factor, often compromised by poor conditions, street furniture and parked vehicles (Basha, 2015). Additionally, Mahmoudi and Mazloomi (2014) highlight physical obstacles such as damaged road and pavement surfaces that further impede the use of mobility aids. Improving accessibility by modifying existing environments is necessary but not always immediately feasible. These findings underscore the importance of addressing various physical barriers in urban planning to ensure more inclusive and navigable environments for individuals with mobility impairments (Mahmoudi and Mazloomi, 2014).

A frequent issue in public spaces, as observed by Bennett, Lee Kirby and MacDonald (2009), is the transition from elevated pavements to road surfaces, which can be a challenge for wheelchair users. Evcil (2010) notes that many studies have limited sample sizes, making it difficult to generalize accessibility issues but highlighting specific challenges at certain locations. Filiz and Meshur (2013) suggest that transforming environments to ensure accessibility often requires only minor alterations.

Transportation Challenges

Individuals with mobility limitations face significant challenges when using public transportation. Velho (2018) notes that even at "accessible" terminals, issues such as malfunctioning ramps and inadequate assistance from staff can occur, leading to frustration, anxiety and social isolation (Velho, 2018; Visnes Øksenholt and Aarhaug, 2018).

Furthermore, there is often a lack of adequate support from staff, which individuals with disabilities need to board and exit buses or trains and navigate complex transit nodes. Without trained or available staff, these essential services become inaccessible (Nakamura and Ooie, 2017). The physical design of public transportation systems also presents obstacles. Overcrowded buses and trains impede the movement and safety of those with mobility impairments (Pyer and Tucker, 2017; Prescott *et al.*, 2020) Elevated curbs at bus stops or the absence of ramps further hinder access to public transportation (Nakamura and Ooie, 2017). These barriers significantly impact individuals psychologically, as the inability to travel spontaneously and independently undermines their sense of autonomy and social engagement (Meyers *et al.*, 2002).

Distinctive Challenges in Swiss Urban Environments

In Switzerland, individuals with disabilities face distinct challenges in public transportation and spaces, hindering mobility and participation. Compared to other countries, Switzerland exhibits certain distinctive characteristics that shape the broader context (Kühnis and Wüst, 2022).

A paper highlighted the common presence of physical barriers in Switzerland's public spaces, such as elevated curbs, inadequate curb ramps, and insufficient crossing points. These obstacles hinder not only individuals with mobility impairments but also those with other disabilities from accessing public spaces and services. One specific challenge in Switzerland is the transition from elevated pavements to road surfaces, which can be particularly difficult for wheelchair users. The uneven surfaces and height differences between the pavement and the road can make it harder to move around and increase the risk of falls or injuries, especially in bad weather (Reinhardt *et al.*, 2016; Kühnis and Wüst, 2022).

While Switzerland has a well-developed public transportation system, there is still a need for improvement to ensure accessibility and mobility for individuals with disabilities (Kühnis and Wüst, 2022). A comprehensive approach that considers both physical and social barriers is essential for the creation of an inclusive and just society in which all citizens have equal access to public spaces and services (Bickenbach *et al.*, 1999). Research underlines the urgent necessity of removing these barriers and enhancing the mobility of people with disabilities. This endeavour requires not only the identification of existing problems but also the implementation of effective solutions. By considering both physical and social obstacles, we can work towards a truly inclusive society (Meyers *et al.*, 2002).

Mapping Accessibility: Perspectives and Challenges

In the field of urban accessibility, accessibility mapping is becoming an essential tool for planners and designers. (Stehlíková and Řezník, 2018) emphasize its growing importance, yet challenges remain in defining the target audience and developing appropriate mapping symbols and visualizations. Wheelchair users have unique requirements for navigating urban environments (Matthews, 1995)

GIS and cartography play a pivotal role in providing accessibility information (Stehlíková and Řezník, 2018a). It is crucial to integrate the perspectives of individuals with disabilities into the cartographic process (Matthews, 1995). Matthews (1995) and Basha (2015) stress that including these perspectives ensures that maps offer current and accurate information about the urban environment, facilitating the full integration of individuals with disabilities into city life. By doing so, public spaces can be made accessible to all (Meyers *et al.*, 2002).

Maps are significant sources of information about the location and availability of facilities and services for wheelchair users (Matthews, 1995). Often, maps reflect the views of the non-disabled population, unintentionally marginalizing wheelchair users by overlooking their specific challenges. Understanding that wheelchair users face significant challenges due to spatial barriers, which may seem trivial to non-disabled individuals, is essential. Geographers and cartographers must incorporate the 'ways of seeing' of wheelchair users into their work. By providing accurate and up-to-date information about the urban environment, they can help facilitate the full integration of wheelchair users into urban life (Matthews, 1995).

In conclusion, GIS and accessibility mapping are powerful tools for providing information on accessibility and supporting inclusive planning. It is essential to incorporate the insights of people with disabilities into the mapping process to break down barriers and create a fairer, more accessible society. By ensuring that maps reflect the needs of all users, urban environments can become more inclusive and navigable for everyone.

1.1.5 Smart City Solutions: Innovations for Wheelchair users

As urbanization accelerates, cities must enhance accessibility for all citizens, particularly wheelchair users who face numerous obstacles. To address these challenges, planners and architects need to prioritize wheelchair accessibility by implementing measures that consider their diverse needs (Lid and Solvang, 2016).

Cities around the world are investing in the construction and renovation of bus stops and railway stations to include ramps and elevators. These improvements not only facilitate easier access to public transport for wheelchair users but also integrate them more fully into the public transport systems, enhancing their mobility in urban areas (Lid and Solvang, 2016; Pyer and Tucker, 2017). Research indicates that individuals with mobility impairments require undivided attention to navigate their surroundings. Consequently, technologies such as GPS systems integrated into specialized apps for wheelchair users may enhance their travel experiences in urban environments (Ding *et al.*, 2007). These apps could provide real-time information on the accessibility of buses and trains, assisting wheelchair users in planning their journeys (Lid and Solvang, 2016). Mobile apps and digital display boards at bus and train stations provide real-time information on the accessibility of public transportation. This enables wheelchair users to select the most suitable mode of transport and plan their journeys more effectively, thereby optimising the utilisation of public transport networks (Stehlíková and Řezník, 2018b).

Cities are increasingly utilising data analysis and AI to comprehend the mobility patterns of wheelchair users. These technologies help implement targeted measures to enhance accessibility and mobility in various urban areas (Toch *et al.*, 2019). By analysing mobility data, cities can make informed decisions and utilise resources more efficiently to better meet the needs of wheelchair users and create inclusive urban environments (Panta *et al.*, 2019).

Technical Innovations to Support Individuals with Mobility Impairments

Smart city technologies, including GPS systems and mobile applications, represent a promising approach to further improving urban accessibility. These innovations utilize information technologies and digital advancements to enhance urban efficiency, sustainability and quality of life (Panta *et al.*, 2019). One effective method is the use of crowdsourcing platforms, where users can share information about accessible features like door widths, elevator availability and accessible toilets. This facilitates rapid access to relevant data for wheelchair users, significantly improving their mobility experience (Panta *et al.*, 2019).

Sustainability is a key component of Smart City development, with efforts focused on rehabilitation, restoration and renovation of buildings to align with sustainable practices (Parra-Domínguez, Gil-Egido and Rodríguez-González, 2022). Smart City initiatives not only address urban challenges but also promote a sustainable and liveable environment (Nam and Pardo, 2011). To achieve true inclusivity, these applications must adapt to user needs, offering customizable interfaces that respond to diverse requirements (Rico, 2021). Designing Smart Cities with accessibility in mind from the outset ensures that the needs of all citizens, including those with disabilities, are met. Prioritizing the safety and comfort of pedestrians, including those with disabilities, is crucial (Wheeler *et al.*, 2020). Advanced technologies like navigation apps can help pedestrians identify efficient routes, further enhancing mobility (Wheeler *et al.*, 2020). Additionally, incorporating accessibility features into digital mapping services such as Google Maps and OpenStreetMap will aid navigation and mobility for individuals with disabilities (Al-lahbakhshi, 2023). This enhancement improves access to urban environments, facilitating greater participation in public life.

It is evident that challenges such as the inadequate consideration of the needs of individuals with disabilities within conventional urban public transport systems (Zhou *et al.*, 2012) necessitate the urgent development of technologies designed to enhance the mobility of individuals with disabilities (Panta *et al.*, 2019). Although digital solutions can facilitate participation in various societal activities, ensuring spatial mobility remains a crucial aspect in meeting the travel needs of all individuals (Visnes Øksenholt and Aarhaug, 2018). Yılmaz (2018) emphasizes the importance of providing appropriate spaces for individuals with disabilities to view, approach and board vehicles. It is important to consider the various applications for individuals with physical disabilities in the built environment, such as stimulating surfaces on the ground or visually respectively audibly stimulating systems (Yılmaz, 2018). Furthermore, the Mobi+ system, implemented on the buses and stops of the Line 2 in Clermont-Ferrand, France, offers an effective solution for barrier-free mobility. This innovative concept aims to enhance accessibility to urban public transportation for individuals with disabilities while simultaneously collecting environmental data. The Mobi+ system, which incorporates features such as DWB recognition, alert notification at bus stops and wireless communication between buses and stations, has demonstrated its efficacy in reducing the overall travel time of the bus line (Zhou *et al.*, 2012).

Initiatives to Improve Accessibility in Switzerland

Individuals with disabilities in Switzerland face unique obstacles when navigating public transportation and accessing public spaces. These challenges include physical barriers like elevated curbs, insufficient lowered curbs and inadequate crossing points. To overcome these mobility barriers, innovative solutions have been devised to improve mobility and participation for people with disabilities in public spaces (Kühnis and Wüst, 2022).

Building on the efforts to overcome the challenges of accessibility, innovative solutions were developed. Swiss companies such as the wheelchair manufacturer SCEWO have developed innovative wheelchairs designed to facilitate the navigation of stairs. These technological advances provide wheelchair users with enhanced mobility and facilitate the overcoming of obstacles such as stairs in urban environments (Morales, Somolinos and Cerrada, 2013). In Basel, a pilot project is being developed for adaptive traffic light systems and wheelchair recognition (Kim, 2016). These systems utilize the latest technology to adjust traffic light sequences at intersections, ensuring that wheelchair users have sufficient time to cross the road safely. The integration of sensors and data analysis enables these systems to optimize traffic flow and enhance the safety of wheelchair users in public spaces (Kim, 2016).

Furthermore, crowdsourcing platforms such as Zürich Act play a pivotal role. They provide individuals with mobility impairments with the opportunity to share their experiences and needs in public spaces (Zanatta *et al.*, 2016). Users can exchange information about accessible locations, obstacles and suggestions for improvement, which lead to greater awareness and collaboration between the community and authorities. It can be argued that these platforms play a role in improving accessibility and quality of life for all Swiss citizens (Panta *et al.*, 2019). In Zurich, innovative solutions are being developed with the aim of enhancing accessibility and quality of life for all inhabitants. Intelligent traffic control technologies, such as smart traffic lights, monitor and optimise traffic in real-time, ensuring the safety of pedestrians and wheelchair users and helping smooth traffic flow (Schindler, 2017). Adaptive traffic light systems for wheelchair users and pedestrians with mobility impairments ensure that they have sufficient time to cross intersections safely. Additionally, there is a focus on the construction of barrier-free bus stops and stations to facilitate the seamless boarding and alighting of public transportation for wheelchair users (Darko *et al.*, 2022).

A primary objective of the Smart City Zurich initiative is to ensure that all residents enjoy equal opportunities and a high quality of life. The city is committed to including the entire population in order to guarantee that everyone can benefit from the opportunities presented by digital transformation, while also being protected from potential risks (Schindler, 2017). In doing so, Zurich takes into account the diverse realities and needs of its residents and guides the transformation process to identify and address regulatory requirements in a timely manner. Consequently, the city of Zurich is striving to maintain or enhance the quality of life for all its inhabitants (Knesebeck *et al.*, 2007). One crucial step towards achieving this goal is the establishment of a data pool, which enables both municipal employees and external stakeholders to share their data with institutions or the public in an autonomous and straightforward manner. Furthermore, sensor data from public infrastructure can be integrated and visualised. In accordance with the principles of open government data, administrative data that does not require specific protection may be freely used (Tanted *et al.*, 2020).

The efforts in Switzerland, particularly in Zurich, demonstrate a strong commitment to creating an inclusive and accessible city. By leveraging technology, participation and crowdsourcing, Zurich is setting an example for other cities. It illustrates that an inclusive city is not merely a vision but a tangible reality (Panta *et al.*, 2019).

1.2 Spatial Accessibility in Zurich, Switzerland

This thesis investigates three central research questions that reveal significant research gaps and are crucial for promoting inclusive urban design in Zurich. Despite the growing recognition of the importance of accessibility, the specific needs of individuals with walking disabilities are often overlooked. This work aims to set new standards and transform Zurich into a city that is truly accessible to everyone through innovative approaches and detailed analyses. The first significant research gap concerns the application of universal design principles to address the mobility challenges of individuals with walking disabilities. Universal design aims to create environments and products that are usable by all people, regardless of their abilities. Although Switzerland has established norms and regulations for accessibility in public spaces for people with disabilities, these are often too general and not specifically tailored to the unique needs of individuals with walking disabilities. Pujiyanti (2023) emphasizes the importance of designing urban spaces to be accessible and usable for all. Similarly, Alzouby, Nusair and Taha (2019) note that the term "accessibility" generally refers to the ease of reaching essential public services without specifically addressing the needs of individuals with walking disabilities. Despite these general approaches, the specific adaptation to the needs of individuals with walking disabilities is often overlooked (Filiz and Meshur, 2013; Nakarmi and Shrestha, 2022).

Research Question 1: What are the norms and standards for accessibility in public spaces for people with walking disabilities?

This question aims to identify and assess the existing standards to determine how well they address the specific requirements and challenges of individuals with walking disabilities. The *Accessibility Standards for Public Spaces for Wheelchair Users* catalogue developed in this thesis, aims to fill this gap by providing detailed and specific standards to improve accessibility for individuals with walking disabilities.

Another significant deficit is the lack of direct tests and monitoring of existing accessibility standards in Switzerland. Particularly in the Lengg healthcare area, which houses major hospitals, there are currently no specific assessments of accessibility. Nakarmi and Shrestha (2022) show that the lack of accessibility significantly impacts the lives of all citizens, especially in critical areas such as healthcare facilities. Although studies in other regions have acknowledged the importance of accessibility in healthcare facilities (Evcil, 2010; Huang, White and Langenheim, 2022), specific investigations and continuous monitoring are lacking in the Lengg healthcare area and in Zurich overall.

Research Question 2: Does the area around the Lengg healthcare area comply with the standards and regulations for accessibility in public spaces for people with walking disabilities?

This question examines the compliance and effectiveness of accessibility standards in the specific context of the Lengg health campus. A quantitative data collection will analyse whether the existing infrastructure meets the established standards and identify necessary improvements. The investigation includes the analysis of accessibility from the Balgrist station to the Bahnhofstrasse/HB station and further to the main building of Zurich Main Station. The aim is to test the developed catalogue and identify specific barriers for wheelchair users. Interviews will capture perceived barriers and obstacles in public spaces and their impact on the quality of life of wheelchair users. Despite significant advances in the development of Smart City solutions to improve urban accessibility, there remains a substantial research gap in Zurich regarding targeted strategies that address the specific needs of wheelchair users. Nam and Pardo (2011) emphasize that Smart City initiatives often do not incorporate the specific requirements of wheelchair users. Parra-Domínguez, Gil-Egido and Rodríguez-González (2022) highlight that despite technological advances, many obstacles for wheelchair users persist if these solutions are not specifically tailored to their needs.

Research Question 3: What improvements can be made and to what extent can the digital implementation of the Smart City approach be applied?

This question aims to identify potential improvements in accessibility through Smart City solutions and assess their practical implementation. The goal is to significantly improve accessibility for wheelchair users and enhance their quality of life through targeted Smart City innovations. This thesis contributes to the promotion of inclusive urban design in Zurich by addressing existing research gaps. It aims to improve the understanding and implementation of specific accessibility norms and standards, systematically monitor barriers for wheelchair users and explore the potential of smart city solutions to enhance the quality of life for individuals with disabilities in urban environments.

2 Methodological Approach

2.1 Identification of Accessibility Standards for Wheelchair Users

A specialized catalogue has been developed to address the specific needs of wheelchair users in urban environments. The "*Accessibility Standards for Public Spaces for Wheelchair Users*" focuses on ensuring the accessibility of public areas without additional accommodations for visual or cognitive impairments. This targeted approach addresses the unique mobility challenges faced by wheelchair users, making the standards practical and directly applicable in urban settings. The catalogue is written in German to assist local planners and architects in Switzerland.

This catalogue builds upon the Swiss standards catalogue VSS SN 640 075, 'Fussgängerverkehr: Hindernisfreier Verkehrsraum,' published by the Swiss Association of Road and Traffic Experts (VSS) in 2014 (Schweizerischer Verband der Strassen- und Verkehrsfachleute VSS, 2014). The standards that improve accessibility and mobility for wheelchair users were specifically adopted, while other regulations less relevant to this group were omitted.

The Fachstelle für Hindernisfreie Architektur played a crucial role in adapting the VSS standards to better serve the needs of wheelchair users. Their expertise was instrumental in revising the relevant norms to optimize mobility and accessibility for wheelchair users. This ensured that the specific requirements and challenges faced by wheelchair users were thoroughly considered and integrated into the planning and design of public spaces.

There is often a distinction between 'standards' and 'guidelines.' Standards are typically rigid and mandatory, while guidelines are more flexible and advisory. However, this catalogue uses the term 'standards' to highlight the critical nature of these accessibility measures. Although 'standards' might not perfectly fit its traditional definition, it closely reflects the intent and application of these measures. This ensures high levels of accessibility and usability for wheelchair users. In this work, the term 'standards' is used to emphasize the importance and necessity of these accessibility measures.

In crafting these standards of the *Accessibility Standards for Public Spaces for Wheelchair Users*, certain elements from the broader 'Fussgängerverkehr: Hindernisfreier Verkehrsraum' guidelines and standards were omitted to avoid conflicts and streamline the focus. For instance, tactile-visual markings and high straight curbs, typically used to guide individuals with visual impairments, were excluded to prevent obstacles for wheelchair manoeuvrability. Instead, the catalogue introduces enhanced specifications tailored to wheelchair mobility, such as stricter standards for ramp inclines, doorway widths and turning radii in public spaces. Additionally, service counters and ticketing areas are designed to be accessible from a seated position and aisles or pavements are widened to facilitate easy navigation.

Special attention was given to public transport stops, ensuring clear boarding markings and good access options to support the independence of wheelchair users. However, the catalogue deliberately excludes considerations for wheelchair-accessible parking spaces, maintaining a focused scope on public transport and excluding private transport concerns.

These adjustments ensure that environments are not only accessible but also optimized specifically for the mobility and independence of wheelchair users. While the catalogue primarily serves wheelchair users, it is also beneficial for other groups like older individuals or families with prams, particularly in settings such as healthcare facilities where easy access is crucial. This focused approach is not intended to prioritize the needs of wheelchair users over other disabilities but rather to address the unique challenges they face and ensure equal access and inclusion in the most frequent public areas.

The *Accessibility Standards for Public Spaces for Wheelchair Users* emphasizes movement, orientation and safety for wheelchair users. They align with the main categories for pedestrian standards in the 'Fussgängerverkehr: Hindernisfreier Verkehrsraum' ordinance. Specific categories and subcategories from the developed catalogue are detailed in Table 1, presented in German, while explanations are provided in English, consistent with the language of this thesis.

In conclusion, the *Accessibility Standards for Public Spaces for Wheelchair Users* refines existing standards to better meet the specific needs of wheelchair users, setting a new benchmark for accessible urban planning. This focused effort enhances inclusivity without compromising the overall functionality of public spaces, providing a valuable resource for architects, engineers and planners dedicated to building accessible environments.

Table 1: Description of categories of the Accessibility Standards for Public Spaces for Wheelchair Users

Categories	Sub-Categories	Description of content
1.Geometrisches Normalprofil	1.1. Breite der Gehfläche 1.2. Querneigung	Minimum width required for wheelchair access and maximum cross slope of the surface
2.Überwindung von Höhendifferenzen	2.1. Längsneigung 2.2. Rampen 2.3. Aufzüge	Standards for the longitudinal slope of walking surfaces, specifications for ramp constructions and requirements for elevators
3.Wegführung, Abgrenzung und Gliederung von Verkehrsflächen	3.1. Trennelemente 3.2. Führungselemente	Requirements for separating elements and guiding elements for clearly defined routing and demarcation of walkways
4.Querung für Fussgängerverkehr	4.1. Punktuelle Querungen 4.2. Flächige Querung	Specifications for barrier-free crossings, both at points and over large areas, for safe use by pedestrians and wheelchair users
5.Möblierungselemente	5.1. Dimensionen und Gestaltung	Requirements for the dimensions and design of furnishings in public outdoor spaces
6.Sicherheitselemente	6.1. Sicherung von Absturzstellen 6.2. Geländer und Abschrankungen 6.3. Schikanen	Specifications for the protection of danger points, railings and barriers, as well as requirements for chicanes to ensure safety.
7.Beläge	7.1. Eignung von Belägen für Gehflächen	Criteria for the suitability of surfaces for walking areas in terms of their quality and safety
8.Information und Orientierung	8.1.Visuelle Informationen 8.2. Akustische Informationen 8.3. Helligkeitskontrast	Requirements for visual and acoustic information and brightness contrast to improve orientation for all users
9.Beleuchtung	9.1. Beleuchtung	Standards for suitable lighting in public spaces to ensure safety and orientation
10.Haltestellen des öffentlichen Verkehrs	10.1. Haltestellen Plattformen 10.2. Fahrgastinformationen 10.3. Haltestelleneinrichtung	Requirements for the accessibility of transport stops platforms, passenger information and transport stop facilities
11.Baustellen	11.1. Baustellen	Specifications for the barrier-free design of construction sites to ensure accessibility and provide safety for wheelchair users

2.2 Examination of Accessibility Standards in the Study Area

2.2.1 Study Area Overview

The selected study areas include the healthcare area of Lengg, surrounding the Balgrist University Hospital in Zurich, Switzerland and the route from the tram stop Bahnhofstrasse/HB to the main building of Zurich's main station.

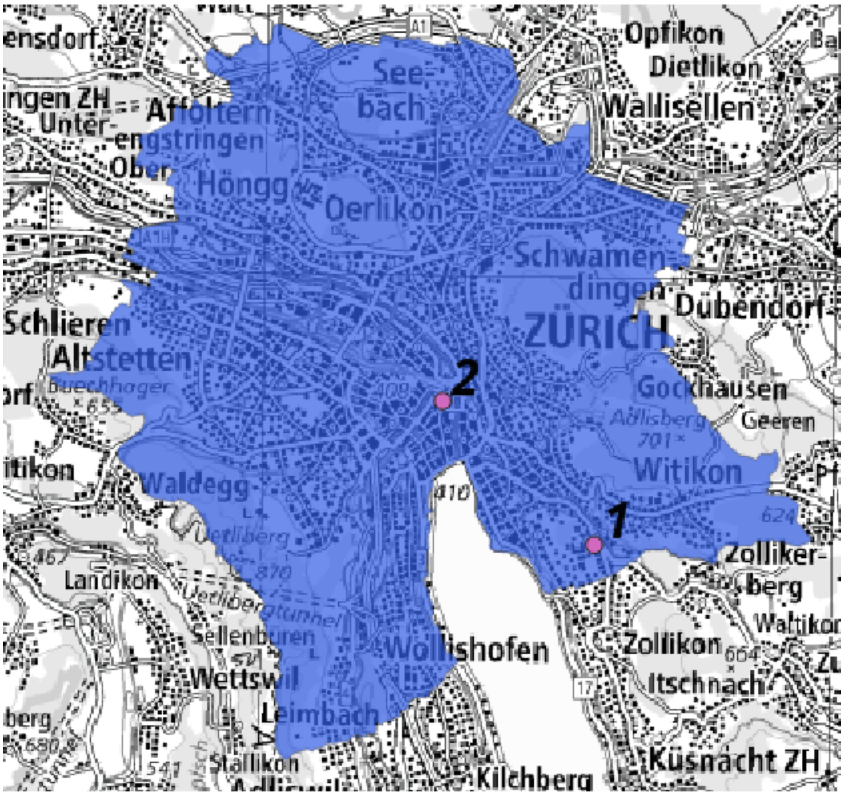


Figure 1: Study Area, Nr.1 Healthcare area Lengg and Balgrist Tram Station, Nr.2 Zurich Main Station and Bahnhofstrasse/HB.

The healthcare area Lengg, located in the eastern part of Zurich (Figure 1, Area 1) is a major medical centre hosting several prominent institutions, including the Hirslanden Clinic, Schulthess Clinic, Psychiatric Clinic and the Mathilde Escher Foundation, which primarily serves people in wheelchairs. Additionally, the new Zurich Children's Hospital is under construction, further enhancing the area's medical infrastructure. In recent years, the Lengg healthcare area has undergone significant urban planning transformations, with more changes anticipated. These developments make it crucial to focus on accessibility to ensure that the area remains navigable for all individuals, especially those with mobility impairments. Lengg was selected for this study due to its extensive range of medical facilities and the ongoing and planned urban transformations, which highlight the importance of accessibility in this key area.

The second study area encompasses the route from the Balgrist station to the Bahnhofstrasse/HB station and onward to the main building of Zurich Main Station, situated in the city centre of Zurich (Figure 1, Area 2). This route is particularly significant due to its provision of direct access to Zurich's main railway station, a major transport node in Switzerland. Notably, the Balgrist station, located near the Balgrist Hospital, serves as a crucial public transport hub. It offers patients, visitors and staff convenient access to the healthcare facilities and seamless connectivity to District 1, centering around Zurich Main Station.

2.2.2 Data Collection

Quantitative Analysis

The quantitative data collection aims to test the *Accessibility Standards for Public Spaces for Wheelchair Users* catalogue to identify potential barriers for people in wheelchairs. This assessment focuses on compliance with accessibility standards and regulations in public spaces within the Lengg healthcare area. Specifically, it examines the tram stations Balgrist and Bahnhofstrasse/HB, as well as the route to the main building of Zurich Main Station. The standards and standards from the *Accessibility Standards for Public Spaces for Wheelchair Users* catalogue are utilized to structure the samples for this examination.

For data collection, the Swisstopo app was used, providing a user-friendly platform for capturing geographical data. This app not only allowed the saving of mobility barriers as point data but also enabled the addition of specific text information to each point. These text entries helped describe measurements like gradients and particular obstacles associated with each point. Adding textual descriptions directly to the data points ensures that all critical information regarding barriers for wheelchair users is fully documented.

Data collection also accounted for external conditions, such as weather (including snow or heavy rain) that could alter walking surfaces and varying levels of pedestrian traffic, which might introduce additional obstacles or provide unforeseen assistance to wheelchair users, potentially affecting the perceived accessibility. Additionally, the personal experiences and perceptions of the evaluator were acknowledged as contributing to the assessment. To ensure objectivity in the data collection process, established accessibility standards were strictly followed, providing a consistent framework to evaluate each recorded barrier rigorously.

The data collection occurred throughout January 2024, immediately following the deadline by which public transport stations were expected to meet the VSS norms as outlined in

Fussgängerverkehr: Hindernisfreier Verkehrsraum (Schweizerischer Verband der Strassen- und Verkehrsfachleute VSS, 2014). This period was chosen to assess whether these accessibility standards had been successfully implemented by the end of 2023 in the Lengg healthcare area (Regierungsrat Kanton Zürich, 2022). Data collected will undergo thorough analysis to identify barriers and challenges. This process is part of broader initiatives to monitor and review infrastructure accessibility within the area.

Qualitative Interview

As part of the research, qualitative interviews were conducted with three individuals from the Mathilde Escher Foundation, who rely on wheelchairs for mobility due to various reasons. These individuals live in one of the residential groups at the Mathilde Escher Foundation. These interviews used a semi-structured questionnaire to explore barriers and obstacles in public spaces that impact wheelchair users. The purpose was to gain firsthand insights and a deeper understanding of the specific challenges faced by wheelchair users in navigating urban environments.

The questionnaire was structured to cover a range of topics, from personal circumstances and daily experiences in public spaces to perceptions of accessibility. Specific attention was given to their experiences in the Lengg healthcare area, discussing mobility barriers encountered and potential areas for improvement. The semi-structured nature of the questionnaire allowed for detailed responses on perceived obstacles in public spaces and transport, with an emphasis on collecting diverse insights. The questionnaire can be found in appendix A1.

The question guide is divided into several sections to capture different aspects of the participants' experiences. The general information section includes questions about age, type and extent of mobility impairment, duration of wheelchair use, type of wheelchair used in public spaces and the need for assistance in public settings. The daily experiences section focuses on how often participants navigate public spaces, their experiences with these environments and the impact of perceived barriers on their quality of life. In the specific challenges section, participants describe the most common mobility barriers they encounter, providing specific examples and highlighting particularly challenging locations. Finally, the suggestions for improvement section aims to gather participants' ideas for enhancing accessibility, especially in the Lengg healthcare area.

Participants were selected from the Mathilde Escher Foundation due to their firsthand knowledge of navigating public spaces and their familiarity with the Lengg healthcare area, where the foundation is located. The interviews were conducted simultaneously with all three participants, enabling a rich dialogue that captured a variety of viewpoints.

The session took place on February 5, 2024, at the Mathilde-Escher Foundation and lasted approximately two hours. This familiar and comfortable setting was chosen to encourage open communication. Prior to the interview, all participants were informed about the handling of the data collected, ensuring their informed consent. They voluntarily agreed to participate, with strict adherence to data protection guidelines, including the anonymization of personal information and secure storage of all data to protect privacy. Furthermore, all data, including audio recordings of the interviews, were securely stored and accessible only to authorized research personnel. Participants were assured that their data would be used solely for research purposes and would not be shared with any third parties.

The interviews were transcribed by uploading the audio files into Word to create an automatic transcript. During the interviews, some off-topic discussions occurred, which were not relevant to the interview questions. These sections were excluded from the transcription. The initial transcript generated by Word was then manually reviewed, supplemented and edited for accuracy. For transparency and detailed examination, the full interview question guide of the interviews are included in the appendix A1.

The interviews were systematically analysed, and responses were categorized based on recurring themes and topics. The analysis led to the identification of six distinct categories: General Independence in Mobility, General Mobility and Use of Public Transport, Challenges and Barriers in Infrastructure, Social Interaction and Perspectives, Specific Challenges and Solutions in the study area and Approaches and Technological Aids.

Significant attention was directed towards the diverse array of barriers encountered by participants, including architectural obstacles, limitations in public transportation accessibility and deficiencies in signage. The analysis also explored the implications of these mobility barriers on participants' quality of life, along with their recommendations for enhancing overall accessibility.

This analytical approach offers insights into the complexities surrounding barriers in public spaces. Wheelchair users are confronted with these barriers, contributing to a broader understanding of accessibility challenges within communities.

2.2.3 Data Processing and Mapping

Both quantitative and qualitative data were integrated to provide a comprehensive analysis of the Lengg healthcare area, focusing specifically on tram stops and the route to Zurich Main Station. The point data, collected via the Swisstopo app, along with insights from interviews with members of the Mathilde Escher Foundation, underwent thorough cleaning and preparation using QGIS, which facilitated their conversion into shapefile format.

For the analysis, the focus was on identifying and precisely locating obstacles within the designated study areas. Rather than displaying them in a matrix format, the barriers were categorized according to a 2x2 framework developed earlier.

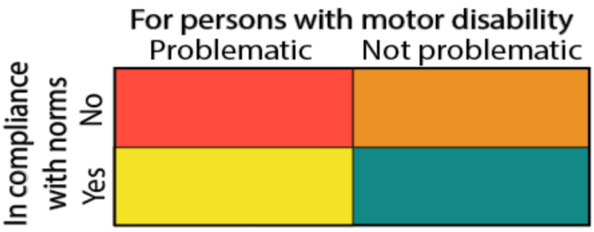


Figure 2: 2x2 Classification Matrix of Accessibility Barriers for Wheelchair Users: Assessing Standards Compliance and Problematic Impact for wheelchair users in the examination area.

During the data collection process, each barrier was evaluated and classified using a newly developed 2x2 matrix, shown in Figure2. Specifically created for this context, this visual representation helps clarify how barriers are categorized. The x-axis of this matrix indicates whether a barrier is problematic for wheelchair users, labelled as 'Problematic' or 'Non-problematic'. This classification integrates both measurable criteria, such as the barrier's dimensions and location and the evaluator's subjective perception. Logical reasoning was employed to identify potential hazards that might not be immediately quantifiable. Specific areas of concern, such as entrances to parking lots and other structural impediments, were marked based on their impact on navigation. The y-axis assesses each barrier's compliance with the *Accessibility Standards for Public Spaces for Wheelchair Users*, categorizing them as 'Compliant' or 'Non-Compliant'. Based on the axes, the matrix organizes barriers into four distinct categories:

1. **Red quadrant (Non-Compliant and Problematic):** This quadrant identifies barriers that both pose navigational challenges and fail to meet accessibility standards, necessitating urgent attention. An example is a high curb without a ramp, which blocks easy wheelchair access.
2. **Orange quadrant (Non-Compliant and Non-Problematic):** This section includes barriers that technically meet accessibility standards but still create practical challenges for wheelchair users.

3. **Yellow quadrant (Compliant and Problematic):** This section includes barriers that technically meet accessibility standards but still create practical challenges for wheelchair users. An example here could be a gradient that, while conforming to regulations, may still be challenging for some individuals depending on their personal strength and wheelchair capabilities.
4. **Petrol quadrant (Compliant and Non-Problematic):** Barriers in this category provide optimal conditions, complying with standards and facilitating easy navigation. An excellent example would be wide pathways with gentle slopes and describes in this thesis the examination path without obstacles.

This structured approach, as illustrated in Figure 2, not only provides a clear framework for assessing accessibility but also enhances understanding of the navigational challenges faced by wheelchair users in public spaces.

The visualization of this data was meticulously crafted using QGIS for mapping, while Adobe Illustrator was employed to refine the map layouts**.** This approach not only highlighted the location of obstacles but also enhanced the maps' utility for both affected individuals and planners. Specifically, photographs of key problem areas were integrated into the visualizations, providing concrete examples of the barriers encountered. These pictures served to bridge the gap between abstract data points and real-world conditions.

Two maps were created. One showing the locations of the Balgrist and Bahnhofstrasse/HB stops along with the routes to Zurich Main Station and another depicting the studied route around Balgrist Hospital. These maps offer a clear visualization of the identified barriers, categorized by the four quadrants and were complemented by photographs that visually underlined the specific challenges.

2.3 Solution Approaches and Smart City Applications

The data analysis identified several barriers in the study areas of the Lengg healthcare area, tram stops and along the route to Zurich Main Station that limit accessibility for wheelchair users. To address these challenges, conventional and Smart City strategies were considered. These potential solutions are based on the core components of Smart City frameworks: inclusion, citizen participation, digital services and equal opportunities.

A comprehensive literature review provided an overview of existing research and best practices for accessible public environments. This background information helped identify several adaptive measures that could effectively address the specific barriers in the study areas. The selection of these measures was based on a preliminary assessment of their practicality and potential impact. It was recognized that these architectural improvements require further detailed evaluation to ensure their effectiveness.

The study combined modern technology with necessary physical adjustments to transform public spaces into accessible environments for all citizens. Conventional architectural modifications such as widening sidewalks, improving curb edges and installing handrails in steep areas were suggested. Additionally, innovative Smart City applications like digital information systems, mobile apps for wheelchair users and intelligent transportation systems were examined.

3 Results

3.1 Accessibility Standards for Wheelchair Users

The creation of inclusive communities relies on ensuring that public spaces are accessible to everyone. The application of this catalogue, titled *Accessibility Standards for Public Spaces for Wheelchair Users*, improves accessibility in public spaces for wheelchair users by addressing their unique needs with comprehensive adaptations and expansions**.** Developed to ensure comprehensive accessibility, the catalogue outlines key standards and principles that make public spaces fully accessible to wheelchair users. The key standards and principles include:

Barrier-Free Mobility: All public pathways and accesses are designed without steps, ensuring unrestricted mobility and independence for wheelchair users.

Spatial Orientation: Effective signage and clear pathway configurations aid in navigation, even in potential dead ends.

Safety at Hazardous Sites: Enhanced lighting and conspicuous markings and sturdy railings increase safety for all users.

These improvements are detailed across the eleven chapters of the catalogue. An overview of the chapter structure and specific contents is presented in Table 1. Each category can be further examined in this table and the entire criteria catalogue *Accessibility Standards for Public Spaces for Wheelchair Users* is available in the appendix A5.

The subsequent analysis delves into the individual chapters of the catalogue, each focusing on different facets of accessibility and their practical implementation. This detailed examination presents the standards outlined in each chapter, clarifying the complexity of the accessibility requirements. It also highlights the adaptive strategies necessary for optimizing urban infrastructure to better serve wheelchair users. Ultimately, this analysis provides a thorough understanding of how various elements collaborate to enhance the accessibility of public spaces.

3.1.1 Geometric Normal Profile

The initial chapter presents the geometric standards for walkways. It specifies the necessary width and cross slope to ensure the safe and comfortable use of public spaces. Walkways should maintain a minimum width of 1.80 meters to accommodate people using mobility aids. Temporary narrowing shorter than 1.00 meter, such as bollards, require a width of at least 1.00 meter. For directional changes of 45° or more, a continuous width of at least 1.50 meters is necessary, with a turning radius of 90° at least 1.90 meters. Additionally, passing places of 4 meters in length are required every 50 meters if the walkway width is less than 1.80 meters.

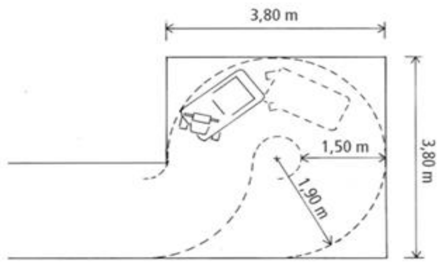


Figure 3: Required maneuvering spaces and turning radii for 45° and 90° directional changes on walkways (Schweizerischer Verband der Strassen- und Verkehrsfachleute VSS, 2014).

A manoeuvring space of at least 3.8 meters to 3.8 meters is required, available both permanently and temporarily, ensuring wheelchair users and others with mobility aids can move freely and safely, as depicted in Figure 3.

The cross slope of sidewalks and footpaths should not exceed 2%. Local adjustments, such as at curbs at crossings or building entrances may go up to 6%, as illustrated in Figure 4. To minimize risks for wheelchair users, drainage design must ensure that the cross slope remains minimal.

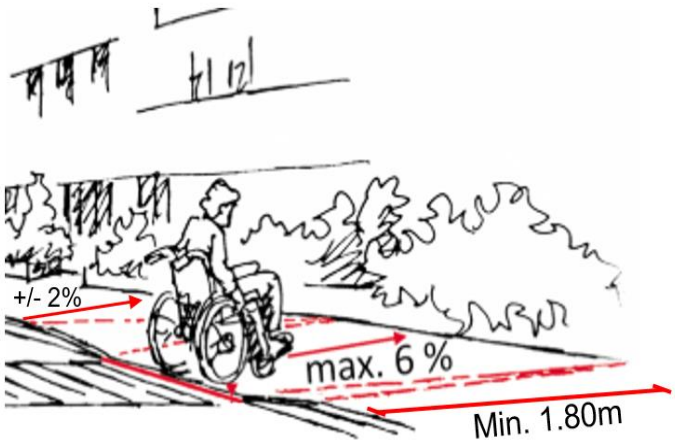


Figure 4: Allowable cross slopes of up to 6% at specific points on sidewalks, emphasizing the minimum width of 1.80 meters (Schmidt and Manser, 2003).

This chapter does not address clear height, as wheelchair users generally sit at a lower height level.

3.1.2 Overcoming Height Differences

This section details measures for implementing step-free alternatives to stairs in public spaces. These alternatives should be easily locatable, accessible with minimal detours and adhere to information and orientation specifications.

The catalogue recommends a maximum incline of 6% (like in Figure 5). Under specific conditions, slopes up to 10% outdoors and 12% in covered areas being acceptable. The same regulations also apply to ramps. For slopes that exceed these values, alternative access routes should be created via additional ramps, elevator or public transport.

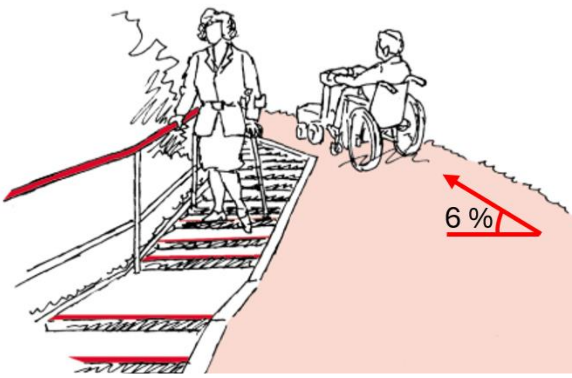


Figure 5: Illustration of a gradient that a wheelchair users can overcome; according to standard max. 6% longitudinal gradient (Schmidt and Manser, 2003).

For significant elevation differences, installing elevators is recommended. Elevators should be accessible and secured with safety systems, including a backup elevator located nearby. Elevator cabins should have a minimum width of 1.1 meters, a minimum depth of 2.1 meters and a door width of at least 0.8 meters, as seen in Figure 6. A manoeuvring space of 2.4 meters by 3.8 meters is required in front of elevator doors. Stairlifts and platform lifts are prohibited due to operational difficulties and safety risks.

Not included are specifications for ramps with handrails, which benefit blind users and safety features are covered in Chapter “Safety Elements”. Stair paths are excluded, assuming wheelchair users cannot navigate stairs. Handrails on slopes over 10% are excluded, considering they primarily serve as safety measures rather than accessibility aids.

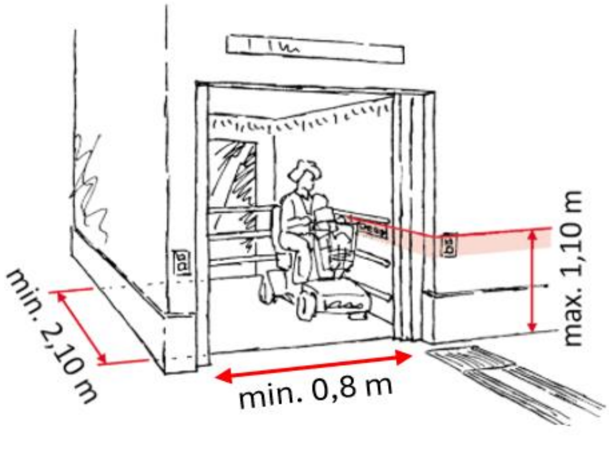


Figure 6: Dimensions of an elevator in public space (Schmidt and Manser, 2003)

3.1.3 Path Layout, Demarcation and Structure of the Traffic Path

Design principles for pedestrian areas and shared spaces with vehicular traffic are covered in this chapter as well as emphasizing separation and guidance elements to ensure clear and safe pathways.

Figure 7: High curb edges with a vertical offset of 0.06 m (Schweizerischer Verband der Strassen- und Verkehrsfachleute VSS, 2014).

Separation elements are essential in delineating various traffic areas. High curb edges with a vertical offset of at most 0.06 meters, as seen in Figure 7, are ideal for traffic-oriented streets to minimize crossing, while low curb edges with a height of 0.04 meters and a width of 0.13 to 0.16 meters are suitable for areas with frequent crossings (seen in Figure 8). Barriers, such as fences or bollards, are used to prevent road crossings at unclear locations, roundabouts, or underpasses. Access ramps with a width of 1 meter are designed at sloped curb edges, maintaining a distance of at least 0.6 meters from traffic signal masts. These separation elements must be recognizable and interpretable, achieved through uniform design and limited variation. Curb edges or barriers serve as separation elements, while bollards and posts are insufficient. Inclined curb edges can be designed as access ramps when needed.

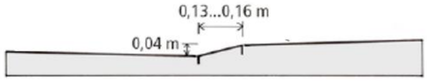


Figure 8: Low curb edge with a height of 0.04 m and a width of 0.13 to 0.16 m (Schweizerischer Verband der Strassen- und Verkehrsfachleute VSS, 2014).

Guidance elements play a crucial role in orientation and improving accessibility in pedestrian and mixed traffic areas. Pavement strips with a width of at least 0.6 meters are used to mark visible paths and highlight special areas, while surface changes provide brightness contrast to visually emphasize specific areas.

Troughs with a depth of 0.02-0.03 meters, a width of 0.4-0.45 meters and a maximum flank angle of 14° allow for effective water guidance and clear area separation, as seen in the example in Figure 9. Elements like facades, walls, fences, paving stones and green spaces help create clear and safe traffic areas.

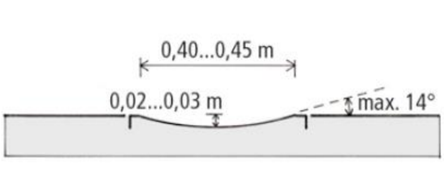


Figure 9: Dimensions of a through (Schweizerischer Verband der Strassen- und Verkehrsfachleute VSS, 2014).

Certain elements have been omitted from the catalogue to better address the needs of wheelchair users. These include curbs with inclined offsets of 0.06 meters, as lower heights are preferred. Handrails on slopes over 10%, which serve mainly as safety precautions, specific measures for the blind, such as floor knobs and narrow ramps have also been excluded, as the focus is primarily on wheelchair users.

3.1.4 Pedestrian Crossings

Examining two types of pedestrian crossings, the focus is on point crossings and area crossings. Point crossings are designed to be step-free by lowering sidewalks with high curbs. Special emphasis is placed on low curb edges with a sloped profile to accommodate wheelchair users. These low curb edges are also needed at the road edge and on safety islands, where they must be wide enough for mobility aids according to standards.

Protection islands at pedestrian crossings are designed to lessen time pressure and stress, offering significant benefits for individuals with disabilities. Traffic signals are adjusted to allow ample time for all wheelchair users, to cross safely. Additionally, activation devices for these signals should be easily accessible to everyone.

Standards for the quality and safety of crossings focus on several key areas. Detectability is prioritized with cross slopes at sidewalk lowering designed to allow a maximum of 6% slope. The design avoids visibility-obstructing elements such as railings, closely spaced bollards, or posts (illustrated in Figure 10). Furthermore, the standards dictate that protection islands should be at least 2.0 meters wide and include lateral guidance with a vertical offset of at least 0.03 meters.

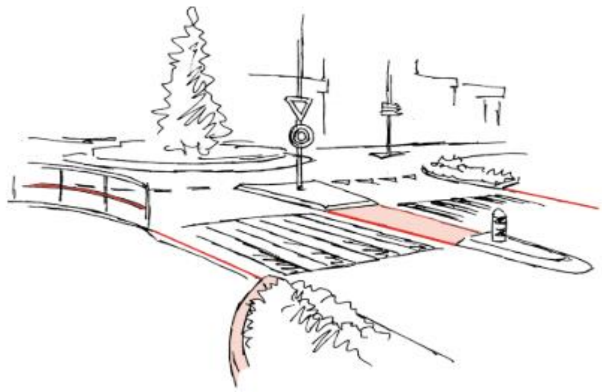


Figure 10: Example of a pedestrian crossing with a roundabout, protection island and safety measures (such as the railing) (Schmidt and Manser, 2003).

Area crossings adopt similar standards to point crossings, focusing on longer stretches where barrier-free access is crucial. These crossings ensure free access to sidewalks on both sides of the roadway, enhancing mobility for all pedestrians.

The chapter omits certain elements, including multipurpose strips, tactile visual markings intended for the visually impaired and acoustic signals for directional guidance, based on the assumption that wheelchair users can visually access the necessary information. Additionally, special considerations for bicycle traffic and clear tactile visual markings in roundabouts are not included, though clear detectability of pedestrian crossings is maintained.

3.1.5 Furniture Elements

Ensuring the safe design and arrangement of fixtures, technical equipment and furnishings in public areas is crucial. All furniture elements must guarantee a straight and unobstructed walking area of at least 1.80 meters in width, regardless of whether the furniture is along streets, facades, or in the middle of the sidewalk. Fixtures and elements of furnishings should generally be arranged outside walking areas to ensure a clear pathway. Furniture elements must avoid sharp edges or protruding parts to prevent injuries. The arbitrary parking of bicycles must not restrict the walking area, as illustrated in Figure 11.

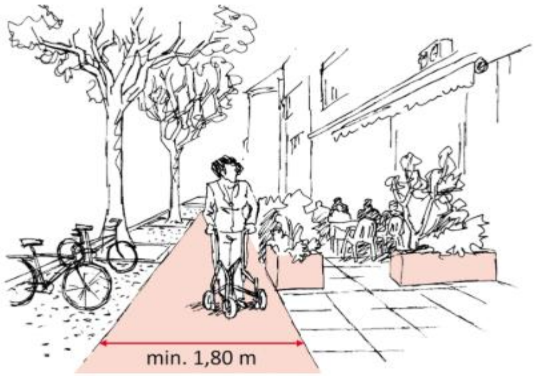


Figure 11: Scenery of furnishing elements and the free walking surface with the minimum dimensions of 1.80 m (Schmidt and Manser, 2003)

The chapter omits specific regulations for areas adjacent to seating and detailed requirements for the design of seating areas. Additionally, provisions for tactile or visual markings are not included.

3.1.6 Safety Elements

Standards for safe walking surfaces in public spaces are established to ensure accessibility for wheelchair users. Handrails and barriers must be securely anchored and stable, with movable elements like chains, ropes, or bands not permitted due to their lack of stability.

Obstacles that obstruct traffic flow should generally be avoided. If necessary for safety, they must be designed to allow clear passage for mobility aids and strollers. Minimum passage dimensions must ensure unimpeded and safe movement for all users.

Special safety measures apply to residential pedestrian areas, particularly for drop-offs over 0.40 meters. Solutions include handrails, which must be at least one meter high, or curb stones, with pedestals of at least 0.03 meters and a crosspiece no higher than 0.3 meters, like Figure 12

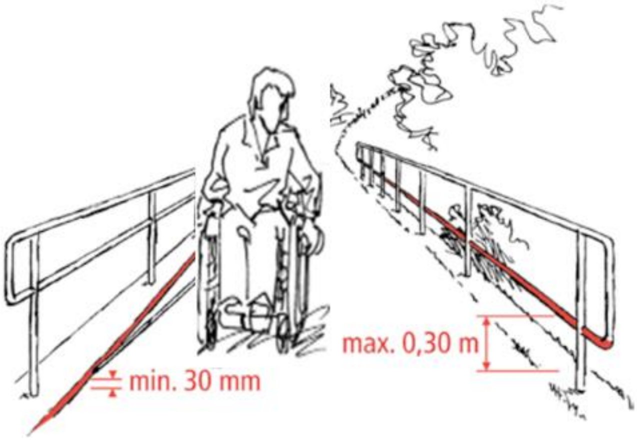


Figure 12:Safety element for a fall height above 0.4m with handrails and its mass (Schmidt and Manser, 2003).

shows. For heights between 0.40 and 0.99 meters, curb stones of 0.1 meters can be used instead of handrails as edge protectors.

Specific instructions for the ends and corners of safety elements, as well as detailed standards for marking steps, are omitted, as steps are generally avoided.

3.1.7 Surfaces

The importance of choosing and designing surfaces to ensure a safe environment in public spaces is highlighted. Surfaces must be resistant to slipping in all weather conditions and hard enough to prevent wheelchair wheels from sinking in. Grates, protrusions and covers should be placed outside of walking areas to avoid tripping hazards.

Suitable materials for pedestrian areas include bituminous layers, concrete/cement, artificial stone paving, concrete block paving and brick paving. Main pathways, which are heavily used and provide access to significant public buildings, must meet higher quality standards. They should be hard, seamless and slip-resistant, especially in wet conditions. Fully edged stones and well-filled joints minimize unevenness and enhance safety.

Certain surfaces and features have been omitted from consideration due to their unsuitability. For example, natural stone paving has been excluded because it does not meet the necessary criteria. Additionally, tactile contrast, surface changes and surface bands are not considered, as they are not directly relevant to wheelchair users.

3.1.8 Information an Orientation

Standards for barrier-free information and orientation in public spaces aim to create an easily recognizable environment for wheelchair users. Information must be prominently displayed for easy perception and specific instructions for wheelchair users, such as alternative routes for stairs, should be clearly identifiable. Essential information should be available both audibly and visually to ensure comprehensive accessibility. Auditory information must stand out from ambient noise and be directed towards the user for clear audibility.

In complex facilities like train stations, airports, exhibition grounds, parks and hospital areas, additional information and orientation systems are necessary. Visual information should have standardized colours, fonts and mounting heights for better visibility and consistency. Text information should be arranged between 1.20 m and 1.60 m above the ground, with adequate font size per meter of reading distance. The font should be not written in serif and easily legible.

Visual information includes signage for wheelchair users, information boards and orientation maps.

Brightness contrasts should be present in traffic areas to enhance orientation and timely hazard detection. It is recommended to use bright fonts on a dark background and avoid distracting reflections. Markings with warning functions should have both brightness and colour contrast to ensure visibility. These standards aim to ensure that public spaces are navigable and accessible for wheelchair users, improving their overall experience and safety in these environments.

3.1.9 Lighting

Standards for adequate lighting in pedestrian areas are provided to ensure good, uniform and glare-free illumination, which is crucial for the perception of guiding elements such as information boards and obstacles. The standards include uniform lighting at transitions from covered to open areas and avoiding glare through appropriate arrangement and shielding. Special attention is given to sufficient vertical illuminance for facial recognition, particularly in residential areas, with installation heights between 1 and 1.8 meters. Luminaires are arranged as guiding elements to provide orientation aids, as shown in Figure 13 in a park setting. Hazardous areas such as crossings, steps and stairs should be well-lit for quick visual perception.

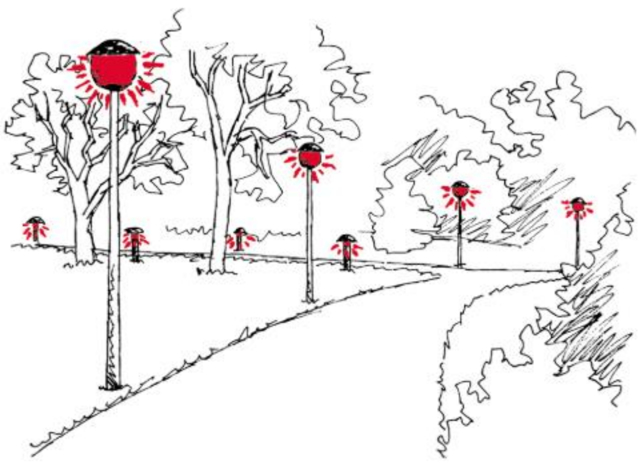


Figure 13: Example of a scenery of park lighting (Schmidt and Manser, 2003).

3.1.10 Public Transport Stops

Establishing standards for designing and equipping transit stops, as illustrated in Figure 14 in, ensures barrier-free access to public transportation for wheelchair users. Transit stops for buses and trams should be highly visible and ideally located in straight, horizontal sections. These stops must be step-free and provide sufficient maneuvering space for boarding and alighting with mobility aids.

Figure 14: Example of a bus stop with a ticket machine, a shelter and information boards (Schmidt and Manser, 2003).

Transit stop platforms should have ramps or low curbs for easy access. A minimum width of 2 meters is required to allow level boarding. The height of the platform should match the vehicle floor to ensure step-free entry. Entry points to the vehicles should be clearly marked at the platform ground to ensure an easy find for wheelchair users. For boarding with a vehicle ramp, the width should be at least 2.90 meters, or 2.30 meters in limited space. Tram platform heights should align with the vehicle floor, while bus stop heights should be 0.22 to 0.30 meters for ramp boarding and 0.16 meters for level boarding. If these standards cannot be met, alternative solutions like vehicle ramps or assistance from staff should be available.

Clear design standards for passenger information include ideally the use of bright text on dark backgrounds, avoiding red text and the transmission of visual information via automatic display changes, including acoustically. Information such as the line number and destination of arriving vehicles must be discernible. Speaker announcements should also be visually displayed using monitors or display boards.

Transit stop facilities should include weather protection, ticket machines and monitors with schedules and other information carriers unobstructed by obstacles. Schedules should be mounted in freestanding signs and behind anti-glare glass instead of showcases to improve readability, ensuring they are not obstructed by trash cans or benches.

3.1.11 Construction Site

Managing pedestrian traffic safely and barrier-free at construction sites is crucial. Key aspects include ensuring accessible detours and temporary paths for wheelchairs, walkers and other mobility aids. Detours should be at suitable locations with safe crossings, following pedestrian crossing standards. Dead ends should be avoided or clearly marked, and paths should be signalled, with requirements for separation elements, path guidance, clearance profile and furniture elements.

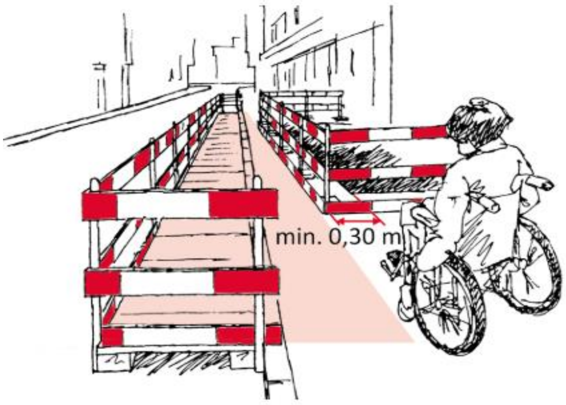


Figure 15: Securing of the construction site with a minimum distance of 0.30m between barriers and excavation (Schmidt and Manser, 2003).

Construction area standards include securing the site with a minimum distance of 0.30 meters between barriers and excavation, like Figure 15. Barriers perpendicular to the travel direction require greater safety distance and secure anchoring. Fencing must be continuous around the construction area and site, with safety ensured by personnel if temporarily removed.

All construction site facilities must comply with section furniture elements. Trenches, building materials and machinery should be within the site enclosure. Temporary pathways and detours must be step-free and accessible, with guided boundaries on both sides and adequate illumination. Separation between walkways and roadways must be maintained, with crossings equipped with low curb ramps for accessibility.

Sufficient manoeuvring space is necessary for wheelchairs, especially at directional changes. Temporary walkways should accommodate directional changes and encounters, even with mobility aids. Installation cables must be wheelchair-accessible, with ramp inclines not exceeding 10%.

3.2 Accessibility Assessment of the Study Area

The comprehensive accessibility assessment of public transportation and urban infrastructure, focusing on the needs of individuals with disabilities, was conducted in January 2024. The evaluated locations included the Lengg healthcare area, the Balgrist tram stop, and the route to Zurich Main Station via Bahnhofstrasse/HB. Utilizing a catalogue of *Accessibility Standards for Public Spaces for Wheelchair Users*, the study identified numerous barriers that impact the mobility and accessibility for wheelchair users. The analysis encompasses both quantitative data, detailing the specific barriers encountered and qualitative insights gathered from interviews with affected individuals, highlighting their experiences and challenges in navigating public spaces. This analysis provides a detailed overview of the current state of accessibility and proposes potential improvements to create a more inclusive environment for all.

3.2.1 Quantitative Analysis in the Study areas

Applying the *Accessibility Standards for Public Spaces for Wheelchair Users* developed in the first part of the study, a detailed barrier analysis was conducted throughout January 2024. Over five days, the Swisstopo app was used to document barriers within the Lengg healthcare area, the Balgrist tram stop and along the route from Balgrist to Bahnhofstrasse/HB station. The survey identified 20 barriers in the Lengg healthcare area and 38 along the route from Balgrist station to Bahnhofstrasse/HB, totalling 58 specific barriers, including high curbs, missing signage and narrow passages. Details on the nature of each barrier were documented.

During the assessment, snowfall occurred, and this is visible in some of the survey photos. The snow reduced curb visibility and narrowed walkways and this factor was considered in the general evaluation of barrier visibility and accessibility. While the snowfall had a notable impact, rain had minimal effect on the assessment.

Traffic density varied significantly throughout the day. During peak periods in the morning and evening, increased traffic affected both vehicles and pedestrians. Shelters at Balgrist stops were often overcrowded, reducing space for wheelchair users and tram access was difficult during busy times.

3.2.2 Barrier Analysis in the Lengg healthcare area

Geometric Standard Profile

In the investigation of the minimum widths, it was found that most sidewalks were generally wide enough to allow comfortable passing between individuals and wheelchair users, or between two wheelchair users. It was specifically noted that the sidewalks themselves provide sufficient space or that suitable passing places are available. A specific bottleneck was identified in front of the car park exit at the Balgrist Hospital (as seen in Figure 17). This location has a width of 1.63 m over a length of 16 meters, where there is no sufficient passing space.

Figure 16: The driveway at the end of the excessively narrow pavement in the Lengg healthcare area (Picture by Silvia Juen).

Additionally, it was observed that during rush hour, cars often parked on the sidewalk, further obstructing the pathway and presenting a safety risk (Figure 16).

There is another spot in the Lengg healthcare area where the sidewalk is 90 cm wide and narrows even further at certain points. Here, the sidewalk extends over 17.5 m. The passing space, like the previous case, is located at a driveway. Observations indicate that pedestrian traffic does not use this sidewalk. Instead, pedestrians move along the wide driveway entrance (as see in Figure 18).

Figure 17: Scene of a pavement that is too narrow in the Lengg healthcare area (Picture by Silvia Juen).

Regarding punctual narrow spots with smaller sidewalk widths of less than 1.80 m, several narrower passages were identified due to lamp posts or temporarily placed construction signs. These areas have passing places that are 4 meters long, which facilitates passing in high pedestrian traffic. Furthermore, bollards were found on the east side of the Balgrist University Hospital, where all passages are more than one meter wide, allowing easy crossing.

Figure 18: A pavement that is too narrow in the Lengg heathcare area on the east side of the Balgrist University Hospital (Picture by Silvia Juen).

All corners with a minimum radius of 1.9 meters provided enough space for easy movement. Mobility aids did not require constant manoeuvring at any location.

The cross slope on the sidewalks was generally low, around 2%. However, at street crossings, the cross slope was greater but still within the permissible norm at up to 6%. Additionally, no specific drainage issues were identified that could present an additional barrier.

Overcoming Height Differences

The investigation found that no ramps were needed to overcome height differences, indicating the path is well adapted to the standard geometric profile. Furthermore, no steps were identified on the path, offering the advantage that no detour is required, and no special information is needed to navigate steps. Similarly, there were no elevators, stairlifts or lifting platforms present.

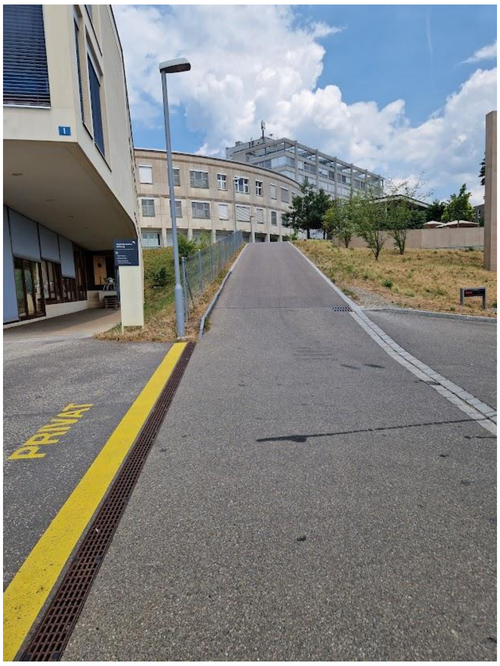


Figure 19: A standardized slope at the Mathilde Escher Heim, but without safety railings (Picture by Silvia Juen).

The only significant incline in this study area was identified near the Mathilde Escher Foundation, where one stretch has an incline of up to 10%. This incline, due to the topographical conditions, could not be implemented differently and thus is Norm compliant applicable under certain spatial and structural conditions (seen in Figure 19**Fehler! Verweisquelle konnte nicht gefunden werden.**). This will be discussed in more detail in a later section under safety elements. Apart from this specific location, all other slopes along the path are within the standard range of 6%.

Path layout, Demarcation and Structure of the traffic path

In the study area, no shared zones for pedestrians and vehicles were found, enhancing pedestrian safety. The separation between pedestrian areas and road traffic was effectively ensured by vertical curbs of the sidewalk. These dividing elements towards the streets are designed such that wheelchair users can automatically recognize that crossing is not possible due to the curbs. All curbs were implemented with vertical edges and, particularly, the transitions at the sidewalks were made with depressions and vertical edges, with a smaller height difference of 4 cm.

There are 8 curbs at crossings that are non-compliant to the standards, as we see in Figure 20. Except at crossings where no flat crossing is intended and traffic-oriented streets should prevent crossing, the vertical curbs are more than 0.06m high, which is compliant to the standards. All path sections are intended exclusively for pedestrians, confirming the absence of vehicles or bicycles on these paths during the data collection. Nevertheless, there are two driveways for parking lots where vehicles must cross the sidewalk.

No barriers were necessary in the study area and there was also no need for specific cross slope ramps. Guidance elements that could provide additional orientation for pedestrians were not necessary on the examined path sections.

Figure 20: Example picture of non-standardized curb edge (Picture by Silvia Juen).

Pedestrian Crossings

On the examined path, all curbs at crossings were lowered to a hight of 0.04 m, but there was a lack of low curbs with sloped edges. Detectability was consistently present and there were no visually obstructive elements. The existing dividing elements at crossings, i.e., the low curbs with vertical edges, were surmountable by wheelchair. They had level surfaces at the curbs and the water crossings were also wide enough. The final measurements never deviated more than 0.05 m from the vertical target dimensions. There were no single protection islands on this route. Pedestrian stripes in this busy area were laid out perpendicular to the roadway, complying with the right-of-way regulations with cars. One traffic light facilitated crossing the street and was compliant to the standards in terms of green times. The control element and access to the request devices were also compliant to the standards. There were no roundabouts in this area and flat crossing was not possible on the paths. However, free access to the sidewalk at crossings was always guaranteed.

Furnishing Elements

No installations, technical facilities or furnishing elements were found on the examined path that hindered the use of the walkway. The furnishing elements were always positioned outside the walking area, or the walking area was wide enough to integrate the elements without restricting the free walking area. There were two electricity boxes positioned next to the path. However, they did not pose an obstruction, as there was enough space around them to pass easily. On a section of the path, larger stones were placed, which did not directly restrict the walking area. Additional furnishing elements, such as signage, were present but did not directly affect the walking area. There were no business displays, advertising boards, chairs or tables that could have restricted the walking area. Other furnishings such as benches were positioned in a way that they did not restrict the walking area and did not pose a risk of injury from sharp edges, or protruding parts. Randomly placed bicycles or motorcycles could potentially obstruct the sidewalk at one location if not parked correctly, although this was not observed during the visits (as seen in Figure 21). At another location, vehicle parking did not restrict the walking area, providing sufficient space for manoeuvring.

Figure 21: Possible obstruction of the footpath by bicycles or motorbikes (Picture by Silvia Juen).

Safety elements

Along the examined path, a fall hazard was identified that requires improving securing. Near the steep slope at the Mathilde Escher House, a firmly anchored fence, a railing, is missing on one side of the meadow (as not seen in Figure 19). On the side of the building, a fence of at least 1.5 m height with a 0.03 m high curb ensures safety. Otherwise, there are no major falling hazards on the path. The existing chicanes on both sides of the park entrance are not designed as conventional chicanes, but as simple barriers to prevent cars from driving into the park. Next to it is a 1.3-meter-wide passage that complies with bollard rules and thus is compliant standards.

Surface

The walking surfaces along the path were found to be consistently suitable, featuring even, hard and seamless materials that facilitate easy and smooth movement. Slip resistance is maintained even in wet conditions. There are no areas with paving; all sidewalks in the pedestrian area are made of bituminous cover layers, ensuring safe and accessible surfaces.

Information and Orientation

Deficiencies were noted in providing specific information for wheelchair users on the path studied. While signs indicating entrances to various hospitals were present, they were not specifically marked for wheelchair users. Four out of five information boards were found to be inadequately designed. Although all information boards were clearly visible, none of them contained specific information for wheelchair users. The information boards showed the logos of the Balgrist and the Mathilde Escher Foundation, but they were incomplete. The information on the information boards had a very small font, with black lettering on a white background, which was dazzling in strong sunlight. The boards also had no lighting, which made them difficult to read in the darker seasons. However, no information was obscured by advertising or other contrasting, marker-like design elements that could lead to misinterpretation.

Figure 22: Information sign for the distances to the main entrances of the hospitals in the Lengg health area (Picture by Silvia Juen).

The one information panel, visible from the Balgrist tram stop, was insufficient. Although it had contrasting colours and readable text (like Figure 22 shows), it lacked acoustic options and signs for wheelchair users. The black text on a light background could also cause glare in sunlight. The information panel for the Mathilde Escher Foundation was contrast-rich and glare-free, while the panels from Balgrist were harder to recognize under strong sunlight due to the colour and font design. The text information was generally accessible, but in some cases, it was placed too high and the font size on some Balgrist signs was small and difficult to read. However, the general signs to the entrances were legible (like Figure 23 shows).

Figure 23: Incomplete information sign of Balgrist Hospital, pointing (Picture by Silvia Juen).

The design of the traffic space was good in terms of brightness contrast. There was no advertising or similar marking-like design elements that could lead to misinterpretations. No warning functions or special markings were required. An overview map of the site was not available.

Lighting

Good, uniform and glare-free lighting was found along the pedestrian path, extending over the entire pedestrian area. Individual information panels along the way were additionally illuminated to enhance perception and guide pedestrians. In general, the vertical lighting in pedestrian and lounging areas were considered adequate and no areas with uneven lighting were found.

The glare-free lighting and careful arrangement and shielding of the lights help prevent disturbing light emission upwards. In the park area, higher-mounted lanterns provide additional illumination, serving as a supplement or replacement to the usual lanterns. These lights also function as guiding elements and are strategically positioned throughout the park to ensure optimal lighting.

Along the path, the lighting is both good and glare-free, enhancing safety and comfort for all users. Crossings and potential hazard areas are also well lit, contributing to the safety of these areas for pedestrians. Although there were no specifically dangerous locations requiring specific lighting, the overall lighting design is well-conceived to create a safe environment.

Public Transport Stop

In this study area, the public transport was not taken into account, as the focus in the second study area will be on the Balgrist and Bahnhofstrasse stops to examine the route to the Zurich main train station. Consequently, the important stops in this area were not specifically analyzed.

Construction Site

During the survey phase, there was a construction site for the new Children's Hospital Zurich. However, the specific path under consideration remained unaffected during data collection. Nearby paths were easily navigable, with the only notable hindrance being a large construction sign that temporarily constricted the walkway. Despite these temporary obstacles, the path remained largely unobstructed and accessible for use.

There were no detours or dead ends in the examined area. The construction sign complied with the regulations regarding path guidance and furnishing elements and there were no confusions in the path guidance due to the construction layout.

Additional safety measures seemed unnecessary on the explored path. A fence separated the construction site from the sidewalk, which was sufficient to ensure the safety of pedestrians without needing contrasting barriers. The construction setup was designed according to furnishing norms and did not impair the public use of the path.

No temporary path guidance, detours or temporary walking and driving lanes were necessary. Likewise, no changes in direction were required to bypass the construction site. The width of the sidewalk met the standard requirements and there were no cables or other installation obstacles on the path.

Summary of the identified barriers of the Lengg healthcare area

The table 2 summarises the barriers found in the Lengg healthcare area: The study path around Balgrist University Hospital (seen as well in Figure 30 or in the appendix A3).

Table 2: Summary of identified barriers of the Lengg healthcare area

Barriers	**Quantity**	**Location on the Map (seen in Figure 30)**	**Severity according to the Matrix**	**Figure Reference**
Narrow walkway section in front of parking exit (width: 163 cm, length: 16 m)	1	Longer barrier between points A and B	Red	Figure 17
Too narrow sidewalk (width 90 cm, length: 17m)	1	Longer barrier next to point D	Red	Figure 18
Insufficient safety dis- tances at driveway	2	Barrier 1 next to point B and Barrier 2 next to point D	Yellow	Figure 16 and Figure 18
Slope of almost 10 %	1	Longer barrier next to point C	Yellow	Figure 19
Lack of low curbs at crossings (vertical and 4 cm and a hight of 4cm)	8	Distributed throughout the study area	Red	Example in Figure 20
Possible incorrectly parked vehicle	1	Longer barrier next to the Wittelikerstrasse	Yellow	Figure 21
Missing railing	1	Longer barrier next to point C	Orange	Figure 19
Missing information for wheelchair users or in complete boards	4	Distributed throughout the study area	Orange	Figure 22 and 23
No overview map	1	Next to the tram station Balgrist	Orange	no Example

3.2.3 Barrier Analysis for the Pathway from Balgrist to Zurich Main Station via Bahnhofstrasse/HB Tram Stops

Geometric Standard Profile

The sidewalks are designed everywhere to ensure that encounters between people with mobility aids are possible. Moreover, the walking surfaces are more than sufficiently wide, at least 1.80 meters, with no narrow spots and no need for permanent or temporary turning manoeuvres that would require manoeuvring spaces. The cross slopes also comply with the standard and are about 2%, although local variations may exist, whether on the sidewalks or at local curb ramps. There is no drainage on the walking surface.

Overcoming Hight Differences

On the examination path, there were steps to the entrance of the Main station building of Zurich, but a ramp was conveniently located next to it, complying with the norms of the geometric standard profile. Therefore, falling from the ramp is not possible. The incline was less than 6% did not require an intermediate landing due to directional changes. Falling from the ramp was not possible. There were no other major height differences that needed to be overcome. An escalator was present without signaling, but it was clear that the alternative route to the Main Station required crossing the street. Additionally, there were no elevators, stairlifts or lifting platforms present (seen in Figure 24).

Figure 24: Scene from the way to the main building Zurich Hauptbahnhof without information sign for wheelchair users and difficult crossing of the road and tram tracks (Picture by Silvia Juen).

Path Layout, Demarcation and Structuring of Traffic Paths

The structuring of pedestrian areas and vehicular traffic is ensured using dividing elements and vertical curbs, which are continuously recognizable and interpretable due to their uniform design. Punctual crossings are also provided with vertical curbs of 0.04m height, which should have been ensured with a lower curb, as seen in Figure 25. Thus, 26 non-standard curbs were identified at crossings in the examination area around the tram stops. Of these, 16 were found at the Balgrist stop, 4 around the Bahnhofstrasse/HB stop, and 6 along the path from the Bahnhofstrasse/HB stop to the main building of Zurich Main Station.

Guidance elements were not used or necessary on the route from Bahnhofstrasse/HB stop to the Main station of Zurich, as the tram roadway was already separated from the pedestrian area by vertical curbs with dividing elements and the sidewalk with furnishings at Bahnhofstrasse by the shops did not restrict the walkway.

Figure 25: Incorrect curbs and difficulty of tram tracks (Picture by Silvia Juen).

Pedestrian crossing

Although all curbs at crossings on the examined path were lowered, they lacked sloped edges, which does not meet the standards. The existing dividing elements at crossings have low curbs with vertical edges, but they should have sloped edges as required at all transitions. As previously mentioned in the path layouts, there are some additional curbs of 2 protection islands, with 16 non-standard curbs found at the Balgrist stop and 10 from the path to Zurich Main Station from the Bahnhofstrasse/HB stop. An Example of the protection Islands and the curbs can be seen in Figure 25.

The detectability of crossings was always clearly visible through the sidewalk depressions and Norm compliant with the geometric standard profile. There were no visually obstructing elements at crossings. Additionally, the curb surfaces were even, had a standard width of 0.15m and had a maximum cross slope of 3%. The final dimensions of the curbs and the pavement structure, along with the cross slope, met the standard specifications.

The protection islands, which were identified, were part of an extended platform for a tram stop the width was measured and found to be consistently over 2.6 meters at all points of the platform extension, providing ample space for pedestrians. The demarcations to the island area and the roadway were largely in order, although, as already mentioned, the curb was not low and had a vertical edge of 0.03 meters.

Traffic lights were installed at the crossing from Bahnhofstrasse to Zurich Main Station to facilitate safe street crossing. The detectability of these crossings was consistently clear, with pedestrian crossings well-marked and cross slopes meeting the standard of not exceeding 6%. There were no obstructions or visibility-reducing elements at these crossings. The traffic lights at Bahnhofstrasse were adequately timed, often providing green signals for longer durations than required by the standard. Additionally, instead of request devices, sensors detected pedestrians and activated the green signal after a short interval. Extra detection devices were installed on the islands and extended platforms at Bahnhofstrasse. On the studied path at Balgrist, there were no traffic lights, roundabouts or flat crossings planned. The Access to the sidewalks on both sides of the streets was consistently ensured.

Furnishing Elements

The use of the surface was not hindered by the installation of technical facilities and equipment elements. Moreover, the furnishing elements were generally positioned outside the walking area, thus keeping the pathway clear (as seen in Figure 26). The straight walking area was at least 1.80 meter wide, often wider. In addition, the furnishing elements had no sharp edges and no protruding parts. On the sidewalk, on the path from the Bahnhofstrasse/HB stop to the Main station of Zurich, there was no random placement of bicycles on the sidewalk.

Figure 26: Furniture on the Bahnhhofstrasse (Picture by Silvia Juen).

Safety Elements

No areas were identified that required additional safety elements.

Surfaces

Regarding the surfaces, continuously suitable walking areas were identified. All sidewalks consist of suitable coverings in the pedestrian area made of bituminous layers. Slip resistance is also ensured in wet conditions, with black ice being an exception to this assessment. The surfaces are even, hard, seamless and joint-free, which enables easy and vibration-free mobility. There are no large areas with paving and where joints occurred, they were processed with full-edged stones, improving the quality of the walking surface.

Information und Orientation

All existing information and orientation aids are clearly visible. However, at the Balgrist stop, one information point was marked as insufficient. There was no detailed information panel at the stop. Acoustic options for information transmission were absent and a larger digital board with departure times was also not available. Additionally, general information about the area was limited to directional signs without detailed maps of the Lengg healthcare area.

On the route from Bahnhofstrasse/HB to Zurich Main Station, there are no indications of an alternative route for wheelchair users, leading directly to an escalator that is inaccessible to them (Figure 27). There are no alternative routes for wheelchair users at Zurich Main Station and they are not clearly signposted. There should also be signposting on how to reach the Main Station building. When entering the Main Station building, there is also a lack of direct orientation aids for the building and the wheelchair routes. Furthermore, there are no additional information and orientation systems in complex facilities like the main train station when entering the Main station. Here, acoustic and visual information is also not always available, mostly only visual, although the possibility would exist at Bahnhofstrasse/HB through installed speakers. Additionally, a warning sign should be placed at the transition from the tram station to the ramp at the main building of Zurich Main Station, as taxis frequently drive over this area. However, no such sign is currently present.

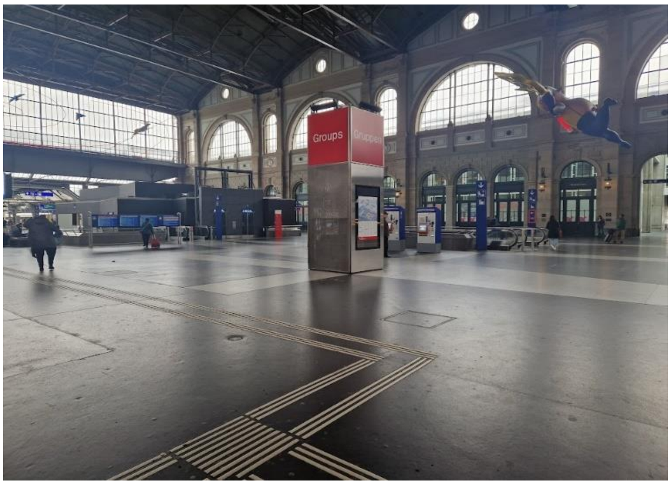


Figure 27: View into the entrance hall of Zurich Main Station without directly visible information signs (Picture by Silvia Juen).

Lighting

Along the examined pedestrian path, good, uniform and glare-free lighting was observed, extending throughout the entire pedestrian area. In general, the vertical lighting in pedestrian and lounging areas is considered sufficient and no areas with uneven lighting were identified. The lighting at the Bahnhofstrasse/HB stop and along the path to Zurich Main Station is well-designed and glare-free, significantly enhancing safety and comfort for all users. Crossings and potential hazard areas, such as at traffic lights, are also well illuminated, contributing to the safety of these areas for pedestrians. Although there were no specifically dangerous locations requiring particular lighting, the lighting is overall well designed to create a safe environment.

Public Transportation Stop

At the Balgrist stop, both the tram and bus stops were considered. At the Balgrist stop, the use of public transport is generally possible for disabled persons, but in some cases, it may be necessary to seek assistance from staff. The exact boarding points on the platform for wheelchair users into the trams are not clearly defined. Orientation and access to important passenger information are ensured by a timetable, however, digital and up-to-date information as well as auditory signals are missing (Figure 28). The tram stops at Balgrist are arranged in a straight line, enhancing visibility and the platforms are wheelchair accessible. However, they lack low curbs with sloped edges. Weather protection is available, but the available space is often insufficient for wheelchair users during rain.

Figure 28: View of the Balgrist tram stop Without digital information sign and acoustic signalling option and entry marking for wheelchair users (Picture by Silvia Juen).

Figure 29: Tram Stop Bahnhofstrasse/HB without entry markings for wheelchair users.

At Bahnhofstrasse, the assessment focused solely on the Bahnhofstrasse/HB tram stop (seen in Figure 29). Public transportation at this stop should be accessible without requiring special assistance. Locatability is also ensured here, but the exact boarding points are not always clear or marked. Passenger information is available, including on a digital display board and it is possible to use audio information, although this was not audible during the period under review. The stop edge is designed for most vehicles and the vehicle floor is level, facilitating boarding. The tram stops are arranged in a straight line allowing to minimize of the gap width. The platforms are easily accessible, and the height is level with the vehicle floor. Good passenger information is available including digital and auditory options. However, there is no weather protection but monitors and ticket machines are present. The timetables are clearly visible and not obstructed by structural obstacles.

Construction Sites

This study area did not have any construction sites.

Summary of the identified barriers of the Pathway from Balgrist to Zurich Main Station via Bahnhofstrasse/HB Tram Stops

In table 3 we present a summary of the barriers found on the tram stops Balgrist and Bahnhofstrasse/HB as well as the way to the main building of Zurich Main Station. The examination path and barriers are illustrated on the map seen in Figure 31 or in the appendix A4.

Table 3: Summary of the identified barriers of the study area of the tram stations Balgrist and Bahnhofstrasse and the pathway to the Zurich Main Station

Barriers	Quantity	Location on the Maps (seen in Figure 31)	Severity	Figure Reference
Non-standard curbs	32	Distributed throughout the study area	Red	Example in Figure 20 and 25
No visible information point at the escalator	1	Bahnhofstrasse next to point C	Orange	Figure 24
Lack of acoustic information	2	Balgrist Tram Station	Orange	Figure 29
Lack of digital Information at the Station	2	Balgrist Tram Station	Orange	Figure 29
Lack of warning sign for the taxi crossing	1	Zurich Main Station	Yellow	Figure 25
No visible Information for wheelchair users	3	next to point C and at the Zurich Main Station	Orange	Figure 24 and 27
Insufficient weather protection for wheelchair users	2	Bahnhofstrasse/HB Tram Station	Orange	Figure 26 and 28
Lack of marking of the boarding points	4	Tram Station Balgrist and Bahnhofstrasse/HB	Orange	Figure 26, 28 and 29

3.2.4 Qualitative Interview

Qualitative interviews were conducted as part of this research initiative with three individuals associated with the Mathilde Escher Foundation, all of whom are wheelchair users. The qualitative analysis focused on identifying recurring patterns and relevant themes. These interviews provided valuable first-hand insights into the participants' experiences with public space barriers.

The analysis is organized thematically, addressing various topics guided by the interview structure and the participants statements were sorted into six main topics. Some topics were influenced by the interview guide. The results offer insights into the challenges and experiences of dealing with mobility restrictions in daily life, particularly concerning public transportation and the physical and social environment. The individual quotations are referenced by line number to the transcript. The interview quotes were translated from German and rewritten for clarity, ensuring that the original meaning was accurately conveyed.

General Independence in Mobility

Despite physical limitations, participants express a strong desire for independence. One interviewee, discussing his Duchenne muscular dystrophy and constant reliance on a wheelchair, emphasized his determination to maintain autonomy. Another participant, who has brittle bone disease, highlighted the importance of attempting tasks alone before seeking assistance:

"I cannot walk because I have brittle bone disease. I try to do most things alone first, to see if it works, before I rely on help or ask for assistance."(Line 195-199)

The choice of wheelchair type greatly impacts independence, especially in travel plans. One interviewee uses a manual wheelchair for vacations where electric ones aren't feasible, stressing safety concerns since a malfunction could leave him immobile. Another participant keeps a backup wheelchair for emergencies, highlighting reliance on others when the electric wheelchair needs repair:

"I also have a manual wheelchair that I now only use for special situations. For example, if my electric wheelchair gets damaged, I will have to switch to the manual one so that the electric wheelchair can be repaired. In such situations, I am dependent on other people!" (Line 260-262)

The discussions highlighted how electric wheelchairs enhance independence, though participants still acknowledge the need for assistance to ensure safety and navigate obstacles. Travel arrangements often include using public transport with family or other accompanying persons. Despite these arrangements, some participants prefer to be alone during their leisure or weekends, emphasizing their desire for autonomy. One participant noted:

"No, I am more independent in my free time or on weekends and yes, I am alone, without assistance." (Line 266-267)

It became clear that while wheelchair users often rely on support, they continually strive to balance this with their pursuit of independence.

General Mobility and use of Public Transport

The challenges of using public transportation by people with mobility impairments

The choice means of transport significantly impacts the level of independence achievable, with trams and trains typically offering superior accessibility compared to buses. This preference for more accessible options is exemplified by one participant who explains:

"For example, with the bus, you have to wait until the driver unfolds the ramp. With the tram, you just need to be where the people are; they press a button, and a board lowers at the door, allowing you to drive in." (Line 394-397)

Using public transportation often requires significant planning, particularly for special access aids. For instance, wheelchair users might need to register an hour in advance to receive assistance for boarding high-speed trains. Even with prior arrangements, support is not always guaranteed, and daily life requires constant monitoring of train schedules for accessibility. This sentiment is encapsulated by one participant:

"Traveling independently means always checking which train is currently running! I usually take the one where I can drive in myself." (Line 311-312)

One respondent highlights a strong dependence on taxis, especially in adverse weather that hinders mobility with other means of public transport forms. While convenient, this reliance is limiting and financially burdensome. Another respondent points out that taxis are often chosen due to the impracticality of carrying essential care materials on trains:

"Why you sometimes take a taxi is because you have so much luggage for a weekend, like care materials that you need, you cannot just transport by train, so you need a taxi." (Line 363-365)

Personal preferences also influence transportation choices. Despite limited luggage space on trains, one respondent prefers train travel over being driven, indicating satisfaction with the overall experience despite its limitations.

Positive Aspects and improvements in the public transport system

Despite obstacles, respondents appreciate the independence offered by public transport, especially trams and trains. They note improvements in accessibility, like newly designed stops, which enhance their travel experience. One respondent mentions the difficulties of driving in Zurich due to frequent traffic jams:

"It is really stupid to drive to Zurich by car! because there is usually traffic jam on the highways or so." (Line 373-374)

This answer underlines the preference for public transport over personal vehicles, highlighting the need for continued enhancements in public transport infrastructure.

Furthermore, another respondent sheds light on the impact of these advancements on daily mobility, emphasizing the convenience of using public transport compared to traveling by car. They highlight the ease and efficiency of accessing tram and train services, contrasting with the cumbersome process of securing wheelchairs in cars. Additionally, they stress the importance of social inclusion and the benefits of improvements in public transport. This perspective is echoed in one respondent's statement:

"If I take a taxi home and then go out again, I honestly use public transport almost every day. I find it good because it prevents me from feeling excluded from the other people who also use public transport every day." (Line 523-526)

Challenges and Barriere in Infrastructure

Navigating public transportation can be particularly challenging for individuals with mobility impairments due to the reliance on special access aids like ramps. One participant illustrates this difficulty:

"Yes, I find that with the bus you always have to wait for the driver because he is the only one who has the key for the ramp, which is secured with a key. I actually prefer trams because you don't need a key to unfold the ramp." (English)

This reliance on others complicates independent use of public transportation. Further challenges include finding the correct entrances and exits:

"Yes, you know it is wheelchair accessible if there is a white line at the stops, and I know exactly that I can get out there. However, finding where the wheelchair doors stop can be tricky; you just have to be lucky. Over time, you get a sense of where it is more or less, but at the beginning, it is really difficult to find out exactly where the tram stops. You just have to quickly drive to the door and somehow get through." (Line 858-863)

These uncertainties in public transportation emphasize the daily challenges for people with mobility impairments. Transportation capacity and accessibility are often inadequate, especially when multiple wheelchair users travel together. Trams generally provide better accessibility, while buses often cause delays due to the need for the driver to set up the ramp. Safety regulations further limit the number of wheelchair users allowed, reducing flexibility and access. One respondent shared their frustration:

"The bus driver doesn't want anything to happen that could risk someone getting injured if they are not in the designated wheelchair spot. But when you are traveling as a group, you have no choice but to either take everyone or take no one. I mean, yes, it is sometimes difficult." (Line 428-431)

Even with clearly marked stops, identifying the exact location of wheelchair doors remains challenging, especially for newcomers who often rely on luck. Despite developing a sense for it over time, the process remains daunting. Uneven urban infrastructures, such as cobblestones, further complicate navigation and smoothing these surfaces could significantly ease mobility. Raised sidewalk edges also cause discomfort and potential back pain despite being lowered.

The type and size of wheels on a wheelchair can present problems, with larger wheels sometimes not fitting properly between the tram and platform. This issue can lead to situations where users get stuck and require assistance to get free.

Despite efforts to address smaller barriers, many places remain only partially accessible. Not every shop is wheelchair accessible and registering to use lifting platforms on trains can be cumbersome. These restrictions impact mobility and quality of life, making spontaneous and independent activities difficult. Shops and public places often have high thresholds or steps and narrow aisles with high shelves, further complicating accessibility. These limitations significantly affect quality of life, as one respondent explains:

"It does have an impact on quality of life. For example, you can get to the most important buildings, but in other places, it's not always possible to get in. It significantly restricts

quality of life when you cannot enter the shop you want and have to send someone else instead." (Line 592-595)

Social Interaction and Perspectives

Social interaction and the perception of people with mobility impairments in public transportation and urban infrastructures significantly influence their daily experiences. A common issue is the lack of understanding and consideration from the general public. One respondent observes that many people use wheelchair-accessible doors on trams and buses, even when they don't need them, making access difficult for wheelchair users. Another frequent issue concerns the use of elevators, as highlighted by one respondent:

"People could be more aware. Quite often, when I wanted to take the elevator, I had to wait until the fourth one because pedestrians who could walk were using it the whole time." (Line 649-651)

Blocked elevator access often limits wheelchair users' mobility and highlights the need for greater societal awareness. The behaviour of others greatly influences their experience and uncertainty about how people will respond to requests for accommodation increases the stress level.

Specific Challenges and Solutions in the Study Area

In the Lengg healthcare area and the way to the Bahnhofstrasse and Zurich Main Station, respondents identified specific challenges and suggested improvements crucial for wheelchair users. A frequently mentioned improvement for the Balgrist stop platform, which is quite long, involves expanding the roof to provide better shelter during bad weather. Another suggestion focuses on the traffic layout at Balgrist, emphasizing the need for more convenient pedestrian access:

" At Balgrist, it would be practical to have a pedestrian crossing or something similar in the middle of the stop. This would allow you to cross directly without having to go all the way to the end of the stop." (Line 936-938)

Improving access and shortening routes for wheelchair users at the Balgrist stop would make navigation easier. At Bahnhofstrasse, respondents suggested adding an elevator to enhance street-crossing accessibility. One participant noted:

" At Bahnhofstrasse, there needs to be an elevator or similar access on this side of the station. This would allow you to get under the entire tram line and the street without always having to be careful. " (Line 946-948)

The addition of an elevator would significantly improve safety and accessibility at this busy location.

Respondents also mentioned the length of the stops, designed to accommodate the S-Bahn, indicating a need for infrastructure adjustments to better meet users' needs. As a result, wheelchair users often select specific routes to avoid obstacles or take the shortest path. These individual adjustments emphasize the necessity of revising the infrastructure to create more direct routes.

Approaches and Technological Aids

To improve accessibility for wheelchair users, various technological aids and structural adjustments are necessary. High curbs support the blind but pose an obstacle for wheelchair users:

"Create a groove in the road in front of the sidewalk for people who are blind and use a white cane. This way, they can place the cane in the groove and feel where the sidewalk rises. Ensure that the groove is not too wide, as it is less noticeable with a wheelchair than a raised surface would be." (Line 493-496)

Technological improvements to traffic light systems could also help shorten waiting times for wheelchair users. As one respondent noted:

"When you are at a traffic light, it should recognize that you are there as a wheelchair user and either turn green immediately or start counting down." (Line 952-954)

Modern technologies in public transport could provide additional support. New trams equipped with cameras can detect wheelchair users and signal the driver to open the doors:

"The new trams should have cameras outside to detect when someone with a wheelchair is waiting. This way, the driver can see when help is needed and open the door accordingly. Increasing the number of these new trams would ensure that drivers can assist passengers with wheelchairs more effectively." (Line 962-965)

Improving the position and operation of tram door buttons could facilitate easier access. Mobile technologies also play a crucial role in enhancing accessibility, with phone holders allowing users to quickly access important information. For example, having the SBB app readily available on a phone attached to a strap can provide crucial information during travel.

Additionally, increasing the size of bus stop shelters could offer better protection from bad weather, making waiting more comfortable. One respondent highlights the inconvenience of inadequate shelter:

" Yes, it's quite unpleasant. It's a shame it has happened to me a few times; you just get rained on because there's no proper shelter! You can stand under the eaves of shops a bit, but there is no adequate cover. It would be practical if the sidewalk or at least the stop had a rain shelter." (Line 894-897)

These suggestions show that there are substantial ways of improving urban infrastructure and public transport for wheelchair users. Technological aids and targeted structural adjustments can significantly enhance their quality of life.

3.2.5 Data Processing and Mapping

The analysis of accessibility in the Lengg healthcare area revealed a range of barriers affecting wheelchair users. These barriers were systematically categorized to provide a comprehensive overview of the accessibility challenges in the study areas. The maps, seen in Figure 30 and 31 or in the appendix A3 and A4, illustrate the distribution of barriers in the Lengg healthcare area, the tram stops Balgrist and Bahnhofstrasse/HB, and along the route to Zurich Main Station. In total, 58 barriers were identified, with 20 barriers found in the Lengg healthcare area and 38 barriers along the route from the Balgrist tram stop, through the Bahnhofstrasse/HB tram stop, to Zurich Main Station. In the Lengg healthcare area, while barriers are distributed across the region, higher concentrations are found at specific locations such as the Mathilde Escher Foundation, the eastern entrance to the Balgrist University Hospital, and around the Balgrist tram stop. At the Balgrist and Bahnhofstrasse/HB tram stops, significant barriers are noted, marked in red for incorrect edging and in yellow for the absence of display boards or shelters. Along the route from the Bahnhofstrasse/HB stop to Zurich Main Station, there is an increase in incorrect curbs at road crossings and missing information signs. These findings highlight critical hotspots at the tram stops and road crossings near Zurich Main Station.

Barriers were classified into four groups based on a 2x2 matrix: "Non-Compliant and Problematic," "Non-Compliant and Not Problematic," "Compliant and Problematic," and "Compliant and Not Problematic." Barriers classified as "Non-Compliant and Problematic" included high curbs without ramps and a missing safety railing in the Lengg healthcare area. "Non-compliant and Not Problematic" barriers primarily consisted of missing or incorrect information signs. Examples of "Compliant and Problematic" barriers were steep slopes near the Mathilde Escher

Heim, which, although meeting standards, posed significant challenges for users. The "Compliant and Not Problematic" category generally referred to the marked examination paths in the areas. All barriers were categorized, and the results are detailed in Table 2 and 3. Criteria for classification included barrier dimensions, compliance with accessibility standards and the perceived impact on wheelchair users.

Qualitative data from interviews with individuals from the Mathilde Escher Foundation revealed specific challenges faced by wheelchair users, including architectural barriers, limited accessibility in public transportation, and inadequate signage. These insights were crucial in categorizing barriers and enhancing the understanding of accessibility issues. The qualitative interview results were integrated into the evaluation process to ensure that the barriers were accurately assessed from the perspective of those directly affected.

The maps (seen in Figure 30 and 31) include detailed routes, highlighting critical areas and points of interest such as major intersections, public transport hubs and key facilities like the Balgrist Hospital and the Zurich Children's Hospital under construction. The resulting maps, seen in Figure 30 and 31or in the appendix A3 and A4, illustrate the distribution of barriers in the Lengg healthcare area, the tram stops Balgrist and Bahnhofstrasse/HB and along the route to Zurich Main Station. In the Lengg healthcare area, barriers are evenly distributed, with higher concentrations at specific locations such as the park entrance to the west and the Balgrist hospital car park entrance to the east. At the Balgrist and Bahnhofstrasse/HB tram stops, significant barriers are noted, marked in red for incorrect edging and in yellow for the absence of display boards or shelters. Along the route from the Bahnhofstrasse/HB stop to Zurich Main Station, there is an increase in incorrect curbs at road crossings and missing information signs. These findings highlight critical hotspots at the tram stops and road crossings near Zurich Main Station.

Each barrier's exact location is pinpointed, offering clear guidance on where improvements are needed. Colors indicate the severity and compliance of barrier points: red, orange, and yellow represent varying levels of urgency, while petrol blue denotes neutral elements. Key locations and barriers are highlighted with specific symbols and colors have been tested for suitability for individuals with color vision deficiencies to ensure the maps are accessible to a wider audience. The investigated routes and categorized barriers are clearly marked, providing a comprehensive overview of the accessibility challenges in the Lengg healthcare area and along the route to Zurich Main Station.

In the Lengg healthcare area, there are 10 red barriers. Two of these are longer, indicating the narrow sidewalks, while the red points mark the non-standard curbs. There are 5 orange barriers, one of which is elongated to indicate the missing safety railing, while the remaining orange points represent incomplete or missing information signs. There are 4 yellow barriers; two points mark the dangerous driveways, the elongated barrier near the Mathilde Escher Foundation indicates the 10% slope, and the elongated barrier east of the Balgrist University Hospital highlights potential obstacles like incorrectly parked bicycles or other vehicles. These barriers are detailed in Figure 30.

In the examination area along the route from the Balgrist tram station, through the Bahnhofstrasse/HB tram stop, to Zurich Main Station, there are similar barriers. At the Balgrist tram stop, there are 16 red barriers indicating the missing low curbs. There are 5 orange barriers; those directly on the platform indicate the missing digital display boards and boarding markings, while other marks a missing orientation sign. At the Bahnhofstrasse/HB tram stop, there are 10 red barriers indicating the missing low curbs. There are 6 orange barriers; those at the Bahnhofstrasse/HB stop indicate the missing weather protection and boarding markings, while the others at the major intersection and in the Zurich Main Station mark missing information signs. Additionally, there is 1 yellow barrier marking the lack of a warning sign at the taxi crossing. These barriers are detailed in Figure 31.

Self-made photographs were integrated into the maps to provide visual examples of barriers, ensuring consistency and facilitating recognition of the maps as related representations of accessibility in the study area. The maps highlighted specific barriers, such as a narrow sidewalk only 1.63 meters wide, an unmarked entrance to a parking lot, a steep slope with a gradient of over 6% and inadequate information panels at public transport stops. These examples, visible in the photographs, illustrates the practical challenges encountered by wheelchair users.

In addition to these highlighted barriers, the maps detail the examined paths taken during the study. These paths are clearly marked and provide a visual representation of the routes evaluated for accessibility. The background map includes a layout of the healthcare facilities, public transport lines and other relevant urban features, making it easy to understand the spatial context of each barrier.

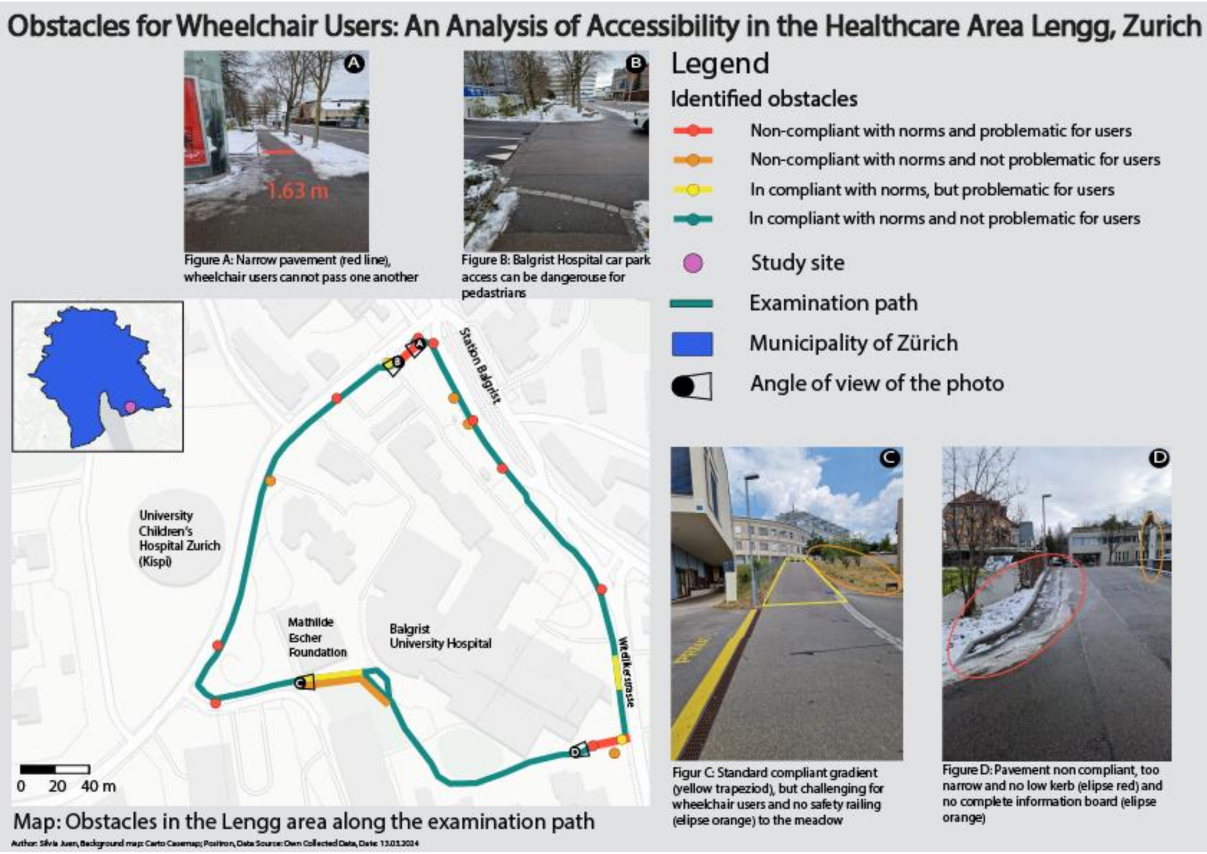


Figure 30: Map of obstacles for wheelchair users on the examination route (in petrol) in the Lengg Healthcare Area in Zurich (Created by Silvia Juen).

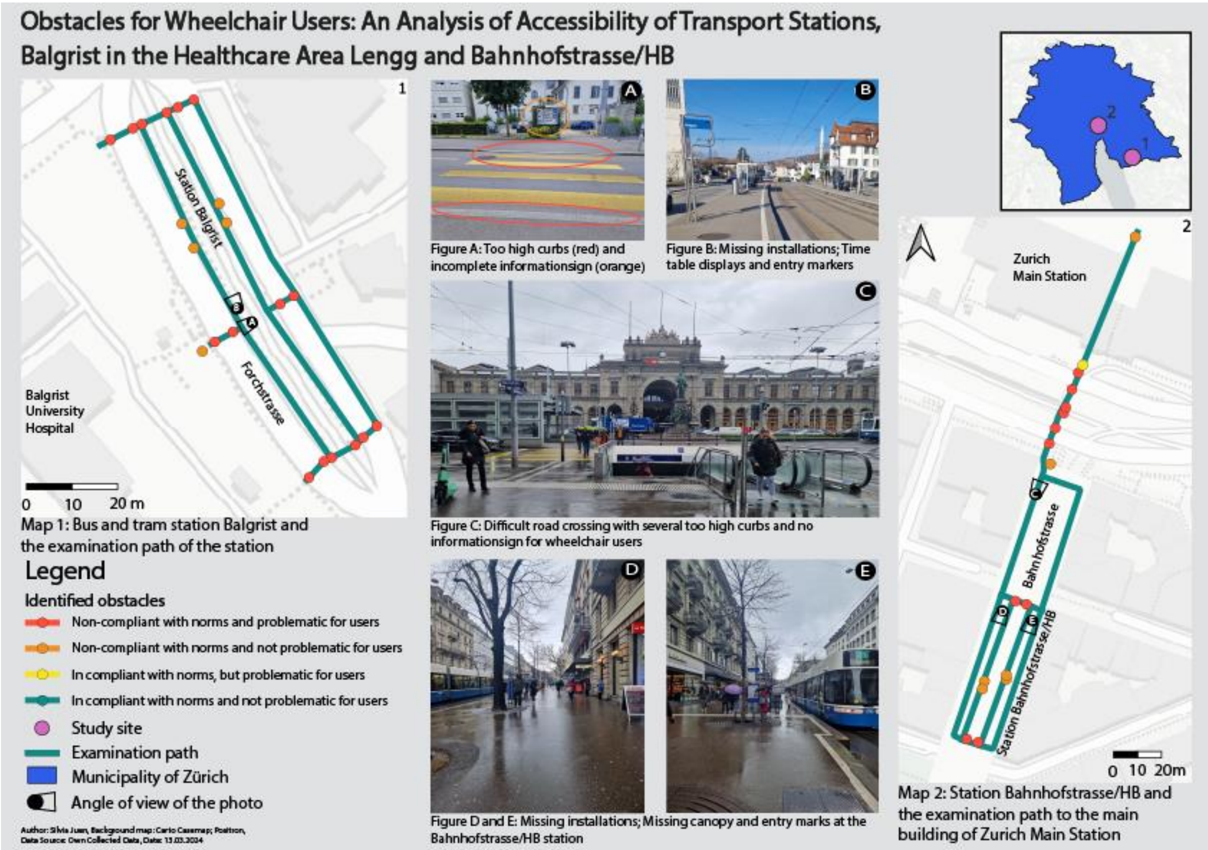


Figure 31: Map of obstacles for wheelchair users on the examination path (in petrol) from the Balgrist and Bahnhofstrasse/HB tram stations to Zurich main station (Created by Silvia Juen).

3.3 Smart City Solution Application

The investigation of accessibility in public spaces in the study areas highlights a series of challenges. Overcoming these barriers requires both traditional and innovative approaches. Conservative solutions provide immediate improvements and ensure sustainable changes. Modern solutions, following the Smart City applications approach, offer opportunities to further optimize accessibility through technology and make public spaces more accessible for everyone.

3.3.1 Identified Barriers

In the investigation of accessibility, specific barriers were identified in the Lengg healthcare area and at the tram stops Balgrist and Bahnhofstrasse/HB and from there the route to Zurich Main Station. These barriers impair the mobility, orientation and safety of wheelchair users.

In the Lengg healthcare area, common barriers, as summarized in Table 2, include narrow sidewalks, confusing driveways, steep slopes without proper safety measures, non-compliant curb edges and improperly placed or inaccessible information boards. Additionally, obstacles such as parked bicycles or motorcycles create further difficulties for wheelchair users.

In the area of the tram stops and the route to Zurich Main Station, several accessibility issues were noted, as summarized in Table 3. These include non-compliant curb edges, inadequate passenger information, unclear markings for alternative routes, insufficient weather protection and the need for assistance at some stops to board buses or trams.

Addressing these issues requires a multifaceted approach. The following chapters will explore conservative solutions and Smart City approaches to enhance accessibility and improve the quality of public spaces for wheelchair users.

3.3.2 Conventional Solutions

3.3.2.1 Solutions for the Barriers in the Lengg healthcare area

In the Lengg healthcare area, narrow sidewalks and confusing driveways present significant challenges. Sidewalks, including those with widths of 163 cm and 90 cm, should be widened to at least 180 cm to meet accessibility standards. Driveways should be clearly marked with right-of-way and stop signs for vehicles. For extremely narrow sidewalks, alternative solutions such as roadway markings could designate pedestrian areas.

A steep incline near the Mathilde Escher Foundation, with a slope of up to 10%, lacks necessary safety features such as railings. Installing railings along this stretch would provide support for wheelchair users and prevent them from veering onto adjacent grass areas. Offering alternative, less steep routes with clear signage would further enhance accessibility and safety.

Non-compliant curb edges in several locations need adjustment to facilitate smooth and safe crossings for wheelchair users. These curb edges should be lowered to meet current standards, ensuring barrier-free transitions across streets and pathways.

Randomly parked bicycles or motorcycles often block sidewalks, creating obstacles. Adding clear ground markings indicating designated parking areas for bicycles and motorcycles would help keep sidewalks clear and improve safety.

Information boards in the Lengg healthcare area are often inaccessible due to improper height and inadequate design. These boards should be installed at a height suitable for wheelchair users, with large, readable fonts and high-contrast colours. Adding lighting to these boards would ensure visibility during darker months. Additionally, the information boards should be standardized across the area, including an overview map of the entire site. This map should highlight key locations, such as the steep slope near the Mathilde Escher Foundation.

3.3.2.2 Solutions for the Pathway from Balgrist to Zurich Main Station via Bahnhofstrasse/HB Tram Stops

At the tram stops, Balgrist and Bahnhofstrasse/HB and along the route to Zurich Main Station, similar accessibility issues were identified. Non-compliant curb edges at specific crossings, inadequate passenger information and lack of clear markings for alternative routes are prevalent. These curb edges should be adjusted to meet accessibility standards, enabling easier crossings for wheelchair users.

Larger, digital information boards that are easily visible and readable should be installed at the tram stops, providing real-time updates on departures, delays and disruptions. These boards should be accessible to wheelchair users and include acoustic signals for additional support. Additionally, accessible ticket machines should be installed to ensure ease of use for all passengers. To further enhance accessibility, clear markings at tram entry points would facilitate easy access for wheelchair users, ensuring that public transportation is more inclusive and navigable for everyone.

At the Bahnhofstrasse crossing on the direct route to Zurich Main Station, an escalator poses a barrier for wheelchair users. Clear signage indicating alternative wheelchair-accessible routes is essential. Ideally, installing an elevator nearby would provide direct access to the underground area of the train station, allowing access to the platforms without crossing tram tracks and multiple streets.

Weather protection at the stops should be enhanced. At the Bahnhofstrasse/HB stop, shelters need to provide adequate space and protection from bad weather, especially during rush hours. Similarly, the shelter at the Balgrist tram stop should be extended to improve comfort and protection.

3.3.3 Smart City Applications to Improve Accessibility in the Study Area

In the Lengg healthcare area, modern navigation apps can significantly support wheelchair users by offering intelligent route guidance, highlighting accessible paths and pointing out specific challenges like steep inclines. These apps provide real-time information and user-friendly interfaces, helping wheelchair users navigate urban areas safely and efficiently.

Digital mapping can mark the locations of non-compliant curb edges and suggest alternative routes. Leveraging sources such as OpenStreetMap or governmental digital mapping resources, these maps can integrate crowdsourcing elements to identify barriers in public spaces. Digital platforms allow users to report barriers and share alternative accessible routes, providing city planners and decision-makers with insights into the daily challenges and needs of wheelchair users.

Mobile apps tailored specifically to wheelchair users can significantly enhance accessibility and mobility. These apps could offer detailed information and directions, including real-time updates and notifications about changes or unexpected obstacles. Advanced GPS systems integrated into the apps could provide real-time information on accessible routes, public transportation options and facilities, creating a unified and comprehensive information base. The government should have easier access to these tools, enabling urban planners to receive direct feedback and information from users to address accessibility issues more effectively. Additionally, organizations representing affected groups should be better integrated into the planning process, especially concerning data analysis. Such navigation apps could guide wheelchair users through stations, showing alternative routes to escalators and providing real-time updates. Beacon technology could communicate with mobile devices, offering orientation aids, directions in real-time and audible information.

Integrating information about accessible elevators into these apps would ensure users always have access to necessary facilities, significantly improving their mobility and independence. Personalized schedules could indicate which vehicles are accessible and where boarding aids, such as ramps, are available. Real-time updates and notifications could inform users of delays, changes, or disruptions, enhancing their travel experience and planning.

At the tram stops and along the route to Zurich Main Station, large digital information boards that are highly visible and easily accessible should be installed. These boards should display current schedule information and specific notices for wheelchair users, including tram accessibility and crowding levels. Digital apps should reflect real-time data from these boards and the tram situations to show current traffic conditions, allowing wheelchair users to make better-informed decisions and plan their trips accordingly. Access to public transportation can be enhanced through various measures. Automated ramps in buses and trams could automatically deploy when a wheelchair user boards or alights, reducing the need for staff assistance and increasing user independence. Sensor-based door opening systems in trams and buses could detect when a wheelchair user approaches and automatically open the doors, improving safety and comfort. An example of such an innovation is the Mobi+ system in Clermont-Ferrand, France (Zhou *et al.*, 2012). This system enhances accessibility for disabled users by utilizing digital alerts and wireless communication to provide real-time updates and improve overall travel efficiency.

Traffic Management Systems offer innovative solutions tailored to the needs of wheelchair users. Smart traffic lights, for instance, can adjust signals dynamically, providing extended green times upon request or via an app, thereby facilitating safer crossings. Complementing this, sensor-based systems intelligently detect wheelchair users, enabling adjustments to sidewalk and street crossing times in real-time. These adjustments could include extending the duration of pedestrian signals and adjusting the timing of traffic lights to allow more time for crossing busy intersections. Such measures ensure smoother mobility experiences for wheelchair users.

Comprehensive Data Analysis, powered by AI and Mobility Analytics, plays a pivotal role in understanding the nuanced mobility patterns of wheelchair users. By integrating administrative and sensor data into a central pool, it becomes possible to visualize and monitor accessibility levels effectively. This holistic approach not only informs targeted improvements but also lays the foundation for future enhancements in accessibility infrastructure.

Moreover, Innovative Wheelchair Technologies hold significant promise in revolutionizing mobility for wheelchair users. Leading examples, such as SCEWO, capable of overcoming stairs, signify a new era of independence and freedom. Encouraging the development and integration of similarly advanced mobility aids tailored to the unique needs of wheelchair users further amplifies accessibility efforts.

A key part of these efforts is creating strong systems for implementation and feedback. Through a continuous feedback loop, insights from user experiences, especially those of individuals with disabilities, drive iterative refinement of systems and solutions. This collaborative approach ensures that accessibility initiatives evolve in tandem with the diverse needs of the community, creating a more inclusive environment.

Regular staff training is also crucial to better meet the needs of wheelchair users, ensuring they receive necessary assistance for safe and comfortable travel. Trained staff can assist with boarding, exiting, and addressing specific needs, thereby improving the overall public transport experience.

4 Discussion

This study investigated three central research questions regarding accessibility in urban spaces. First, it analysed the standards for accessibility in public spaces for people with walking disabilities. To this end, a comprehensive criteria catalogue, titled *Accessibility Standards for Public Spaces for Wheelchairs Users*, was compiled. This catalogue summarizes the key standards and serves as a guide for assessing and improving accessibility in urban areas. Second, a detailed investigation was conducted to determine whether the Lengg healthcare area in Zurich and the route to Zurich Main Station via tram meet these standards. Specific barriers were identified and their impact on the mobility of wheelchair users was evaluated. Finally, the third research question addressed potential improvements and the application of the Smart City approach to optimize accessibility.

The findings of this investigation reveal that despite existing standards, numerous barriers significantly impede the mobility of wheelchair users. The study adapted and utilized a criteria catalogue, which proved to be helpful regarding the evaluation. The detailed analysis of the Lengg healthcare area and the route to Zurich Main Station revealed that this study area does not fully comply with accessibility standards. Identified barriers include narrow sidewalks, missing or inadequate signage, and insufficient crossings at intersections. These barriers were confirmed to be relevant through qualitative interviews with wheelchair users, who highlighted the daily challenges and dangers posed by these obstacles. The study furthermore found that Smart City technologies offer significant potential for improving accessibility. Technologies such as sensor-based door systems, smart traffic lights, and navigation apps that allow wheelchair users to report barriers could provide long-term solutions.

4.1 What are the norms and standards for accessibility in public spaces for people with walking disabilities?

The standards for accessibility in public spaces are crucial for integrating wheelchair users into urban environments. The *Accessibility Standards for Public Spaces for Wheelchair Users* catalogue outlines detailed measures to ensure accessibility.

The standards for accessibility in public spaces are of crucial importance for the integration of wheelchair users in urban environments. The *Accessibility Standards for Public Spaces for Wheelchair Users* catalogue sets out detailed standards to ensure that public spaces are accessible for wheelchair users. These standards cover various aspects of barrier-free mobility, orientation and safety. Key elements included the analysis of geometric standards for sidewalks, methods to overcome height differences, the design of pedestrian crossings and the strategic placement of furniture elements to ensure obstacle free movement. Additionally, safety measures such as handrails and barriers, surface design and clear visual respectively auditory information systems were examined. Considerations also extended to adequate lighting and the accessible design of transportation stops and construction sites.

Identifying the necessary standards is important for better the integration of people in wheelchairs into urban environments, particularly regarding their freedom of movement in public spaces. Enhancing current accessibility measures is essential to ensure that public spaces are truly inclusive, navigable and supportive of a better integration of individuals with mobility impairments (Bennett, Lee Kirby and MacDonald, 2009).

The design of public spaces for wheelchair users is complex and multifaceted. The specialized approach in the catalogue *Accessibility Standards for Public Spaces for Wheelchair Users* allows a precise adaptation of urban infrastructure to the needs of wheelchair users. This targeted consideration leads to detailed and practical standards that directly address specific challenges faced by wheelchair users.

Literature such as Bennett et al. (2009) and Ferreira et al. (2007) emphasizes the importance of such targeted standards, highlighting the necessity for appropriate curbs and maximum ramp inclines. These detailed standards significantly enhance accessibility and convenience for wheelchair users.

4.1.1 Practical Challenges

Despite these guidelines, there are several points of discussion regarding the standards set. One major challenge is the physical effort and control required for wheelchairs on steep slopes. Basha (2015) and Filiz and Meshur (2013) confirm that steep slopes increase physical effort and make wheelchair control more difficult. For example, wheelchair users have to exert more force to go uphill, which can be very strenuous. When going downhill, there is a risk of the wheelchair gaining to much speed, increasing the risk of falls. Nakarmi and Shrestha (2022) point out that inclines of 10% or more outdoors and 12% or more indoors are particularly critical and often represent a compromise to accommodate topographical conditions and existing structures but are not feasible for the majority of wheelchair users.

To overcome these challenges, alternative solutions should be considered in the catalogue, such as elevators or longer ramp sections with gentler inclines. In urban areas with limited space, additional ramps or elevators may be difficult to implement, requiring creative solutions. Alternative routes that are less steep could also be considered, although these often require longer distances and thus more time and energy. Darcy and Harris (2003) confirm that public transport could be a possible solution to overcoming the challenges of steep or inaccessible routes, although they are not accessible, and they involve additional costs for the individuals. Dependence on public transport can also limit the independence of wheelchair users, as they can no longer flexibly cover short distances (Visnes Øksenholt and Aarhaug, 2018).

There are also issues that the standards do not adequately address. For example, there is a lack of detailed requirements for the design of the seating area environment to further improve usability, accessibility and participation. This could include incorporating sufficient manoeuvring space or accessible tables to ensure that wheelchair users can use these areas as well as others. Additionally, these aspects are not mentioned in other international guidelines found in the literature, indicating a broader gap in addressing these specific needs.

Another significant concern is the height of platforms from tram or bus stops, which may present challenges. Ideally, these should match the level of the vehicle floor, but this is not always practical, for instance with older vehicles or uneven roads. Here, alternative solutions such as mobile ramps or staff assistance may be necessary, but these bring additional logistical challenges, costs, and can increase boarding and alighting time, affecting overall travel efficiency (Nakarmi and Shrestha, 2022).

Ensuring accessible pathways at construction sites is crucial, as construction work often creates unexpected obstacles. Clearly defined safety distances and continuous barriers on the pathways improve safety but require careful planning and additional costs. In practice, the relevance of these standards is often overlooked due to tight space conditions and high traffic volumes, which make implementation difficult. Continuous railings and temporary safety measures secured by staff are also essential to maintain safety during construction. However, the absence of these safety measures significantly increases the risk of accidents. Implementing these measures can be particularly challenging on large or rapidly changing construction sites due to the dynamic nature of the environment. The required manpower and associated costs are often seen as prohibitive. Assigning staff for safety tasks can take away resources from actual construction work, causing delays and increasing costs. Therefore, it's hard to justify hiring more people just for safety when the focus is on finishing the construction quickly.

Implementing accessibility measures can be costly and technically demanding, requiring significant investments in technology, infrastructure and regular maintenance. Without sufficient financial resources, these measures could be incompletely implemented, reducing the intended accessibility (Huang, White and Langenheim, 2022). For example, lighting systems require governments and municipalities to invest in high-quality and energy-efficient technologies to ensure sustainable and continuous lighting that meets the needs of wheelchair users.

Another important aspect is maintenance and upkeep of the implementation of the standards. Materials like concrete and cement can crack over time, creating new obstacles for wheelchair users. Regular maintenance is required to keep surfaces in optimal condition. Also, the specific requirements for surfaces can lead to higher costs, as materials and construction methods optimal for wheelchair users might be more expensive than standard options. This presents a financial burden for cities and municipalities (Basha, 2015).

4.1.2 Flexibility and Implementation of Standards

Focusing on the specific needs of wheelchair users, Bennett, Lee Kirby and MacDonald (2009) emphasize the necessity of specific standards to ensure accessibility. Implementing these standards often requires flexibility, as rigid specifications are not always feasible in practice. Consequently, the standards intentionally include vague formulations such as "if possible" or "where feasible," allowing for compromises and adjustments to local conditions. While this flexibility is practical, it also risks inconsistent application of the standards, which can reduce their effectiveness. Vague formulations may lead not implementing measures for improving accessibility not being implemented. This demonstrates that despite the targeted focus on wheelchair users, precise and clearly defined implementation of the standards are essential to achieve the intended improvements.

In densely built urban areas, the implementation of these standards can be particularly challenging. Often, the available space is limited, leading to conflicts with other urban requirements such as bicycle lanes and green spaces. Evcil (2010) confirms that such conflicts of interest frequently arise and require careful planning. Especially in older city districts, extensive structural changes might be necessary and are often associated with high costs and potential interventions in the existing city structure. Basha (2015) points and acknowledges this particularly for historical areas. Huang, White and Langenheim (2022) support this view and emphasize the need for careful consideration of these conflicts of interest.

Another important aspect is the traffic environment, as different barriers can arise depending on the situation. Traffic density varies significantly at different times of the day, influencing the mobility of both pedestrians and vehicles. During peak times, when traffic is heaviest, specific access barriers such as unsafe pedestrian crossings and driveways that cross sidewalks become more dangerous for pedestrians. These conditions increase the risk for people with mobility impairments, making it more difficult for them to navigate safely (Prescott *et al.*, 2020).

To is not need spatial constraints, climatic conditions affecting accessibility must also be considered. Extreme weather conditions such as snow, ice, or heavy rain pose particular challenges that require specific solutions. Snow can reduce the visibility of curbs and narrow sidewalks, which should be considered in the barrier assessment. Future evaluations should therefore take weather conditions more into account to achieve more realistic and practical results. For example, non-slip surfaces are necessary to ensure the safety of wheelchair users under such conditions(Bennett, Lee Kirby and MacDonald, 2009).

4.1.3 Risk and Ethical Considerations

The specialized approach for persons in wheelchairs carries the risk of neglecting the needs of other groups, such as visually or hearing-impaired individuals. Measures important for visually impaired people, like vertical curbs and tactile guidance systems, have been deliberately omitted because they can be obstructive for wheelchair users. Studies by Matthews (1995) and Ferreira, Da and Sanches (2007) show that such curbs present significant obstacles for wheelchair users and that tactile guidance systems can cause vibrations and increased rolling resistance. This underlines the difficulties that arise when trying to meet all needs simultaneously.

The decision to omit inclined curbs, handrails on steep inclines and special measures for the blind highlights the focus on wheelchair users in the catalogue *Accessibility Standards for Public Spaces for Wheelchair Users*. Nakarmi and Shrestha (2022) confirm that such adjustments are particularly challenging for wheelchair users and can cause space issues. This targeted approach aims to provide detailed and practical solutions that significantly enhance mobility and independence for wheelchair users. However, this focus raises ethical considerations about inclusivity. While it brings substantial improvements for wheelchair users, it overlooks the needs of other disabled groups. Esfandfard et al. (2018) emphasize the importance of universal designs, which aims to develop solutions suitable for all disabled groups without additional adjustments, creating an inclusive environment where no one is disadvantaged.

The challenge lies in balancing specific and general needs. The catalogue's focused approach delivers immediate benefits to wheelchair users but may compromise broader inclusivity. Integrating universal design principles could ensure that the specific needs of wheelchair users are met while also addressing the requirements of other disabled groups. However, universal design often requires compromises between different standards and the needs of various disability groups, necessitating careful consideration to avoid disadvantaging any group. Regularly reviewing and adapting these standards ensures inclusivity and practicality in diverse urban environments. Achieving this balance is crucial for creating public spaces that are accessible and beneficial for everyone. (Darcy and Harris, 2003).

Achieving this balance is important for creating public spaces that are accessible and beneficial for wheelchair users. Regularly reviewing and adapting these standards ensures inclusivity and practicality in diverse urban environments (Darcy and Harris, 2003).

4.2 Does the area around the Lengg healthcare area comply with the standards and regulations for accessibility in public spaces for people with walking disabilities?

Applying the criteria catalogue to assess accessibility in the Lengg healthcare area and along the route from Balgrist station to Bahnhofstrasse/HB revealed several necessary adjustments and improvements. The findings of the specific mobility barriers in the study areas are detailed in Tables 2 and 3 and illustrated in the maps from Figure 30 and 31 or in the Appendix A3 and A4, what show that the area only partially complies with accessibility the standards. Key findings from the assessment indicate a need for enhanced measures to address identified barriers, ensure compliance with accessibility norms, and improve overall mobility and safety for wheelchair users.

4.2.1 Discussion of the quantitative results in the context of the qualitative Interviews

The survey of accessibility in the Lengg healthcare area and along the route from the Balgrist station to Bahnhofstrasse/HB identified a total of 64 specific barriers (shown in Table 2 and 3) that significantly impair the freedom of movement and safety of people in wheelchairs. This aligns with the understanding that urban planning without barriers not only benefits the majority of the population but also the wider community, especially people with disabilities (Nakarmi and Shrestha, 2022). In the Lengg healthcare area, these barriers occur particularly at bottlenecks and critical areas, such as the car park at Balgrist Hospital and the slope near the Mathilde Escher Foundation. The presence of such barriers underlines the necessity for urban planning that incorporates principles of accessibility to ensure all citizens have unhindered access to public spaces (Huang, White and Langenheim, 2022). In the study area of the Balgrist and Bahnhofstrasse/HB tram stations, the barriers are mainly concentrated at road junctions and main traffic routes, where low curbs and inadequate markings significantly restrict mobility. This situation reflects the broader issue in many European cities, which have historically been designed for young, healthy and dynamic individuals, often neglecting the needs of people with disabilities (Yılmaz, 2018). The distribution and concentration of these barriers highlight the need for targeted measures to improve accessibility and safety in these areas. A detailed discussion of these challenges and their impact on wheelchair users is provided in the following subsections, which deal specifically with the results of the Lengg healthcare area and the route to Bahnhofstrasse/HB.

4.2.2 Examination of accessibility in the Lengg healthcare area

In the Lengg healthcare area, a total of 20 barriers were identified that significantly impair the accessibility and mobility of people with disabilities (see Table 2 and 3). These barriers are evenly distributed throughout the study area but are also concentrated in specific bottlenecks and critical areas, such as in front of the parking lot of the Balgrist Hospital or the slope near the Mathilde Escher Foundation. This concentration indicates that targeted measures in these zones could significantly improve accessibility.

The main barriers include narrow sidewalks, missing signage, non-standard compliant curbs, and a steep sidewalk without safety railings. There are significant bottlenecks reducing sidewalk widths to 163 cm near the Balgrist Hospital parking lot and, in one instance, to just 90 cm at a driveway on the eastern side of the Balgrist University Hospital. These bottlenecks pose significant obstacles and endanger the safety of wheelchair users, especially in the presence of oncoming traffic, as safe bypass options are lacking.

When considering the 90 cm wide sidewalk at the driveway on the eastern side of the Balgrist University Hospital, it is unclear if this path was intended for pedestrian use, as it is rarely used by pedestrians. This makes the purpose of the barrier unclear and potentially misleading. Similarly, the 163 cm wide path near the Balgrist Hospital parking lot narrows significantly at a driveway, creating additional challenges for wheelchair users. The narrow width, combined with the presence of driveways, forces wheelchair users into potentially dangerous situations as they have to navigate around parked or moving vehicles. These barriers are particularly critical because they restrict mobility and lead to hazardous situations when wheelchair users are forced to move onto the roadway, increasing the risk of accidents and injuries. The lack of accessible infrastructure is a common issue in urban environments, often resulting in higher risks for people with disabilities (Nakarmi and Shrestha, 2022).

Another major point of criticism is the lack of or incorrect informational signs. This is in line with the observation that the absence of clear, accessible information can significantly impact the lives of all citizens (Nakarmi and Shrestha, 2022). There is a need for an overview map of the Lengg healthcare area near the Balgrist tram station, including information on slopes, such as the one near the Mathilde Escher Foundation. Additionally, the informational signs lack markings for wheelchair routes, such as those directly at the tram stop (see Figure 28). It would also be beneficial to design uniform information signs throughout the Lengg healthcare area to improve orientation. These signs should preferably be black with white text and have font sizes adjusted for readability from a distance. Information specifically for wheelchair routes also should be displayed. Effective signage is crucial for ensuring that people with disabilities can navigate urban spaces independently (Lid and Solvang, 2016).

The separation of pedestrian and vehicular traffic by vertical curbs is generally well implemented in the Lengg healthcare area. However, several intersections were found to have curbs with a height of 0.04 m that do not have flattened transitions and thus do not meet standards. These non-standard curbs make it difficult for wheelchair users to cross the street and increase the risk of accidents. Qualitative interviews confirmed that these curbs are a considerable obstacle.

A particular concern is the slope near the Mathilde Escher Foundation, where the sidewalk has a gradient of up to 10%. Despite meeting the norms for certain topographical conditions, this slope remains a challenge for wheelchair users due to the difficulty in navigating steep inclines. Particularly problematic is the lack of safety railings, which significantly increases the risk of accidents in bad weather or slippery conditions, as wheelchair users might lose control and potentially be led down the steep grassy slope. The absence of safety railings heightens the risk of falls, especially in bad weather. These concerns were confirmed in qualitative interviews, where wheelchair users mentioned they avoid this slope, validating the criticism.

The analysis of the study area involved a thorough investigation route around the Balgrist Hospital and past the Mathilde Escher Foundation. This emphasizes the importance of inclusive urban planning that ensures mobility across diverse population groups and fosters active participation from community members (Huang, White and Langenheim, 2022). In the interviewed individuals have mentioned that they rarely use the route through the park to reach the tram station. Instead, they often take a direct path across the Balgrist Hospital parking lot to the tram station. The perspective of the interviewed individuals highlights the specific preferences and challenges faced by this group.

4.2.3 Examination of accessibility at the Balgrist and Bahnhofstrasse/HB tram stations to Zurich Main Station

In the at the Balgrist and Bahnhofstrasse/HB tram stations to Zurich Main Station study area, a total of 38 barriers were identified that significantly impair the accessibility and mobility of people with disabilities (see Table 3). These barriers are not evenly distributed and are concentrated in specific bottlenecks, such as street crossings to the train station hall and along main roads. This concentration of barriers, especially at critical points like street crossings, highlights major issues with low curbs but with vertical edges of 0.04 cm, which severely hinder wheelchair users and affect the overall accessibility of the area (Filiz and Meshur, 2013).

The uneven distribution of barriers, with a high concentration at street crossings, suggests that while these zones are particularly problematic, other areas may still be overlooked. This could mean that even if major crossings are improved, the overall mobility for wheelchair users remains compromised. For instance, critical areas like the crossings to the train station hall are essential for daily commutes and any barriers in these zones can disrupt the flow of movement and accessibility.

Moreover, the long platform at the Balgrist tram stop requires wheelchair users to travel a considerable distance to reach the shelter. There are only transitions at the top and bottom of the platform, making it difficult to cross in the middle where the platform is too high. This design flaw forces wheelchair users to travel the entire length of the platform, causing unnecessary exertion. This issue highlights a broader problem in urban planning, where the practical needs of all users are not fully considered, emphasizing the need to integrate inclusive design principles to ensure infrastructure is accessible and convenient for everyone. Inclusive urban planning is essential to suit the needs of diverse populations, such as those with disabilities (Huang, White and Langenheim, 2022).

Furthermore, both the Balgrist and Bahnhofstrasse/HB tram stops lack clear boarding markings. These markings are crucial to help wheelchair users identify the correct boarding points quickly and efficiently. The absence of these markings can lead to confusion and delays, as wheelchair users must search for suitable boarding areas, often requiring additional assistance from others. This lack of clear entry points not only complicates the boarding process but also undermines the independence of wheelchair users. Interviews revealed that finding tram doors is particularly problematic during rush hour due to the high number of passengers boarding, further complicating the process. The integration of clear, visible boarding markings is essential to facilitate smooth and autonomous use of public transportation for all passengers, especially those with disabilities.

There is also a lack of proper shelters at the Bahnhofstrasse/HB stop. Although extended store awnings provide some shelter, they are not adequate substitutes for dedicated shelters. Proper shelters are essential for protecting passengers from the elements and ensuring a comfortable waiting area. The absence of these shelters makes waiting for public transport particularly challenging for people with disabilities during bad weather. Similarly, at the Balgrist stop, the existing shelter is almost too short, especially when there are many people waiting. In crowded conditions, wheelchair users often find there is no space left for them under the shelter. This issue, highlighted in interviews, underlines the need for more spacious and accessible shelters at tram stops to accommodate all passengers comfortably.

Additionally, significant orientation issues further complicate accessibility. The Balgrist tram stops lack digital information displays and the main Train Station building lacks clear informational signage. The existing information panels along Bahnhofstrasse do not provide specific information for wheelchair users, such as indications of accessible routes or acoustic options. This inadequate signage not only complicates navigation but also increases the risk of wheelchair users choosing unsuitable paths, exposing them to potential dangers and detours. For instance, near the escalator from the Bahnhofstrasse/HB tram stop to the main building of Zurich's main Train Station, clear guidance is necessary to prevent wheelchair users from mistakenly approaching the escalator, posing serious safety risks. Additionally, just before reaching the main building, there is an unmarked taxi crossing, which can be hazardous without a warning sign. The lack of such essential information tools reflects a broader neglect of inclusive design principles in urban planning.

The failure to provide comprehensive, accessible information signifies a systemic oversight in urban planning (Huang, White and Langenheim, 2022). It suggests that the needs of people with disabilities are not fully integrated into the infrastructure development process. The absence of digital displays and clear signage highlights a lack of consideration for all users, leading to an environment where navigating the area can be confusing and hazardous for those with disabilities. This systemic neglect underlines the broader issues within urban planning that fail to prioritize inclusive design principles, a point also noted by Imrie and Hall (2001) regarding the policies and values of professionals who design the built environment.

4.2.4 Application of the Catalogue and its Limitations

The application of the criteria catalogue to assess accessibility in public spaces offers several advantages. The catalogue enables a structured and comprehensive recording of various barriers, ensuring a detailed evaluation of accessibility. During the examination 58 specific barriers were identified in a very limited area, including high curbs, missing signage and narrow passages. This systematic approach aligns with the principle that urban planning must ensure that all citizens have equal access to public facilities and services, tailored to their individual needs and abilities (Filiz and Meshur, 2013). The structured nature of the criteria catalogue allowed for a systematic analysis of the examined field and a clear categorization of the identified barriers. This enabled a precise determination of the relevant problems in the areas.

An advantage of the data collection is the use of modern technologies such as GIS for data processing and visualization**.** This use of GIS technologies has been emphasized as crucial for creating inclusive urban environments by accurately recording and representing barriers, thus significantly improving analysis and planning (Zimmermann-Janschitz, 2018). By integrating GPS data and the ability to overlay different layers, complex spatial analyses can be conducted, providing detailed insights into the distribution of obstacles. This creates a solid foundation for assessing and improving accessibility, as current and precise information can be visualized and analysed in real-time. Additionally, the use of QGIS facilitates collaboration between various disciplines by providing a common platform for data evaluation and decision-making. This leads to more efficient and coherent planning of measures to eliminate barriers(Beale and Briggs, 2002).

The use of GPS data for recording barriers further enhances the accuracy and reliability of the assessments. GPS data allows for precise location tracking of identified barriers, making it easier to map and visualize these obstacles within the GIS platform. This ensures that the recorded data is not only accurate but also easily accessible for analysis and decision-making. However, the effectiveness of GPS data relies heavily on the accuracy and functionality of the GPS devices used. In urban environments with tall buildings or dense tree cover, GPS signals can be obstructed, leading to potential inaccuracies in data recording. To mitigate this, it is important to use high-quality GPS devices and consider supplementary methods, such as manual verification, to ensure data reliability. Despite these challenges, the use of GPS data provides a robust framework for continuous monitoring and updating of accessibility information, supporting dynamic and responsive urban planning efforts.

A digital version of the criteria catalogue could further enhance the efficiency and accuracy of data collection. By directly linking collected data and barriers with GIS, data collection becomes easier and faster. Barriers could be documented immediately on-site, and the information could be directly transferred into the GIS, increasing data accuracy and allowing for timely analysis(Beale and Briggs, 2002). This aligns with the idea that utilizing modern technologies such as GIS can greatly support the planning of inclusive urban environments (Allahbakhshi, Huang and Weibel, 2018). The digital version of the catalogue could thus serve as a central tool for the continuous monitoring and improvement of accessibility.

However, while the criteria catalogue enables standardized assessment, it became evident that not all barriers could be adequately captured by the established standards. For example, specific issues like unevenness caused by tram tracks at crossings were not considered in the original criteria. This underlines the necessity of adapting the criteria catalogue to be applicable in various environments. To achieve this, the catalogue should include the ability to note or identify specific issues unique to each area, such as tram tracks, to ensure comprehensive and practical application across different contexts.

Qualitative interviews with wheelchair users from the Mathilde Escher Foundation revealed that standardized criteria often miss personal experiences and individual needs. Independence and autonomy depend heavily on the functionality of aids, such as manoeuvrability on different surfaces and ease of overcoming obstacles. Some wheelchairs handle uneven surfaces better, while others struggle with inclines or need specific ramps. Powered wheelchairs may require accessible charging stations, which the current criteria do not address. Interviews also highlighted issues at tram stops, like finding tram doors during rush hour and the lack of clear boarding markings. This suggests the need for the catalogue to better account for the functionalities and limitations of different aids to support user independence and autonomy.

The interviews also emphasized the importance of user feedback in identifying barriers that standardized assessments might overlook. Personal experiences provide valuable insights into daily challenges, such as navigating long platforms, finding adequate shelter at stops and dealing with crowded conditions. Incorporating qualitative data into the assessment process can lead to a more comprehensive understanding of accessibility issues and more effective solutions. This approach aligns with the broader understanding that incorporating the insights from people with disabilities into the planning process is essential for breaking down barriers and fostering a fairer, more accessible society (Matthews, 1995a; Basha, 2015).

Even though, the criteria catalogue is a valuable tool, it faces several challenges. One major issue is the currency and dynamics of the data. Urban environments are constantly changing and temporary obstacles such as construction sites or seasonal conditions may not be captured in the catalogue in a timely manner, making it challenging to integrate these obstacles as a norm. However, it is important to include standards in the catalogue to note such temporary barriers when encountered. Ensuring the *Accessibility Standards for Public Spaces for Wheelchair Users* catalogue remains up to date with these dynamic changes requires regular reviews and updates.

Another critical aspect is the need for further differentiation within the criteria catalogue. Although the weighting of categories is done through the 2x2 matrix, more detailed differentiation could help set priorities for barrier removal more effectively. For instance, high curbs may pose a more severe obstacle than narrow passages, thus requiring more nuanced weighting in the catalogue. Expanding the criteria to include varying degrees of severity and impact can provide a clearer prioritization framework, ensuring that the most significant barriers are addressed first. Regular updates and reviews of the catalogue are essential to maintain its relevance and effectiveness in capturing the dynamic nature of urban environments. By incorporating these improvements, the catalogue can better support the goal of enhancing accessibility in public spaces.

Particularly, the weighting of the barriers shows that some barriers are more severe than others. High curbs and steep sidewalks without safety railings pose a greater risk than narrow sidewalks, as they directly impact safety and mobility.

Additionally, the use of technologies such as QGIS assumes that users have the corresponding technical knowledge and access to appropriate software. This requirement can promote the applicability of the catalogue in tech-savvy groups but may also limit it in less tech-savvy populations or smaller municipalities that may not have the necessary expertise in spatial planning or handling GIS. This could result in certain regions or groups having difficulty effectively using the *Accessibility Standards for Public Spaces for Wheelchair Users* catalogue, hindering its user-friendliness and the widespread implementation and standardization of accessibility.

To further improve the effectiveness of the criteria catalogue, it should be designed more flexibly to better consider specific circumstances. For example, additional categories for special barriers such as tram tracks or temporary obstacles should be introduced. While it is challenging to integrate social and psychological factors, such as the behavior of other road users and the sense of safety of users, into standardized criteria, acknowledging their impact is crucial. For instance, the aggressive or inattentive behavior of drivers and cyclists can significantly affect the safety and comfort of wheelchair users. Although these behaviors cannot be codified into norms, the catalogue could include standards for assessing areas where such behaviors are prevalent and recommend measures such as increased signage, public awareness campaigns, or enhanced enforcement of traffic laws to mitigate their impact. Furthermore, the catalogue should include a dedicated section for general notes and observations, allowing assessors to document the overall environmental impact, including weather conditions and traffic, which cannot be specifically codified into norms. This would provide a more holistic understanding of the accessibility challenges in different contexts. By considering these factors, the catalogue can provide a more comprehensive assessment of accessibility, addressing both physical barriers and the broader environment to create a safer and more inclusive public space.

Furthermore, the current catalogue lacks a dedicated space for general notes and observations, which limits the ability to capture unique or unforeseen issues encountered during assessments. Incorporating a section for general notes would allow for a more detailed and nuanced understanding of accessibility challenges, highlighting areas for improvement and adaptation.

Finally, the catalogue should be regularly expanded with feedback from people with disabilities and other affected groups. A continuous feedback mechanism could be established to ensure the relevance and practicality of the catalogue. This approach is consistent with the idea that integrating feedback from people with disabilities is crucial for developing effective and inclusive urban planning solutions (Huang, White and Langenheim, 2022). To ensure the correct application of the catalogue, training programs for urban planners, traffic engineers and other relevant actors could be developed. These training sessions should cover the interpretation and application of the criteria as well as the use of GIS technologies. A system for long-term monitoring and evaluation of accessibility should be integrated. This could be achieved by developing criteria for the regular review and updating of recorded barriers to document progress respectively ensure ongoing improvements.

4.2.5 Discussion of the maps and their meaning

In the investigation of accessibility in the Lengg healthcare area and along the route from Balgrist station to Bahnhofstrasse/HB, detailed maps (seen in Figure 30 and 31) played a central role. These maps are crucial for planning and improving accessibility as they provide a clear visual representation of the identified barriers. Raising awareness of the challenges faced by people with disabilities, the maps serve as a valuable tool for urban planners and decision-makers. This is aligned with the concept that effective urban planning must ensure accessibility for all citizens, as emphasized by Filiz and Meshur (2013). They aid in developing targeted measures to improve accessibility, providing a basis for prioritizing projects and allocating resources. Regular updates can monitor progress in removing barriers and identify new challenges.

These barriers were categorized and color-coded according to a 2x2 matrix system, which allows for clear prioritization and visualization of the issues. Red symbols mark the most problematic barriers requiring immediate attention, while petrol symbols represent compliant barriers. Yellow symbols indicate moderate issues that need attention but are less urgent and orange symbols denote significant issues that are not as critical as red but still require prompt action. The color-coding follows an intuitive warning system, making it easy to quickly identify and prioritize the most urgent areas and plan targeted measures effectively.

However, the assessment and classification of barriers can be subjective and depend on the individual experiences of data collectors, potentially leading to inconsistencies. The importance of considering diverse user experiences is highlighted by Huang, White and Langenheim (2022), who stress the necessity of inclusive urban planning that serves to all users. Different data collectors might perceive the severity of a barrier differently based on their personal experiences and biases. This subjectivity can result in variations in how barriers are identified and classified, which may affect the reliability of the maps. To mitigate this, it is crucial to have standardized training for data collectors and to use objective criteria as much as possible in the assessment process. Regular reviews and updates based on user feedback can also help improve the consistency and accuracy of the maps. Additionally, the Accessibility Standards for Public Spaces for Wheelchair Users catalogue can be a helpful tool, providing a structured framework to guide data collectors and ensure a more consistent and reliable assessment process.

Furthermore, the use of GIS requires technical knowledge and access to appropriate software and hardware, which may complicate the creation and updating of the maps for some stakeholders. Zimmermann-Janschitz (2018) emphasizes that the use of GIS is vital for creating inclusive urban environments but acknowledges that technical expertise is necessary to fully leverage its capabilities. Additionally, the maps might not account for all individual needs and perspectives of people with different disabilities. What constitutes an insurmountable barrier for one person might be less problematic for another. Therefore, it is essential to consider the diverse experiences and requirements of all users to create more inclusive and representative maps.

A key advantage of the maps is their ability to encourage collaboration between various disciplines such as urban planning, traffic engineering, social sciences, and disabled persons. This collaborative approach is necessary for effective urban planning, as it integrates different perspectives and expertise, leading to more comprehensive and inclusive solutions (Huang, White and Langenheim, 2022). They provide a common basis for discussions and decisions to improve accessibility. The inclusion of feedback from affected individuals and other stakeholders is facilitated by the use of the maps, leading to more inclusive and needs-based solutions.

These maps can be used as a communication tool to raise public awareness about the barriers faced by people with disabilities. Raising public awareness is crucial in fostering a sense of community and collective responsibility, which is essential for addressing accessibility issues effectively (Lid and Solvang, 2016). By making these maps accessible to the general public, it becomes easier to create a sense of community and collective responsibility in addressing accessibility issues.

Despite their numerous advantages, the maps also have limitations. Urban environments are dynamic and subject to constant changes due to construction sites, temporary obstacles and seasonal conditions. It is important to note that while seasonal conditions are not explicitly included in the catalogue, they can significantly affect the accessibility of certain areas. For example, during winter, snow and ice can create additional barriers on sidewalks and ramps that are otherwise accessible in warmer months. An area that is easily navigable in summer might become treacherous in winter due to snow accumulation or ice patches, which are not reflected in the static maps. Therefore, the maps need to be regularly updated to account for these changes and ensure accuracy.

One limitation of the maps is that they do not explicitly indicate the type of barrier present. Users, especially urban planners, need to refer to the detailed data in Tables 2 and 3 in this work to understand the specifics of each barrier. Including all specific barriers on the maps was not feasible due to space constraints and the need to maintain clarity and readability of the map. While this requires additional effort from planners, it still serves as an important alert for wheelchair users and others, indicating areas where caution is needed.

To further improve the maps, integrating a continuous feedback loop is essential. This aligns with the idea that continuous feedback from users is crucial for developing effective and inclusive urban planning solutions (Huang, White and Langenheim, 2022). Users should be able to report new barriers and provide updates on existing ones through an accessible platform, such as a mobile app or an online portal. This approach would enable real-time updates and ensure the maps remain accurate and relevant.

4.3 What improvements can be made and to what extent can the digital implementation of the Smart City approach be applied?

The investigation of accessibility in public spaces in Zurich, particularly in the Lengg healthcare area and at the two surrounding tram stops, reveals significant challenges for wheelchair users. Addressing these barriers requires both conventional and innovative approaches to enhance mobility, orientation and safety. Conventional solutions provide improvements and ensure sustainable long-term changes, while innovative Smart City applications offer additional opportunities to further optimize accessibility through technology.

The investigation identified several key barriers in the Lengg healthcare area and at the tram stops Balgrist and Bahnhofstrasse/HB along the route to Zurich Main Station. Narrow sidewalks, with widths of 163 cm and 90 cm, need to be widened to at least 180 cm to meet accessibility standards. Driveways should be clearly marked with priority and stop signs to enhance safety, while the steep incline near the Mathilde Escher Foundation requires safety features like railings and alternative, less steep routes with clear signage. Non-compliant curb edges need adjustment to facilitate smooth and safe crossings. Randomly parked bicycles and motorcycles create obstacles on sidewalks, which can be addressed with clear ground markings for designated parking areas. Information boards should be installed at heights suitable for wheelchair users, with large, readable fonts, high-contrast colours and lighting to improve visibility.

At tram stops, shelters should be expanded to provide adequate protection from the elements and larger, digital information boards that are highly visible and accessible should be installed to provide real-time updates on departures, delays and disruptions. Clear markings at tram entry points, automated ramps and sensor-based door opening systems are necessary to enhance accessibility and independence for wheelchair users. Additionally, clear signage indicating alternative wheelchair-accessible routes, especially near escalators, is essential.

By addressing these barriers through both conventional and Smart City solutions, the quality of public spaces can be significantly improved, creating a more accessible and inclusive urban environment for all.

4.3.1 Conventional Solutions

To address the challenges faced by wheelchair users in urban environments, the implementation of the criteria catalogue involves a range of conventional solutions aimed at improving accessibility and mobility. These conventional measures include widening sidewalks, eliminating bottlenecks and securing access roads through clear priority markings and stop signs. These fundamental steps are designed to facilitate the movement of wheelchair users and enhance their safety as well as their comfort.

Widening sidewalks to at least 180 cm is a fundamental measure to improve accessibility and significantly facilitate the mobility of wheelchair users in the Lengg healthcare area. According to Lid and Solvang (2016), wider sidewalks allow for easier manoeuvrability, reduce the risk of collisions with pedestrians and provide sufficient space for wheelchair users to navigate comfortably. This measure is especially important in high-traffic areas where narrow sidewalks can create bottlenecks. For example, in busy shopping districts or near public transportation hubs, wider sidewalks can prevent congestion and allow wheelchair users to move more freely.

Another important measure is securing access roads through clear priority markings and stop signs. Well-marked pedestrian crossings and stop signs at intersections help avoid confusion and dangerous situations for both wheelchair users and other pedestrians. Smith et al. (2018) confirms that these measures are easy to implement and cost-effective yet play a crucial role in enhancing safety. Clear priority markings ensure that drivers are aware of pedestrian rights-of-way, reducing the risk of accidents. Arias and Batista (2019) support the view that well-marked crossings and stop signs at busy intersections, such as those near schools or hospitals, can significantly improve safety for all pedestrians. Prioritizing these simple yet effective measures can greatly enhance the safety and accessibility of urban spaces.

Adjusting curbs to current standards makes it easier for wheelchair users to cross streets and increases their safety. Improving surface conditions by replacing cobblestones and uneven pavements with smooth, hard and non-slip surfaces reduces the risk of accidents and improves comfort for wheelchair users (Bennett, Lee Kirby and MacDonald, 2009).

Improved signage and information through highly visible, illuminated and wheelchair-accessible information signs facilitate orientation and increase accessibility. In the Lengg healthcare area, it is particularly important to have uniform information signs that clearly indicate wheelchair-accessible routes. At tram stops, digital displays should provide real-time information about vehicle arrival times and accessibility features. Similarly, at the main Train Station, there should be consistent information boards that include guidance on wheelchair-accessible paths. This measure enhances the user-friendliness of public spaces but requires continuous resources for maintenance and updates. Ensuring that signs are kept clean, functional and up to date with current information is crucial. This involves regular inspections, timely repairs and updates to reflect any changes in the environment, such as new constructions of infrastructure or modified routes. in terms of both time and financial resources, the resulting benefits of improved accessibility and increased user satisfaction justify these costs. This contributes to a more inclusive and navigable urban environment, ensuring that the infrastructure meets the needs of all users.

Weather protection at stops, through larger shelters, provides coverage from the elements and increases comfort for all passengers, including wheelchair users. However, expanding such shelters could cause space issues, as larger structures might obstruct pedestrian pathways or reduce boarding space.

Finally, regular training for public transport staff enhances the quality of assistance provided to wheelchair users. Zhou et al. (2012) confirm that solutions like sensitivity training, hands-on workshops and customer service education are essential. These measures improve staff assistance, inclusivity and societal awareness. While organizing such training requires time and financial resources, the investment ensures better service, greater accessibility and a more inclusive public transportation system.

4.3.2 Solutions with Smart City Applications

The investigation highlights that Smart City solutions can enhance accessibility for wheelchair users. Key findings include the effectiveness of navigation apps in finding accessible routes, digital mapping and crowdsourcing platforms for reporting barriers, automated ramps and sensor-based systems for easier access to public transport and smart traffic lights for safer crossings. Additionally, AI-powered data analysis helps understand mobility patterns and advanced wheelchair technologies offer new mobility solutions. While these innovations require substantial technical expertise and financial investment, their effectiveness is not guaranteed without proper implementation, continuous updates, and user engagement. Thus, they have the potential to provide long-term benefits by creating a more accessible urban environment, but their success depends on overcoming these challenges (Quelle).

One of the primary benefits of Smart City solutions is the use of modern navigation apps, which help wheelchair users find accessible routes and avoid challenges, thereby increasing their mobility and independence. Tome (2019) confirms that such apps can greatly enhance the experiences of wheelchair users in urban environments. However, these technologies require technical expertise and financial resources for development and maintenance.

Another effective Smart City solution involves digital mapping and crowdsourcing platforms. These allow users to report barriers and share accessible routes, promoting community involvement and continuous infrastructure improvement. However, the accuracy and timeliness of the collected data can vary, and the platforms need to be user-friendly and continuously updated. Large digital information boards and mobile apps providing real-time information on schedules and accessible routes improve the user experience and increase mobility.

In addition to apps and digital platforms, mobile apps with personalized schedules and real-time updates can provide wheelchair users with valuable information for planning their journeys, enhancing efficiency and convenience(Zhou *et al.*, 2012). While several mobile apps and open-source data is available, they often lack standardization and integration at the local level. Smith et al. (2018) suggest that developing a unified app at the state level could address these gaps, improving local planning and creating a more cohesive, efficient system. Such an app would require significant technical expertise and financial resources for development and maintenance, but the long-term benefits could justify the investment by streamlining accessibility features across various regions.

Automated ramps and sensor-based door opening systems facilitate access to buses and trams for wheelchair users, increasing their independence and safety. Nam and Pardo (2011) confirm that these technologies can be costly to implement and maintain, posing financial challenges for public transportation agencies. The high initial investment and ongoing maintenance costs require careful consideration and prioritization in budget planning.

Beyond public transport enhancements, the promotion of modern wheelchairs capable of overcoming obstacles significantly improves the mobility of wheelchair users. For instance, the company SCEWO has developed a wheelchair capable of climbing stairs, making it particularly useful for navigating urban environments with staircase(Morales, Somolinos and Cerrada, 2013). However, such advanced wheelchairs can be expensive and may not be suitable for all users due to their cost and specific design features. Establishing continuous feedback loops to collect user experiences contributes to improving accessibility based on the needs of wheelchair users but requires careful organization and management.

Smart traffic lights and sensor-based systems optimize traffic flow and increase safety for wheelchair users, contributing to the creation of an accessible infrastructure. Despite their benefits, Chen et al. (2020) note that these systems are expensive and technically demanding to implement. The complexity of installation and the need for ongoing technical support may limit their widespread adoption, particularly in smaller municipalities with limited budgets.

The investigation showed that technological aids such as mobile apps and modern traffic light systems can improve accessibility. Therefore, Müller (2021) confirms that the criteria catalogue should also consider the availability and effectiveness of such technological solutions to enable a more comprehensive assessment. Traffic Management Systems offer innovative solutions tailored to the needs of wheelchair users. Smart traffic lights, for instance, can adjust signals dynamically, providing extended green times upon request or via an app, thereby facilitating safer crossings. Complementing this, Nam and Pardo (2011) discuss that sensor-based systems intelligently detect wheelchair users, enabling adjustments to sidewalk and street crossing times in real-time, ensuring smoother mobility experiences. However, the implementation of these systems can be costly and technically demanding, which may limit their adoption, especially in smaller municipalities with limited repetition. Moreover, the reliability of these systems can be a concern, as technical failures could lead to significant accessibility issues.

Comprehensive data analysis, powered by AI and mobility analytics, plays a decisive role in understanding the nuanced mobility patterns of wheelchair users. Arias and Batista (2019) confirm that by integrating administrative and sensor data into a central pool, it becomes possible to visualize and monitor accessibility levels effectively. This holistic approach not only informs targeted improvements but also lays the foundation for future enhancements in accessibility infrastructure. However, the accuracy and timeliness of the collected data can vary, requiring continuous updates and user-friendly platforms. There is also the risk of data privacy concerns, as collecting detailed mobility data could infringe on the privacy of individuals. Ensuring the protection of personal data is paramount to gaining the trust of users.

Central to these endeavours is the establishment of robust implementation and feedback mechanisms. Through a continuous feedback loop, insights from user experiences, especially those of individuals with disabilities, drive iterative refinement of systems and solutions. Visnes Øksenholt and Aarhaug (2018) emphasize that this collaborative approach ensures that accessibility initiatives evolve in tandem with the diverse needs of the community, fostering a more inclusive environment. This requires careful organization and management, as well as significant financial and technical resources. Additionally, the feedback mechanisms must be designed to genuinely incorporate user input, rather than being token gestures to ensure real improvements

Evaluating the proposed conventional and Smart City solutions in terms of their feasibility, costs and potential impacts on accessibility provides a comprehensive basis for considering and assessing both approaches. Ultimately, addressing these issues can lead to a more accessible and inclusive urban environment for all inhabitants.

4.4 Limitation and Future Research

The present study on accessibility in the Lengg healthcare area and along the route from Balgrist to Bahnhofstrasse/HB has yielded significant insights. However, several limitations must be considered, which future research should address. One of the main constraints lies in the limited geographical coverage. The study focused specifically on certain areas in Zurich, which means the results may not be transferable to other urban or rural areas in Zurich or Switzerland. Future research should aim for broader geographical coverage to increase the generalizability of the findings. Additionally, the data collection occurred over a limited time period in January, which may not capture variations in accessibility that could occur at different times of the year or during different events. Future research should include longitudinal studies to capture these temporal variations.

Another issue concerns seasonal and weather-related influences. Although winter conditions such as snow and ice were considered during the January study, they were not systematically integrated into the barrier assessment. Snow and ice can render sidewalks and ramps impassable, creating additional barriers for wheelchair users. Future studies should systematically investigate how different climatic and seasonal conditions affect the usability of public spaces for wheelchair users and develop adaptive strategies to mitigate these impacts.

Subjectivity in barrier recognition is also a limitation. Despite the structured criteria catalogue, the perception of the severity of barriers can vary among different evaluators, leading to inconsistencies. Standardized training for data collectors and the use of objective criteria could help minimize these biases and ensure more uniform assessments.

The study primarily focused on the needs of wheelchair users, while the needs of people with visual or hearing impairments were not specifically considered. Future research should develop inclusive accessibility standards that consider the diverse needs of all disability groups. This is crucial for creating truly inclusive public spaces. By addressing the needs of all disabled individuals, urban environments can be made more accessible, allowing everyone, regardless of their impairment, to navigate and utilize public spaces with ease.

Technological requirements and resources are also a significant aspect. The application of GIS and other technological solutions requires technical knowledge and access to appropriate software and hardware, which could limit the applicability of the proposed solutions in less tech-savvy communities or smaller towns. More user-friendly and accessible technical solutions, along with appropriate training programs, could help address this issue.

Another critical aspect is the long-term sustainability and maintenance. The effectiveness of measures depends heavily on continuous maintenance and regular inspections. Materials like concrete and cement can crack over time, creating new obstacles for wheelchair users. Regular maintenance is necessary to keep surfaces in optimal condition. Future research should conduct long-term studies to monitor the sustainability and long-term impact of implemented measures. Research should track changes in mobility patterns, user satisfaction and safety incidents before and after the implementation of accessibility improvements to assess their long-term success.

Financial and logistical constraints also pose a challenge. Implementing the measures requires significant financial investment and logistical planning. Municipalities and other responsible entities may not have the necessary resources to remove all identified barriers promptly. This is particularly problematic in smaller communities that often operate with limited budgets. Effective application of the catalogue also requires collaboration between various disciplines such as urban planning, traffic engineering and social sciences. Lack of interdisciplinary collaboration can significantly hinder the implementation and effectiveness of the proposed measures.

Another limitation concerns the qualitative interviews conducted in this study. The small sample size may not provide a comprehensive view of all potential barriers and experiences faced by wheelchair users. Increasing the number of participants in future studies could yield more robust and generalizable data. This approach would also enable the inclusion of diverse perspectives, further enriching the understanding of accessibility challenges and potential solutions.

Despite these limitations, the study has provided essential insights into improving accessibility and laid the foundation for future research and action. Building on the research gaps identified in the introduction, this study highlights several key areas for future research to enhance accessibility in urban environments for wheelchair users. The potential of Smart City applications to improve accessibility is significant, but their long-term impacts and user acceptance require further investigation. Studies should examine the practical implementation and user acceptance of technologies such as automatic ramps, sensor-based door systems and smart traffic lights. Additionally, exploring the development and integration of advanced mobility aids, such as stair-climbing wheelchairs, can provide valuable insights into overcoming existing barriers.

The importance of user feedback in identifying and addressing barriers cannot be overstated. Future research should develop and evaluate robust feedback mechanisms that continuously collect input from wheelchair users and other people with disabilities. This can ensure that urban planning efforts are responsive to the evolving needs of these communities.

Future studies should also focus on creating more inclusive criteria catalogues that encompass a broader range of disabilities beyond wheelchair users. This includes developing standards that address the specific needs of visually impaired, hearing-impaired and cognitively disabled individuals, ensuring a truly inclusive approach to urban planning. Research should also explore the integration of real-time data analytics and machine learning to predict and address accessibility issues dynamically, allowing for more proactive and adaptive urban planning strategies.

Overall, this study has made significant contributions to improving accessibility and provided valuable insights for future research and practice. The methodology of the study, including the application of a structured criteria catalogue and the use of GIS technologies for data collection and analysis, proved effective in identifying and categorizing barriers. The combination of quantitative analyses and qualitative interviews allowed for a comprehensive assessment of the current situation and provided valuable insights into the specific challenges faced by wheelchair users in urban environments. Despite the identified limitations, this study offers a solid foundation for further investigations and actions to enhance accessibility in public spaces.

5 Conclusion

This study aimed to evaluate the accessibility of public spaces for wheelchair users in the Lengg healthcare area and at two tram stops along the route to Zurich Main Station. The key findings highlight persistent barriers such as narrow sidewalks, non-standard curbs and inadequate signage, despite existing accessibility standards. Additionally, steep slopes and uneven surfaces pose significant challenges for wheelchair users, exacerbating physical effort and increasing the risk of accidents. The study also explored the potential of Smart City solutions to enhance mobility, orientation and safety for wheelchair users.

The research addressed three main questions. First, it examined the norms and standards for accessibility in public spaces for people with walking disabilities. The study found that while comprehensive standards exist, practical challenges such as navigating steep slopes and misaligned platform heights remain significant barriers. This evaluation utilized the *Accessibility Standards for Public Spaces for Wheelchair Users* catalogue, specifically tailored to enhance wheelchair accessibility, highlighting the necessity for more detailed and practical standards. The findings suggest that current standards often lack specificity for wheelchair users and require continuous refinement to address evolving needs and conditions.

Second, it assessed whether the Lengg healthcare area complies with these accessibility standards. The results show partial compliance. In the Lengg healthcare area, 20 barriers were identified, including narrow sidewalks, missing signage and steep sidewalks without safety railings. In the Bahnhofstrasse/HB area, 38 barriers were identified, primarily at street crossings and along main thoroughfares. These barriers significantly impair the mobility and safety of wheelchair users, indicating that more targeted measures are needed to improve accessibility. The *Accessibility Standards for Public Spaces for Wheelchair Users* catalogue proved effective in identifying these barriers, providing a comprehensive overview of the public space's accessibility and highlighting areas needing improvement.

Finally, the study examined potential improvements through the application of Smart City solutions. It highlighted the potential of technologies like navigation apps and automated ramps to improve accessibility. These solutions, however, require substantial financial investments and user involvement to ensure effectiveness. The study also pointed out the benefits of advanced mobility aids, such as stair-climbing wheelchairs, which can provide valuable insights into overcoming existing barriers. Additionally, the integration of digital mapping platforms can facilitate community involvement in identifying and reporting barriers, ensuring that urban planning efforts are responsive to real-time needs.

The findings underline the need for flexibility in applying accessibility standards, balancing strict standards with practical adjustments for local contexts. Financial and technical challenges are significant obstacles to implementing accessibility measures. Continuous user feedback is essential to address dynamic urban environments and evolving needs. This comprehensive approach enhances inclusivity and fosters social equity by removing barriers affecting wheelchair users.

However, this study was limited to specific areas within Zurich and the findings may not be generalizable to other regions. The reliance on existing standards and criteria may overlook unique local challenges and user experiences. Although temporary obstacles from construction sites were considered, seasonal weather conditions were not explicitly integrated into the catalogue, presenting a challenge for continuous monitoring and adaptation.

Future research should explore the integration of universal design principles to accommodate diverse disabilities, not just wheelchair users. Long-term studies are needed to monitor the effectiveness and sustainability of implemented measures. Developing robust feedback mechanisms to continuously collect and integrate user input is crucial. Detailed cost-benefit analyses of accessibility improvements can aid in resource allocation. Recommendations for practice include regular updates to the criteria catalogue, interdisciplinary collaboration in urban planning and the promotion of advanced mobility technologies. These steps can help create more inclusive and accessible urban environments, improving the quality of life for people with disabilities.

This study contributes significantly to the field of urban accessibility by providing a comprehensive evaluation of existing barriers and proposing both conventional and innovative solutions. It emphasizes the importance of continuous adaptation and inclusion of diverse user experiences in urban planning. Reflecting on the research process, this study highlights the dynamic and multifaceted nature of accessibility challenges, advocating for a collaborative and technology-driven approach to creating more inclusive public spaces.

6 References

Allahbakhshi, H. (2023) ‘Towards an Inclusive Urban Environment: A Participatory Approach for Collecting Spatial Accessibility Data in Zurich’, in *Leibniz International Proceedings in Informatics, LIPIcs*. Schloss Dagstuhl- Leibniz-Zentrum fur Informatik GmbH, Dagstuhl Publishing, pp. 13:1-13:6. Available at: https://doi.org/10.4230/LIPIcs.GIScience.2023.13.

Allahbakhshi, H.;, Huang, H.; and Weibel, R. (2018) ‘A study design for physical activity reference data collection using GPS and accelerometer’. Available at: https://doi.org/10.5167/uzh-161051.

Alzouby, A.M., Nusair, A.A. and Taha, L.M. (2019) ‘GIS based Multi Criteria Decision Analysis for analyzing accessibility of the disabled in the Greater Irbid Municipality Area, Irbid, Jordan’, *Alexandria Engineering Journal*, 58(2), pp. 689–698. Available at: https://doi.org/10.1016/j.aej.2019.05.015.

Basha, R. (2015) ‘Disability and Public Space-Case Studies of Prishtina and Prizren’, *International Journal of Contemporary Architecture*, 2(3), pp. 54–66. Available at: https://doi.org/10.14621/tna.20150406.

Baudirektion Kanton Zürich (2015) *Gebietsmanagement Lengg*. Zürich. Available at: https://www.zh.ch/de/planen-bauen/raumplanung/gebietsplanungen/gebietsmanagement-lengg.html (Accessed: 26 June 2024).

Beale, L. and Briggs, D. (2002) ‘A GIS-based Route Mapping Tool for Disabled Access in Urban Environments’, *Environmental Communication in the Information Society - Proceedings of the 16th Conference*, 35(1), pp. 34–45. Available at: https://doi.org/10.1111/1475-4762.00108.

BehiG; SR 151.3 (2004) ‘Behindertengleichstellungsgesetz BehiG’.

Bennett, S., Lee Kirby, R. and MacDonald, B. (2009) ‘Wheelchair accessibility: Descriptive survey of curb ramps in an urban area’, *Disability and Rehabilitation: Assistive Technology*, 4(1), pp. 17–23. Available at: https://doi.org/10.1080/17483100802542603.

Bickenbach, J.E. *et al.* (1999) ‘Models of disablement, universalism and the international classification of impairments, disabilities and handicaps’, *Social Science & Medicine*, 48(9), pp. 1173–1187. Available at: https://doi.org/10.1016/S0277-9536(98)00441-9.

Castrodale, M. and Crooks, V.A. (2010) 'The production of disability research in human geography: an introspective examination', *Disability & Society*, 25(1), pp. 89–102. Available at: https://doi.org/10.1080/09687590903363415.

Darcy, S. and Harris, R. (2003) 'Inclusive and accessible special event planning: an Australia perspective', *Event Management*, 8(1), pp. 39–47. Available at: https://doi.org/10.3727/152599503108751685.

Darko, J. *et al.* (2022) 'Adaptive personalized routing for vulnerable road users', *IET Intelligent Transport Systems*, 16(8), pp. 1011–1025. Available at: https://doi.org/10.1049/itr2.12191.

Ding, D. *et al.* (2007) 'Design Considerations for a Personalized Wheelchair Navigation System', in *2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. IEEE, pp. 4790–4793. Available at: https://doi.org/10.1109/IEMBS.2007.4353411.

Esfandfard, E. *et al.* (2018) 'Universal Design in Urban Public Spaces for People with Disability, Case Study of Tehran, Iran.', *PLANNING MALAYSIA*, 16(5), pp. 173–182. Available at: https://doi.org/10.21837/pmjournal.v16.i5.421.

Evcil, N. (2010) 'Designers' attitudes towards disabled people and the compliance of public open places: The case of Istanbul', *European Planning Studies*, 18(11), pp. 1863–1880. Available at: https://doi.org/10.1080/09654313.2010.512178.

F Bromley, R.D., Matthews, D.L. and Thomas, C.J. (2007) 'City centre accessibility for wheelchair users: The consumer perspective and the planning implications', *Cities*, 24(3), pp. 229–241. Available at: https://doi.org/10.1016/j.cities.2007.01.009.

Ferreira, M.A.G., Da, S. and Sanches, P. (2007) 'Celso Augusto Guimarães Santos PROPOSAL OF A SIDEWALK ACCESSIBILITY INDEX', *Journal of Urban and Environmental Engineering*, 1(1), pp. 1–9. Available at: https://doi.org/10.2307/26203303.

Filiz, H. and Meshur, A. (2013) 'Accessibility for people with disabilities in urban spaces: A case study of Ankara, Turkey', *International Journal of Architectural Research Archnet-IJAR*, 7(2), pp. 43–60. Available at: https://doi.org/10.26687/archnet-ijar.v7i2.154.

Huang, X., White, M. and Langenheim, N. (2022) 'Towards an Inclusive Walking Community—A Multi-Criteria Digital Evaluation Approach to Facilitate Accessible Journeys', *Buildings*, 12(8). Available at: https://doi.org/10.3390/buildings12081191.

Imrie, R. and Hall, P. (2001) *Inclusive Design, Designing and Developing Accessible Envirmonments*. 1 st ed. Taylor & Francis. Available at: https://doi.org/10.4324/9780203362501.

Kadir, S.A. and Jamaludin, M. (2012) 'Applicability of Malaysian Standards and Universal Design in Public Buildings in Putrajaya', *Procedia - Social and Behavioral Sciences*, 36, pp. 659–669. Available at: https://doi.org/10.1016/j.sbspro.2012.03.072.

El Karim, A.A. and Awawdeh, M.M. (2020) 'Integrating GIS accessibility and location-allocation models with multicriteria decision analysis for evaluating quality of life in Buraidah city, KSA', *Sustainability (Switzerland)*, 12(4). Available at: https://doi.org/10.3390/su12041412.

Kim, E. (2016) 'Wheelchair Navigation System for Disabled and Elderly People', *Sensors*, 16(11), p. 1806. Available at: https://doi.org/10.3390/s16111806.

Knesebeck, O. von dem *et al.* (2007) 'Socio-economic position and quality of life among older people in 10 European countries: results of the SHARE study', *Ageing and Society*, 27(2), pp. 269–284. Available at: https://doi.org/10.1017/S0144686X06005484.

Kocaman, S. and Ozdemir, N. (2020) 'Improvement of disability rights via geographic information science', *Sustainability (Switzerland)*, 12(14), pp. 1–17. Available at: https://doi.org/10.3390/su12145807.

Kühnis, J. and Wüst, N. (2022) *Erleben von Barrieren im öffentlichen Raum für Personen im Rollstuhl und die Auswirkungen auf die gesellschaftliche Partizipation*. Available at: https://doi.org/10.21256/zhaw-26080.

Langford, M. *et al.* (2008) 'Urban population distribution models and service accessibility estimation', *Computers, Environment and Urban Systems*, 32(1), pp. 66–80. Available at: https://doi.org/10.1016/j.compenvurbsys.2007.06.001.

Lid, I.M. and Solvang, P.K. (2016) *(Dis)ability and the experience of accessibility in the urban environment*, *Alter*. Elsevier Masson SAS. Available at: https://doi.org/10.1016/j.alter.2015.11.003.

Lima, J.P. *et al.* (2019) 'A spatial fuzzy multicriteria analysis of accessibility: A case study in Brazil', *Sustainability (Switzerland)*, 11(12). Available at: https://doi.org/10.3390/su11123407.

Madanipour, A. (2010) *Whose Public Space?* Edited by A. Madanipour. Routledge. Available at: https://doi.org/10.4324/9780203860946.

Mahmoudi, A. and Mazloomi, M. (2014) ‘Urban Spaces, Disabled, and the Aim of a City for All: A Case Study of Tehran’, *International Journal of Sciences: Basic and Applied Research (IJSBAR) International Journal of Sciences: Basic and Applied Research*, 14(1), pp. 530–537. Available at: http://gssrr.org/index.php?journal=JournalOfBasicAndApplied.

Matthews, M.H. (1995) ‘Private worlds and public places: mapping the environmental values of wheelchair users’, *Environment and Planning A*, 27(7), pp. 1069–1083. Available at: https://doi.org/10.1068/a271069.

Mavoa, S. *et al.* (2012) ‘GIS based destination accessibility via public transit and walking in Auckland, New Zealand’, *Journal of Transport Geography*, 20(1), pp. 15–22. Available at: https://doi.org/10.1016/j.jtrangeo.2011.10.001.

Meyers, A.R. *et al.* (2002) ‘Barriers, facilitators, and access for wheelchair users: substantive and methodologic lessons from a pilot study of environmental effects’, *Social Science & Medicine*, 55(8), pp. 1435–1446. Available at: https://doi.org/10.1016/S0277-9536(01)00269-6.

Morales, R., Somolinos, J. and Cerrada, J. (2013) ‘Dynamic control of a reconfigurable stair-climbing mobility system’, *Robotica*, 31(2), pp. 295–310. Available at: https://doi.org/10.1017/S0263574712000276.

Mouratidis, K. (2021) ‘Urban planning and quality of life: A review of pathways linking the built environment to subjective well-being’, *Cities*, 115, p. 103229. Available at: https://doi.org/10.1016/j.cities.2021.103229.

Nakamura, F. and Ooie, K. (2017) ‘A study on mobility improvement for intellectually disabled student commuters’, *IATSS Research*, 41(2), pp. 74–81. Available at: https://doi.org/10.1016/j.iatssr.2017.07.002.

Nakarmi, S. and Shrestha, S. (2022) ‘Proceedings of 12 th IOE Graduate Conference Accessibility in Public Buildings for People with Disability: A Case of Patan, Nepal’, in *Design for Inclusivity*, pp. 233–258. Available at: https://doi.org/10.1007/978-3-031-36302-3_18.

Nam, T. and Pardo, T.A. (2011) ‘Conceptualizing Smart City with Dimensions of Technology, People, and Institutions’, in *Proceedings of the 12th Annual International Conference on Digital Government Research*. Available at: https://doi.org/10.1145/2037556.2037602.

Nischith, K., Bhargava, M. and Akshaya, K. (2018) ‘Physical accessibility audit of primary health centers for people with disabilities: An on-site assessment from Dakshina Kannada district in Southern India', *Journal of Family Medicine and Primary Care*, 7(6), p. 1300. Available at: https://doi.org/10.4103/jfmpc.jfmpc_177_18.

Panta, Y.R. *et al.* (2019) 'Improving accessibility for mobility impaired people in smart city using crowdsourcing', in *Proceedings - 2019 Cybersecurity and Cyberforensics Conference, CCC 2019*. Institute of Electrical and Electronics Engineers Inc., pp. 47–55. Available at: https://doi.org/10.1109/CCC.2019.00-10.

Parra-Domínguez, J., Gil-Egido, A. and Rodríguez-González, S. (2022) 'SDGs as One of the Drivers of Smart City Development: The Indicator Selection Process', *Smart Cities*, 5(3), pp. 1025–1038. Available at: https://doi.org/10.3390/smartcities5030051.

Penchansky, R. and Thomas, J.W. (1981) 'The Concept of Access: Definition and Relationship to Consumer Satisfaction', *Med Care*, 19(2), pp. 127–140. Available at: https://doi.org/10.1097/00005650-198102000-00001.

Pot, F.J., van Wee, B. and Tillema, T. (2021) 'Perceived accessibility: What it is and why it differs from calculated accessibility measures based on spatial data', *Journal of Transport Geography*, 94. Available at: https://doi.org/10.1016/j.jtrangeo.2021.103090.

Prescott, M. *et al.* (2020) 'Factors that affect the ability of people with disabilities to walk or wheel to destinations in their community: a scoping review', *Transport Reviews*, 40(5), pp. 646–669. Available at: https://doi.org/10.1080/01441647.2020.1748139.

Pujiyanti, I. (2023) 'Study of Accessibility Principles for Persons with Disabilities in Yogyakarta City Spatial Regulation', in *IOP Conference Series: Earth and Environmental Science*. Institute of Physics. Available at: https://doi.org/10.1088/1755-1315/1218/1/012016.

Pyer, M. and Tucker, F. (2017) '"With us, we, like, physically can't": Transport, Mobility and the Leisure Experiences of Teenage Wheelchair Users', *Mobilities*, 12(1), pp. 36–52. Available at: https://doi.org/10.1080/17450101.2014.970390.

Qiu, N., Zhang, T. and Cheng, J. (2023) 'Examining the impact of spatial accessibility to rehabilitation facilities on the degree of disability: A heterogeneity perspective', *SSM - Population Health*, 23. Available at: https://doi.org/10.1016/j.ssmph.2023.101489.

Regierungsrat Kanton Zürich (2022) *Aktionsplan Behindertenrechte Kanton Zürich 2022-2025*. Zürich.

Reinhardt, J. *et al.* (2016) ‘Perceived impact of environmental barriers on participation among people living with spinal cord injury in Switzerland’, *Journal of Rehabilitation Medicine*, 48(2), pp. 210–218. Available at: https://doi.org/10.2340/16501977-2048.

Rico, C.I.V. (2021) ‘Smart Cities for all: Usability and disability bias’, *European Review of Digital Administration & Law - Erdal*, 2(1), pp. 157–169. Available at: https://doi.org/10.1016/j.cities.2022.103613.

Rodger, S. *et al.* (2019) ‘JourneyCam: Exploring experiences of accessibility and mobility among powered wheelchair users through video and data’, in *Conference on Human Factors in Computing Systems - Proceedings*. Association for Computing Machinery, pp. 1–15. Available at: https://doi.org/10.1145/3290605.3300860.

Sanford, J.A., Story, M.F. and Jones, M.L. (1997) ‘An Analysis of the Effects of Ramp Slope on People with Mobility Impairments’, *Assistive Technology*, 9(1), pp. 22–33. Available at: https://doi.org/10.1080/10400435.1997.10132293.

Schindler, A. (2017) *FactSheet Strategie ‘Smart City Zürich’*.

Schmidt, E. and Manser, J.A. (2003) *Richtlinien «Behindertengerechte Fusswegnetze» Strassen-Wege-Plätze*. Zurich.

Schweizerische Eidgenossenschaft (2022) *Implementing the 2030 Agenda for Sustainable Development: Voluntary National Review of Switzerland 2022*.

Schweizerischer Verband der Strassen- und Verkehrsfachleute VSS (2014) *Fussgängerverkehr, Hindernisfreier Verkehrsraum*.

Shahraki, A.A. (2021) ‘Urban planning for physically disabled people’s needs with case studies’, *Spatial Information Research*, 29(2), pp. 173–184. Available at: https://doi.org/10.1007/s41324-020-00343-9.

Stehlíková, J. and Řezník, T. (2018) ‘An accessible brno city centre for people with impaired mobility’, *Journal of Maps*, 14(1), pp. 81–87. Available at: https://doi.org/10.1080/17445647.2018.1526716.

Tanted, S. *et al.* (2020) ‘Database and Caching Support for Adaptive Visualization of Large Sensor Data’, in *Proceedings of the 7th ACM IKDD CoDS and 25th COMAD*. New York, NY, USA: ACM, pp. 98–106. Available at: https://doi.org/10.1145/3371158.3371170.

Toch, E. *et al.* (2019) 'Analyzing large-scale human mobility data: a survey of machine learning methods and applications', *Knowledge and Information Systems*, 58(3), pp. 501–523. Available at: https://doi.org/10.1007/s10115-018-1186-x.

United Nations (2024) *Accessibility: A guiding principle of the Convention*. Available at: https://www.un.org/esa/socdev/enable/disacc.htm (Accessed: 20 June 2024).

United Nations, C. (2019) *Committee on the Rights of Persons with Disabilities List of issues in relation to the initial report of Switzerland* A. Purpose and general obligations (arts. 1-4)*. Available at: https://www.ohchr.org/EN/HRBodies/CRPD/Pages/CRPDStatements.aspx.

Velho, R. (2018) 'Transport accessibility for wheelchair users: A qualitative analysis of inclusion and health', *International Journal of Transportation Science and Technology*, 8(2), pp. 103–115. Available at: https://doi.org/10.1016/j.ijtst.2018.04.005.

Velho, R. (2021) *'They're changing the network just by being there': Reconsidering infrastructures through the frame of disability studies 1*. Available at: https://dsq-sds.org/index.php/dsq/article/view/7087/5939.

Visnes Øksenholt, K. and Aarhaug, J. (2018) 'Public transport and people with impairments–exploring non-use of public transport through the case of Oslo, Norway', *Disability and Society*, 33(8), pp. 1280–1302. Available at: https://doi.org/10.1080/09687599.2018.1481015.

Wheeler, B. *et al.* (2020) 'Personalized accessible wayfinding for people with disabilities through standards and open geospatial platforms in smart cities', *Open Geospatial Data, Software and Standards*, 5(1). Available at: https://doi.org/10.1186/s40965-020-00075-5.

Wu, Y. *et al.* (2022) 'Alignment Work for Urban Accessibility: A Study of How Wheelchair Users Travel in Urban Spaces', *Proceedings of the ACM on Human-Computer Interaction*, 6(CSCW2). Available at: https://doi.org/10.1145/3555165.

Yılmaz, M. (2018) 'Public Space and Accessibility', *ICONARP International Journal of Architecture & Planning Received*, 6, pp. 1–14. Available at: https://doi.org/10.15320/ICONARP.2018.46-E-ISSN.

Zanatta, A.L. *et al.* (2016) 'Software Crowdsourcing Platforms', *IEEE Software*, 33(6), pp. 112–116. Available at: https://doi.org/10.1109/MS.2016.151.

Zhou, H. *et al.* (2012) ‘Intelligent urban public transportation for accessibility dedicated to people with disabilities’, *Sensors (Switzerland)*, 12(8), pp. 10678–10692. Available at: https://doi.org/10.3390/s120810678.

Zimmermann-Janschitz, S. (2018) ‘Geographic information systems in the context of disabilities’, *Journal of Accessibility and Design for All*, 8(2), pp. 161–193. Available at: https://doi.org/10.17411/jacces.v8i2.171.

Appendix

A1: Qualitative Questionnaire: Affected person interview

Qualitativer Fragebogen: Betroffenen Interviews

Herzlich Willkommen zu diesem Interview im Rahmen meiner Masterarbeit. Vielen Dank, dass Sie sich Zeit nehmen an diesem Interview teilzunehmen. Ihr Beitrag ist von unschätzbarem Wert für meine Forschung.

Thema der Befragung:

Diese Befragung zielt darauf ab, die Perspektiven von Menschen im Rollstuhl im Hinblick auf Hindernisse im öffentlichen Raum besser zu verstehen. Die Befragung ist eingebettet in folgende generelle Forschungsfragen der Masterarbeit:

- Welche Normen und Richtlinien gibt es für die Zugänglichkeit öffentlicher Räume für Menschen mit Gehbehinderungen?
- Entspricht das Untersuchungsgebiet Lengg den Normen und Richtlinien für die Barrierefreiheit im öffentlichen Raum für Menschen mit Gehbehinderung?
- Welche Verbesserungen können vorgenommen werden und inwieweit kann die digitale Umsetzung des Smart-City-Ansatzes angewendet werden?

Ihre persönlichen Erfahrungen und Sichtweisen sind dabei von entscheidender Bedeutung.

Forschungsfrage des Interviews:

1. Inwiefern beeinflussen wahrgenommene Hindernisse und Erfahrungen im öffentlichen Raum die Lebensqualität von Menschen im Rollstuhl?
2. Welche Verbesserungen der Barrierefreiheit schlagen die betroffenen Personen im Bereich Barrierefreiheit vor, auch im Hinblick auf die digitale Transformation?

In diesem Kontext interessieren uns zum einen Ihre persönlichen Erfahrungen im Allgemeinen, als auch im spezifischen Untersuchungsgebiet. Zum anderen möchten wir Sie auch einladen, eine Expertenposition einzunehmen und die Fragen aus Sicht möglicher anderer Betroffenen zu beantworten. Vielen Dank für Ihre Bereitschaft, Ihr Wissen und Ire Erfahrung zu teilen.

Einverständniserklärung

Durch Ihre Teilnahme an diesem Interview erklären Sie sich damit einverstanden, dass Ihre Antworten für die Zwecke dieser Masterarbeit verwendet werden und Audioaufnahmen gemacht werden. Alle

Informationen werden vertraulich behandelt, und Ihre Anonymität wird gewahrt. Sie haben das Recht, die Befragung jederzeit abzubrechen, wenn Sie dies wünschen, ohne dass dies negative Konsequenzen für Sie hat.

Audioaufnahme:

Zum Zwecke der Genauigkeit und zur Gewährleistung einer detaillierten Analyse wird das Interview aufgezeichnet. Die Aufnahmen dienen ausschließlich der Forschung und werden vertraulich behandelt. Ihre persönlichen Daten werden dabei anonymisiert.

Freiwillige Teilnahme:

Ihre Teilnahme an diesem Interview ist vollständig freiwillig, und Sie können sich jederzeit zurückziehen, wenn Sie sich unwohl fühlen oder das Gespräch beenden möchten.

Zum Abschluss:

Falls Sie weitere Fragen haben oder zusätzliche Informationen benötigen, stehe ich Ihnen gerne zur Verfügung. Meine Kontaktdaten finden Sie im beiliegenden Informationsdokument.

Vielen Dank, dass Sie einen Beitrag zu meiner Forschung leisten!

Generelle Fragen

1. Altersangabe: Bitte nennen Sie Ihr Geburtsdatum.
2. Welche Art von Gehbeeinträchtigung haben Sie und in welchem Masse sind sie in Ihrer Mobilität / im Alltag beeinträchtig?
3. Wie lange sind Sie schon auf einen Rollstuhl angewiesen?
4. Welche Art von Rollstuhl nutzen Sie im öffentlichen Raum (Power Chair, manuell, etc.)
5. Benötigen Sie Hilfe von einer Person/Assistenz, wenn Sie im öffentlichen Raum unterwegs sind?
6. Wie weit ist Ihr Wohn-von Ihrem Arbeitsort entfernt?
7. Welche Rolle spielt die Barrierefreiheit im öffentlichen Raum für Sie?
8. Nutzen Sie öffentliche Verkehrsmittel (öV)? Wenn nicht, was sind die Gründe dafür?
9. Gibt es Präferenzen, welchen öffentlichen Transport Sie bevorzugen? Wenn Ja, welche Art (Bus, Tram, oder Zug)?
10. Legen sie häufiger grössere Strecken mit dem öV zurück? Wie oft?

Alltagserfahrungen generell

11. Wie oft sind Sie im öffentlichen Raum unterwegs? (pro Woche etc.)

12. Wie erleben Sie den öffentlichen Raum im Alltag mit ihrem Rollstuhl?
13. Inwiefern beeinflussen wahrgenommene Hindernisse im öffentlichen Raum Ihre Lebensqualität?
14. Welche Art von Barrieren erleben Sie im öffentlichen Raum am häufigsten?
    a. Können Sie Beispiele dazu nennen?
    b. Gibt es spezifische Orte oder Situationen, die besonders herausfordernd sind?

Stellen Sie sich bitte vor, Sie seien am Zürich Hauptbahnhof:

15. Gibt es Hindernisse oder Barrieren, die Ihnen den Zugang zu öffentlichen Verkehrsmitteln (Bus, Tram, Zug) erschweren oder unmöglich machen?

Bilder zeigen von zum Beispiel Noppen bei Lichtsignalen:

16. Haben Sie Erfahrungen gemacht oder beobachtet, wie sich Massnahmen zur Barrierefreiheit für Sehbeeinträchtigte und Gehbeeinträchtigte gegenseitig beeinflussen?

Speziell auf das Untersuchungsgebiet bezogen

Ab diesem Abschnitt wird eine Karte und Fotos des Untersuchungsgebietes gezeigt, damit die Visualisierung fokussierter ausfällt.

17. Wie oft sind Sie hier im Untersuchungsgebiet unterwegs (pro Woche etc.)
18. Sind Sie mehrheitlich allein oder mit einer Assistenzperson unterwegs?
19. Wie erleben Sie den öffentlichen Raum im Untersuchungsgebiet im Alltag mit ihrem Rollstuhl?
20. Welche Art von Barrieren erleben Sie dort am häufigsten?
    a. Können Sie Beispiele dazu nennen?
    b. Gibt es spezifische Orte oder Situationen, die besonders herausfordernd sind?
21. Gibt es Hindernisse oder Barrieren, die Ihnen den Zugang zu öffentlichen Verkehrsmitteln erschweren oder unmöglich machen?

Ab hier werde ich zunächst nach dem Untersuchungsgebiet fragen und danach im allgemeineren öffentlichen Raum.

Verbesserungsvorschläge für das Untersuchungsgebiet

22. Was würden Sie sich wünschen, um die Barrierefreiheit im Untersuchungsgebiet zu verbessern?

23. Haben Sie konkrete Ideen für Massnahmen oder Veränderungen, auch im Hinblick auf die digitale Transformation?
24. Was könnte an der Haltestelle Balgrist oder Bahnhofstrasse für die barrierefreie Nutzung verbessert werden?

Notwendigkeit von Unterstützung für das Untersuchungsgebiet

25. Gibt es bestimmte Ressourcen oder Unterstützung, die Ihnen helfen würden, den öffentlichen Raum besser zu nutzen, gegebenenfalls mit Hilfe Ihres Smartphones?
26. Informationstafeln und Beschilderung:
    a. Welche Art von Informationen oder Hinweise würden Ihnen im öffentlichen Raum helfen, sich besser zurechtzufinden?
    b. Gibt es Orte im Untersuchungsgebiet an welchen Sie mehr Inforationshinweise (Tafeln und Beschilderungen) vermissen/ wünschen?

Jahreszeitliche und Wetterbedingte Herausforderungen für das Untersuchungsgebiet

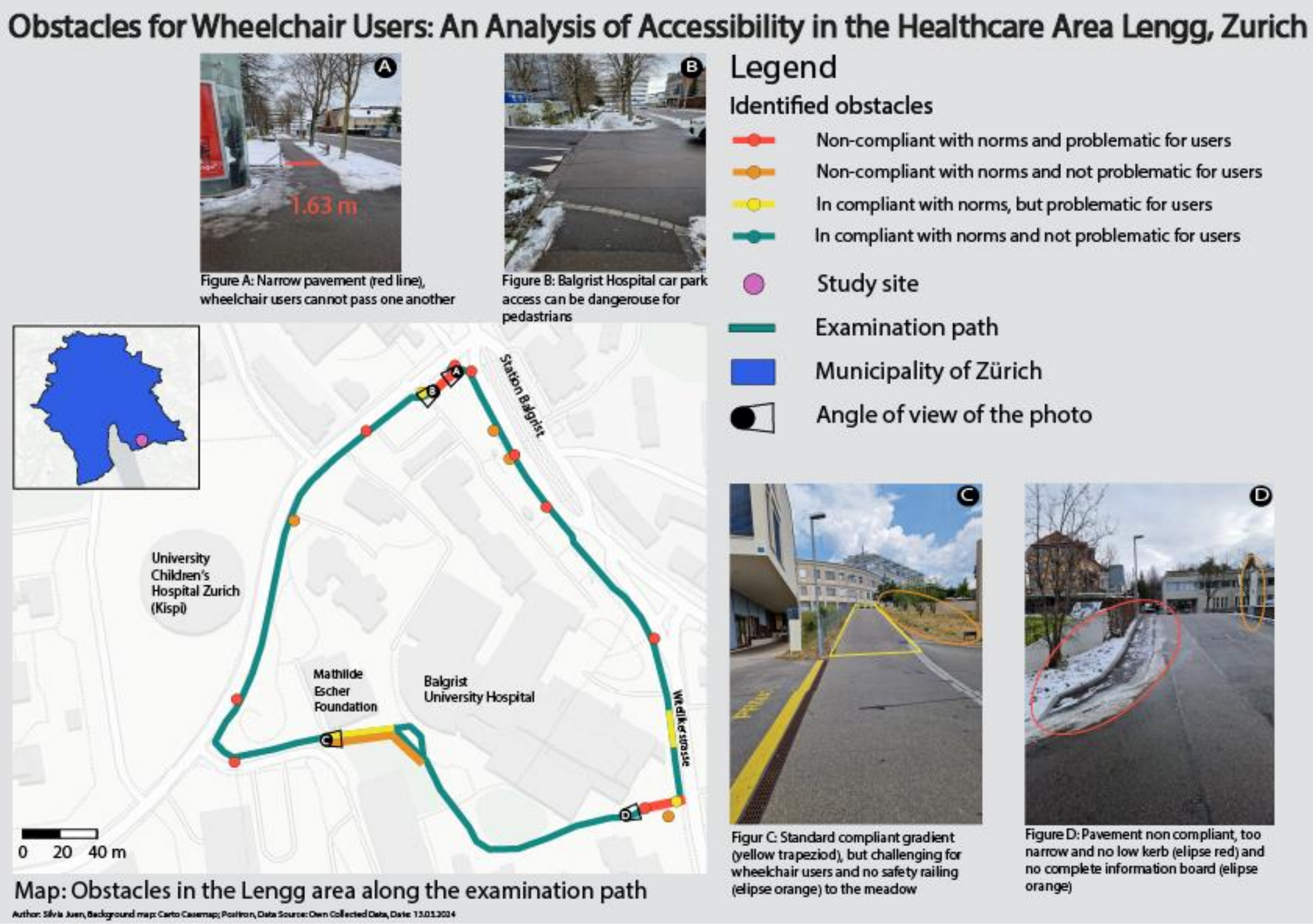
Spezifisch nach Wettersituationen fragen, ob Sommer, Winter oder Herbst, Regen oder Eis.

27. Beeinflusst das Wetter oder bestimmte Jahreszeiten Ihre Mobilität im öffentlichen Raum?
28. Gibt es spezifische Herausforderungen, die mit bestimmten Wetterbedingungen verbunden sind?

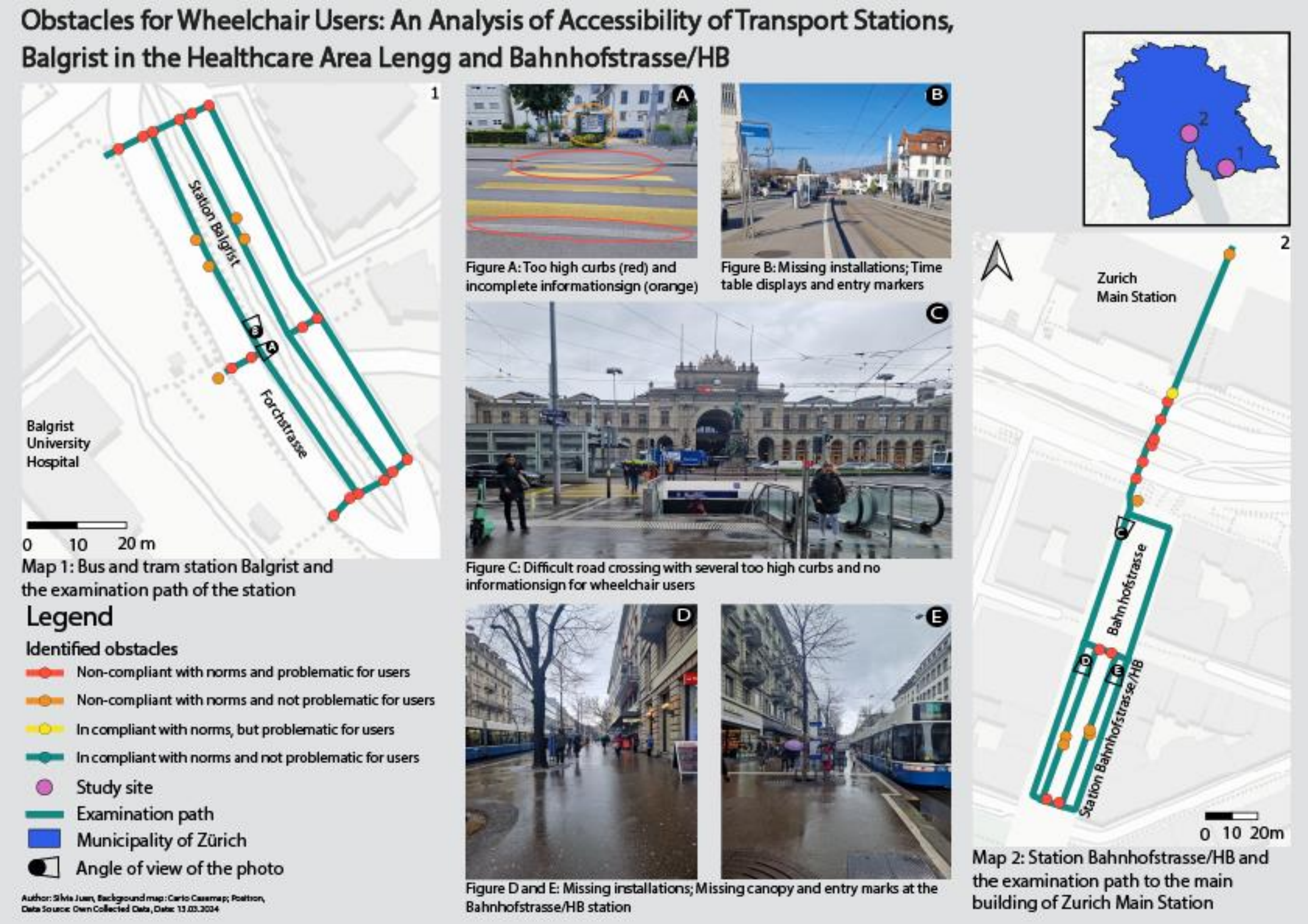
Positive Beispiele für das Untersuchungsgebiet

29. Zum Beispiel, wenn Sie an den HB denken oder an das Untersuchungsgebiet?
30. Haben Sie Erfahrungen gemacht, bei denen Sie positiv überrascht waren von Barrierefreiheit in bestimmten Bereichen?
31. Können Sie Beispiel für eine gelungene barrierefreie Gestaltung des öffentlichen Raumes nennen?

A2: Map of the mobility barriers found and identified in the study area in the Lengg healthcarea area



A3: Map of the mobility barriers found and identified in the study area of the route to Zurich main station



A4: The catalogue for accessibility standards for public spaces for wheelchair users

From the next page onwards, the *Accessibility Standards for Public Spaces for Wheelchair Users* catalogue, created for this work, is attached.

Declaration of Authorship

I, Silvia Juen, hereby declare that the submitted thesis is the result of my own, independent work. All external sources are explicitly acknowledged in the thesis.

Name: Silvia Juen

Matriculation Number: 17-642-471

Date: 30.06.2024

Signature: ……………………………………………………………………