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The barriers on the walkways' formation for wheelchair users in Wuhan city

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Abstract

This study investigates the barriers affecting the mobility of wheelchair users (WUs) within the walkways network of the city of Wuhan in China. Utilizing an access audit and comparative research approach, the research aimed to identify and evaluate obstructions affecting WUs' navigation. The methodology involved two key components: visual observations and a comparison against Chinese accessibility standards, specifically the Codes for Accessibility Design (GB50763-2012) and the General Code for Barrier-free Construction and Municipal Engineering (GB 55019-2021). A comprehensive evaluation checklist, encompassing structural and physical barriers, access points, pick-up/drop-off areas, area information, and traffic control, was employed to systematically assess the environment. Key findings reveal several critical issues, including uneven pavement surfaces, insufficient curb cuts, and overcrowded sidewalks. These problems significantly impair smooth navigation and increase safety risks. Uneven sidewalks often cracked or poorly maintained, exacerbate travel discomfort and accident risk. Inadequate curb cuts restrict access to sidewalks, compelling WUs to navigate unsafe areas or alternative routes. Overcrowded sidewalks and obstructive street furniture further impede maneuverability. The research underscores the need for improvements in urban planning to create a more accessible and barrier-free environment for wheelchair users. Recommendations are aimed at enhancing walkway design to ensure safer and more efficient mobility for WUs.

Keywords: Accessibility; Wheelchair Users; Universal Design; Chinese Standards; Walkways Formation; Physical Barriers

1. Introduction

The accessibility of public spaces is a fundamental component of development in the pursuit of social progress and inclusivity. Everyone has to make a route in a walkway environment on a daily basis for their personal needs, so the ability to move freely through the built environment is a very valuable privilege. But for people who use wheelchairs getting around in cities can sometimes want to navigate a maze full of obstacles. These issues go beyond simple frustrations because they create significant obstacles to the realization of fundamental rights by impeding social interaction, economic participation, and even basic mobility. With the passage of the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) in 2006 the foundation for an accessible society was established early in the twenty-first century [1]. According to Article 9 of the UNCRPD, equity in access to the physical environment, transportation and information is crucial for enabling people with disabilities to live independently and participate fully in all aspects of life [2]. The identification and removal of barriers across multiple domains such as transportation, infrastructure and information dissemination are central to this concept.

The concept of universal design has surfaced as a guiding principle in the pursuit of universal accessibility supporting solutions that improve usability for people of all ages and abilities [3]. This commitment was further cemented in 1990 with the enactment of federal legislation known as the Americans with Disabilities Act (ADA) which forbade discrimination against individuals with disabilities in public areas [4]. Standardizations that follow like the ADA

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Standards for Accessible Design establish minimal requirements to guarantee accessibility in newly built and renovated spaces [5]. Even with these advancements a sizable segment of the world's population still faces accessibility obstacles. Disabilities affect 1.3 billion people worldwide or about 16 percent of the total population [6]. Furthermore, demographic changes such as an aging population implies a continuous increase in these numbers highlighting the critical need to address accessibility-related issues [7].

Transportation serves as a poignant example of the intersection between accessibility and daily life. Reports indicate that a substantial portion of disabled individuals experience difficulties leaving their homes due to transportation obstacles [8]. Moreover, disparities in travel distances between individuals with and without disabilities underscore the systemic inequalities ingrained in urban infrastructure [9]. Additionally, people with disabilities tend to travel shorter distances and make fewer trips compared to those without disabilities, often relying on others for transportation and limiting travel to daytime hours [10]. In the United Kingdom, where one in four individuals identifies as disabled, disparities in transport access persist, leading to a significant reduction in travel frequency among disabled individuals as they do 30% fewer journeys per year than non-disabled individuals, a statistic that has not improved in over two decades [11]. The impact of these barriers extends beyond mere inconvenience while it poses significant implications for health and well-being. For wheelchair users with daily propulsion activity an average of 1.6 km, a commute may consume up to five times more time compared to non-disabled individuals, highlighting the profound repercussions of inaccessible environments [12, 13]. The World Health Organization (WHO) stresses that having access to physical activity is a fundamental right that has an impact on health outcomes rather than just being a convenience [14]. In order to decrease physical inactivity by 15% by 2030 the WHOs Global Action Plan on Physical Activity 2018–2030 provides guidelines for boosting physical activity globally [15].

In light of this, it is important to understand the barriers that wheelchair users face in urban environments. This paper aims to highlight the ubiquitous nature of accessibility barriers and their implications for mobility and participation, shedding light on the difficulties faced by wheelchair users in Wuhan's route environment. By identifying these challenges, we highlight how crucial it is to create environments free from barriers that protect the rights and dignity of every person, promoting a more inclusive and equitable society for future generations.

2. Materials and Methods

This study employed an access audit and comparative research approach [16, 17] to evaluate the barriers faced by wheelchair users (WUs) in the walkways of Wuhan city, China. The research involved two main categories: visual observation and comparison to Chinese accessibility standards. The methodology aimed to identify existing problems in the city's walkways environment, those obstructing WUs' movements from one location to another.

The data collection began with a detailed site survey and visual observation to assess the walkway environment. The audit focused on identifying barriers that affect WUs' transportation across the city. A comprehensive evaluation checklist was constructed based on Chinese standards, including the Codes for Accessibility Design (GB50763-2012) and the General Code for Barrier-free Construction and Municipal Engineering (GB 55019-2021).

The checklist included five main sectors: 1) Structural and Physical Barriers, 2) Access Points and Connections, 3) Passengers Pick-up and Drop-off Points, 4) Area Information and Pedestrian Guidance, and 5) Traffic Control and Safety. Elements observed included curb ramps, general ramps, and area morphology, walking surfaces, pedestrian crossings, transportation terminals, building entrances, guidance information, traffic safety, parking lots and other general obstructions.

All identified problem areas were photographed as evidence and used in data analysis. The collected data were compared to the Chinese standards to determine the level of accessibility. This research aimed to estimate the current access situation and recommend improvements for WUs. The main objective was to enhance planning for a barrier-free urban environment, ensuring the walkway routes are accessible and usable by WUs.

2.1. Wuhan City Profile

Wuhan is the capital of Hubei Province in central China, located where the Yangtze and Han Rivers converge. It is a major city in the area acting as a hub for integrated transportation as well as an industrial and educational complex. The city has 13 districts, including the old towns of Hankou, Hanyang and Wuchang which make up the urban area. Also, Wuhan has 6 functional zones for economic and industrial development [21]. As of 2021, Wuhan permanent resident population is 13.65 million, a rapid urbanization and one of the biggest cities in China. The city has a total area of 8,569.15 square kilometres, urban built-up area is 885.11 square kilometres, increased more than 4 times from 214.22

km^2 as it was in 2004. The maximum distance on x-axis and y-axis in Wuhan coordinate system is about 134 km and 155 km respectively [18, 22].

Wuhan has gone through tremendous economic transformation and growth with infrastructure and industrial development investments. In the past decades, it has moved from traditional industries to a strong secondary industry and contributed a lot to the GDP. The 2004 provincial plan for Wuhan Metropolitan Area has further solidified its position as a growth pole in central China and promoted regional integration and economy [18, 19]. While Wuhan has been a poster city for the region's economic success, challenges remain. These span urban planning, transportation management as well as environmental sustainability and housing market dynamics. At the heart of these is rapid urbanization, requiring comprehensive planning strategies in order to manage this growth effectively and ensure sustainability. Policy priorities have recently turned to developing governance frameworks and mechanisms that will help the city remain economically resilient and continue progress as a livable place in years to come [20].

With its fast urban growth and revolutionary development Wuhan emerges as a dynamic city at the center of China's economic landscape. Wuhan is positioned for long-term prosperity due to its advantageous location proactive governance and significant investments. In light of changing local and international circumstances addressing persistent issues via integrated urban planning and community involvement will be essential to determining the city's future course. Wuhan provides insightful information about how cities can adapt to rapid growth and change by highlighting the opportunities and complexities of modern urbanization.

2.2. People with Disabilities and Aging Population

China is home to an estimated 85 million individuals with disabilities, making up approximately 6% of the total population, of which 24.72 million have physical disabilities. A survey conducted in 2006 revealed that 17.8% of households had at least one family member with a disability. Disability categories in China are divided into visual, hearing, physical, speech, intellectual, and psychiatric, each with four levels of severity. By 2021, approximately 38 million people had received official disability certificates. Based on these statistics, Wuhan is estimated to have around 800,000 individuals with disabilities [23, 24].

Furthermore, China is experiencing a rapid expansion of its elderly population, with 267 million individuals aged 60 and above in 2021. It is projected that this number will surpass 300 million by 2025 and exceed 400 million by 2035, accounting for over 30% of the total population [25]. This shift in demographics, attributed to longer life expectancy and reduced birth rates, presents significant challenges for public health and socioeconomic progress. Addressing these challenges involves the development of comprehensive health and social care systems, especially in rural areas, and the establishment of age-friendly urban environments. Essential innovations such as internet-based medical platforms and community-led care systems are needed to effectively meet these requirements. Policy interventions that ensure fair access to care play a crucial role in enhancing the quality of life for both elderly individuals and their caregivers [26, 27].

2.3. The Street Environment in Neighbourhoods

Neighbourhoods' environments significantly influence residents' quality life, urban vitality, and cultural preservation, as highlighted by various studies on public spaces, street networks, and residents' perceptions. In Wuhan revealed that rapid urbanization threatens the preservation of its rich historical heritage. Despite notable sites districts suffer from disorderly urban spaces, inadequate road connectivity, and insufficient green areas, leading to reduced public space quality and walkability [28]. The importance of street design in urban planning, demonstrating that leisure activities such are affected by closeness, underscoring the need for optimized street networks to enhance urban vitality [29].

Examining the street quality perception shows that beauty and wealth were rated higher along the Yangtze River, whereas older residential areas received negative perceptions. Enhancing green spaces and sky visibility were identified as key to improving overall street quality and resident experiences [30]. Resident participation in neighborhoods rehabilitation identifies critical factors such as financial incentives, transparent information dissemination and trust. Different stakeholders emphasized varied priorities, necessitating tailored strategies to foster effective resident engagement in rehabilitation projects [31]. Additionally, the evaluation of Wuhan's neighbourhoods by using an urban livability index revealed disparities among 13 districts, with Jianghan, Wuchang, and Jiangan achieving higher scores due to balanced development, Hongshan below middle level, while Dongxi Lake and Qingshan lagged due to infrastructure deficiencies [32].

Street Pedestrian Friendliness and Usability, identifying commercial streets like Jianghan Road as the safest and most pedestrian-friendly, while eastern lifestyle streets required improvements [33]. Investigating neighbourhoods' satisfaction revealed the importance of aligning amenities and outdoor activity areas with residents' demands,

particularly in old danwei neighborhoods with higher elderly dependency [34]. The street centrality significantly influences urban vitality, with betweenness being crucial for walking and straightness for driving, highlighting the need to consider street network configurations in urban planning [35]. This collectively demonstrate that enhancing livability, pedestrian friendliness, amenities, and urban vitality requires addressing economic, social, and environmental factors, improving pedestrian environments, aligning amenities with residents' needs, and optimizing street centrality to create more livable and vibrant neighborhoods in rapidly developing cities like Wuhan.

2.4. Accessibility Standards

In China, standards for accessibility play a crucial role in ensuring equitable access for people with disabilities. The Codes for Accessibility Design (GB 50763-2012) and the General Codes for Accessibility of Buildings and Municipal Engineering Projects (GB 55019-2021) represent significant strides in this area. GB 50763-2012 provides comprehensive guidelines for designing accessible environments, emphasizing features such as accessible routes, facilities, and communication aids to enhance inclusivity. This standard is pivotal in promoting universal design principles across various infrastructure projects, including public buildings and transportation facilities [36].

Similarly, GB 55019-2021 updates and expands upon previous regulations, aiming to further improve accessibility standards in urban development and infrastructure projects. It addresses advancements in assistive technologies and design strategies, ensuring that new constructions and renovations comply with rigorous accessibility criteria. This standard not only focuses on physical accessibility but also integrates considerations for sensory impairments and cognitive disabilities, reflecting a holistic approach to inclusivity [37].

These standards underscore China's commitment to enhancing the quality of life for individuals with disabilities by fostering environments that are not only accessible but also respectful of diverse needs. By adhering to these guidelines, architects, engineers, and urban planners contribute to a more inclusive society where everyone, regardless of ability, can participate fully in civic life. Continuous updates and adherence to these standards are crucial as China continues to urbanize rapidly, ensuring that accessibility remains a cornerstone of its development agenda.

2.5. The new Law for people with Disabilities on Barrier-free Design

The new Law on Barrier-free Design for People with Disabilities, effective from September 1, 2023, marks a significant step forward in enhancing accessibility and inclusivity in public spaces and buildings. This legislation mandates rigorous standards for architectural design, ensuring that all facilities are accessible to individuals with disabilities. By implementing comprehensive guidelines for ramps, elevators, signage, and other accommodations, the law aims to eliminate physical barriers that hinder mobility and participation in society [38]. This proactive approach not only addresses longstanding issues of accessibility but also aligns with international standards set forth by the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD), emphasizing the right to full and equal participation in all aspects of life [1]. Furthermore, the law stipulates penalties for non-compliance, thereby incentivizing businesses and public entities to prioritize accessibility during construction and renovation projects [39]. The Law on Barrier-free Design represents a commendable effort towards creating a more inclusive environment where people of all abilities can live, work, and interact without limitations.

3. The Barriers on the walkways' network which affects the mobility of Wheelchair Users

The urban walkways environment has been designed to facilitate pedestrian movement, thus there exists a critical but often overlooked concern of the barriers that impede the mobility of wheelchair users (WUs). The way people navigate through unfamiliar environments offers insights into the challenges faced by individuals reliant on mobility aids. For WUs, accessibility is not merely a matter of convenience but a fundamental aspect of daily life, shaping their ability to independently navigate and participate in their communities. Despite regulations and standards aimed at ensuring inclusivity, recent audits have unveiled pervasive issues along sidewalks, leisure paths, and general community walkways. These audits highlight numerous obstructions which ranging from inadequate access points to surface conditions that significantly prevent the seamless movement of wheelchair users. The intersection between pedestrian pathways and other modes of transportation further complicates matters, often exacerbating accessibility issues. As cities strive to harmonize the needs of diverse pedestrian groups, the barriers identified in Wuhan city, underscore the ongoing imperative for meticulous design, maintenance, and regulatory adherence in ensuring that public spaces are truly accessible to all.

Figure 1 The Route Environment for wheelchair users on the Walkways Network

Table 1 Checklist of the Walkways Network

Sectors	Type of Elements
Structural and Physical Barriers	Walkways surface, Walkways width, Area morphology gradient, Street furniture, Curbs edges, Street gutter/drainage, Street curbs, Parking rails
Access and Connection Points	Curb ramps, Crosswalks, Ramps and Entrances Access
Passengers Pick-up and Drop-off points on Means of Transport (Public and Private)	Bus stops, Metro stations, Private Transport - Taxi and Personal cars
Area Information and Pedestrian Guidance	Information Maps, Signage and Guidance
Traffic control and Safety	Parking, Traffic signals, Walkways use, Walkway and Road markings

3.1. Structural and Physical Barriers

Wheelchair Users face significant challenges due to structural and physical barriers embedded in walkways, which can severely impact their mobility and safety. One of the primary issues that were found is the condition of the walkways' surfaces. Irregular textures, uneven paving, and large openings between paved elements often create unstable and hazardous conditions. There are surface openings larger than 30 mm in diameter, making it hazardous for the wheelchair to roll over them. These issues are typically the result of improper compression of the sub-base during installation, leading to an unstable surface where paved materials lack cohesion. The free-paved technique, which lacks connecting materials in the sub-base, exacerbates this problem by failing to stabilize the paved elements, thus contributing to a bumpy and unreliable surface. The deterioration is further compounded by poor maintenance practices, such as broken sections and missing tiles, which contribute to a rough and uneven pathway. Additionally, the use of low-quality materials often results in crumbling pavements, further impeding safe and smooth navigation.

Figure 2 Walkways surface condition

In Figure 2A, there is a surface deformation, and in Figure 2B, there is an abruption and movement of paved tiles of walkways. Figure 2C at Huazhong University of Science and Technology (HUST) Youth Park and Figure 2D at East Lake Park show the walkways with rough paved materials and large openings between paved elements.

Figure 3 Walkway paving and damaged surface

Figure 3A shows a typical detail of the sidewalk construction technique, and in 3B, the repair of a deformed walkway at HUST, because of its uncompacted sub-base. In Figure 3C, there are damaged surfaces in front of South Gate 2, and in Figure 3D, a newly made curb ramp was damaged a short time after its construction.

The walkways width, the placement of street furniture and bicycle parking facilities are another area of concern. Frequently, such installations are not designed with accessibility in mind, resulting in narrow or cluttered walkways. This misplacement forces wheelchair users to navigate around or through obstacles, which can be both challenging and dangerous. The width of the walkways also poses significant barriers to free movement. Inadequate sidewalk width, especially where it narrows unexpectedly, creates difficulties for wheelchair users, as does the complete absence of sidewalks in some areas. Such design flaws not only limit maneuverability but can also force WUs into hazardous situations on streets or other vehicular traffic areas. Surface abnormalities, such as subsidence, landslides, morphological steep hills with gradient issues or receding pavements, introduce further obstacles that can be dangerous and challenging to navigate.

Figure 4 Walkways formation

In Figure 4A, there is a narrow sidewalk of about 0.7 m in width instead of 1.50 m, including on street furniture such as utility poles. There are also abnormal gutters and drainage grates that obstruct free movement on the route. In Figure 4B, there is an absence of a sidewalk. In Figure 4C, there is a gradient issue on the walkway with steep slopes, and in Figure 4D, there is a morphological issue with steep hills in the walkway environment in Hust, especially in the area by Yujia Mountain.

Other critical barriers include curbs and drainage features found. Raised curbs without proper curb cuts, and poorly designed street gutters or drainage grates, present substantial hazards. These elements are often not aligned with accessible design principles, making transitions between the roadway and sidewalks difficult. The presence of parking

rails, street furniture and other obstructions can further intrude into the path of travel, creating additional hazards. The physical and structural deficiencies in walkways, ranging from uneven surfaces and inadequate width to poorly designed curbs and drainage systems significantly affect wheelchair users. These barriers underscore the need for more thoughtful and inclusive urban planning that considers the needs of all users, ensuring safe, smooth, and accessible pathways.

Figure 5 Obstructions of free movement on walkways environment

The street gutter in Figure 5A creates a difficult access point on the sidewalk for WUs. In picture 5B, stairs, curb edges, and parking rails block access to the sidewalk. The walkways in HUST often have manholes, which are mostly placed in the middle of the way, usually for rainwater drainage (Figure 5C), making the route uncomfortable. Furthermore, on the way to the South Gate 4 of the university (Figure 5D), there are sidewalks without curb cuts and utility poles in the middle of them, making pedestrians walk through the road.

3.2. Access and Connection Points

Curb ramps and ramps are critical access points in the walkways network, facilitating the mobility of wheelchair users (WUs). However, many of these access points fail to meet established standards, posing significant challenges. One major issue is the steepness of ramps at the junctions of sidewalks and carriageways. Such steep ramps create a dangerous incline that can be difficult to navigate and can potentially lead to accidents. Many curb ramps and ramps, even those newly constructed, have slopes greater than 20%, which exceeds the minimum standards. The standards require curb ramps to have slopes between 5% and 8.3%, and ramps should not exceed slopes depending on their running length and height of the transition. Furthermore, the transition between the ramp and the carriageway often includes a height difference that exacerbates the difficulty for WUs, who may find it challenging to manage the uneven surface.

Figure 6 Curb ramps

In Figure 6A, there is a full-width single-sided curb ramp that had recently undergone partial modification but remains too steep, with 29.2% at the start point and 11.6% in the overall area instead of 5%. For the built-up curb ramp, which afterwards added extra (Figure 6B), the slope is 25.2% instead of 8.3%, as is the maximum slope for general curb ramps. A newly made three-sided curb ramp, Figure 6C, has a slope of 19.3 instead of 8.3%. The curb ramp in Figure 6D, which transits between carriageways within different height levels, has no rest platform, which creates hazards for all pedestrians crossing the street, and the slope is 24.5% instead of 5% for a single-sided curb ramp.

Crosswalks and general walkways connections often does not provide smooth transition from carriageway to the sidewalk, particularly most of them has curb edges which exceeds the minimum requirement, which is 10mm, has damages on the surfaces or are interrupted. Major roads often have crosswalks connected with pedestrian traffic islands, presenting additional barriers. These islands can obstruct the path, forcing wheelchair users to manoeuvre around them, which can be both physically demanding and potentially hazardous. Additionally, elevated or raised walkways with steep slopes can further complicate navigation, creating difficulties for WUs who must either ascend or descend these inclines.

Figure 7 Crosswalks and general walkways connections

The pedestrian traffic island can be difficult to access by WUs (Figure 7A), as there are curb edges with more than 10 mm, which is the maximum height. The crosswalk in Figure 7B connects with a damaged sidewalk, creating discomfort for any pedestrian, especially for WUs. In Figure 7C, the crosswalk has an uneven surface to a manhole and is interrupted. The sidewalk in Figure 7D has very steep longitudinal and transverse slopes that connect to a private entrance, making the passage difficult for WUs.

The access of public buildings and other buildings that provide services to the general public, such as restaurants, shopping centres, museums, university buildings, and other government buildings is another area of concern. Many of these facilities have not fully embraced accessible design principles. Narrow doorways and insufficient pull spaces often prevent smooth entry, discouraging or even deterring WUs from entering these establishments. The lack of accessible entryways exacerbates the problem, limiting the ease with which WUs can access essential services and amenities.

The physical strain experienced by wheelchair users due to challenging ramp characteristics such as excessive running slopes, cross-slopes, running length, and height is a significant concern. Prolonged use of poorly designed ramps can lead to increased strain and potential functional performance deficits. As ramp slopes become steeper, even if within permissible limits, the physiological strain increases, potentially causing fatigue and reducing the overall mobility of WUs.

Figure 8 Buildings' entrances and public space ramps

Building approach areas frequently include problematic elements, such as poorly designed ramps and obstructive entrance features. These issues are particularly prevalent in the design of doorways and entrances, which are often too narrow or lack adequate manoeuvring space. Such barriers can create multifaceted challenges for wheelchair users, impacting their ability to access buildings and navigate indoor spaces efficiently.

In Figure 8A, the walkway is directed to shops without access, as there are only stairs and WUs cannot approach them. The ramp that leads to the shopping center (Figure 8B) is 16.2% instead of 10% for ramps up to 0.60 m in height. In Figure 8C, the ramp at the public space of HUST has a run slope of 15.5% instead of 5%, which is for the maximum height up to 1.20 m. The ramp should have a rest platform as the height difference from the start point to the top exceeds 1.20 m. The ramp that assists WUs to access the School of Architecture and Urban Planning at HUST, Figure 8D, has a run slope of 15.5% instead of 5%, which is from height levels between 0.90 and 1.20 m.

The current design and implementation of curb ramps, crosswalks, ramps, and building entrances often fall short of providing adequate accessibility for wheelchair users. Addressing these issues requires a concerted effort to adhere to accessibility standards and guidelines, ensuring that walkways and public buildings are truly inclusive and functional for all users.

3.3. Passengers Pick-up and Drop-off points on Means of Transport (Public and Private)

The audit of public transportation infrastructure revealed significant accessibility challenges for wheelchair users (WUs). Bus stops, metro stations and other means of transportation while expanding in coverage, frequently present barriers that hinder independent use by WUs. Inadequate boarding facilities are a primary issue is the height discrepancy between bus platforms and the surrounding walkway surfaces. Many bus stops feature platforms that are elevated significantly from the surrounding ground, making it difficult for wheelchair users to board without assistance. Additionally, the ramps designed to facilitate this boarding are often found to have excessively steep inclines, surpassing the acceptable slope thresholds as outlined in Chinese standards. This not only complicates the boarding process but also poses safety risks for WUs.

The boarding ramps, which are intended as a temporary solution to bridge physical gaps in transport operations, are often suboptimal. These ramps frequently exceed the maximum slope limits, which makes them challenging to navigate for wheelchair users. This design flaw is prevalent in both bus stops and metro stations, impeding access and contributing to a lack of overall usability for WUs.

Figure 9 Bus stops facilities

In Figure 9A, the walkway is directed through the tram line tracks on a raised sidewalk to the bus stop and the tram stop. Figure 9B shows a newly constructed ramp to access the bus stop platform, which is 21% instead of 10%, which should be from heights between 0.30 m and 0.60 m. Furthermore, there is no curb cut on the parallel sidewalk to provide access for WUs through the intermediate road. In Figure 9C, there are steps to prevent from both sides the accessibility of the bus stop and a fire hydrant in the middle of the passage stand on the raised curb edge. In addition, the effective width of the platform is less than 1.50 m, which is the minimum requirement. During the audit, several buses were found not accessible to WUs, as shown in Figure 9D. As Figure 9E shows, the bus stops on the HUST campus also do not meet accessibility standards. The bus stop has no effective platform width and is placed on the roadside. Its location provides many obstacles and hazards to pedestrian flow, and all buses are not accessible to WUs.

Metro stations present additional barriers, with many stations being outright inaccessible to wheelchair users. Issues range from insufficient elevators to narrow, congested passageways that are not wheelchair-friendly and steep ramps leading to the entrance of the stations. These limitations significantly reduce the independence of WUs and their ability to use public transit effectively.

In personal transportation, the audit highlighted a critical lack of designated stopping points for private transportation means, such as taxis and personal cars. This is especially problematic for wheelchair users who require these stopping points to facilitate safe and convenient pick-up and drop-off. The absence of such points can force WUs to wait in less

than ideal locations, potentially exposing them to risks or causing unnecessary delays. Inadequate curbside facilities of the infrastructure often fail to accommodate the needs of wheelchair users. Many areas lack appropriate curb cuts or ramps, making it difficult for WUs to access vehicles from the sidewalk. This lack of curbside accommodation exacerbates the challenges faced by WUs when trying to arrange private transport.

Figure 10 Metro access (A-B) and side stop for personal transportation (C-D)

In Figure 10A, there is a new ramp to access the metro station which has 11.9% instead of 10%, which is the max slope for height between 0.30 m and 0.60 m. In Figure 10B, there are parking railings that prevent access to WUs in the area where there is public space and the way to the metro station, as there is not enough space to pass by. The roadside access in Figure 10C has curb edges greater than 10 mm, which is the maximum height on accessibility standards, and also the access is prevented by parked vehicles. In Figure 10D, there is no side area for vehicles to stop on the main street to pick up and drop off a passenger.

The main facilities underscore the pressing need for improved design and implementation of accessibility features in both public and private transport infrastructures. Public transit systems must address the issues of platform height and ramp slope to meet accessibility standards. Similarly, private transport scenarios require enhanced curbside facilities and designated stopping points to support wheelchair users effectively. Addressing these gaps is crucial for fostering a more inclusive and accessible transportation environment for all individuals.

3.4. Area Information and Pedestrian Guidance

In urban environments, especially in such megacities as Wuhan is, wheelchair users (WUs) face significant challenges navigating walkways due to a lack of adequate information maps, signage, and guidance. This issue is compounded in unfamiliar areas where WUs struggle with orientation and finding accessible routes. The absence of clear and sufficient signage is a major barrier that exacerbates the difficulties faced by individuals with mobility impairments.

One of the main problems identified is the insufficient number of route information signs. In many urban spaces, there are inadequate indicators to guide wheelchair users regarding directions, locations, and distances. This lack of signage makes it extremely challenging for WUs to determine the most accessible routes to their destinations. Without clear route information, wheelchair users may encounter unnecessary obstacles, dead ends, or areas that are not wheelchair accessible, further complicating their journey.

Furthermore, the scarcity of area information maps and guidance systems adds to the difficulty. For WUs, navigating in unfamiliar environments requires not only a detailed understanding of the route but also knowledge of the accessibility features of the path. The absence of comprehensive route diagrams and guidance mechanisms can leave WUs feeling disoriented and frustrated, unable to find accessible paths or facilities. This lack of orientation support severely limits their ability to participate fully in city life, as they might avoid certain areas altogether due to fear of encountering inaccessible features.

Figure 11 Information and pedestrian guidance

In Figure 11A, a road sign shows the direction for the underground pedestrian crossing, but there is no information about the access by WUs, as there is an elevator at this crossing. The entrance point of the metro station in Figure 11B is not accessible by WUs, but nearby there is an elevator that provides accessibility, and there is no directional sign to provide information about it. In Figure 11C, it is a pedestrian crossing through a pedestrian traffic island on a main road. The route direction of the pedestrian crossing is not straightway as it should be, because there is a utility structure on the way. There is no information about it, and there isn't a sign with a route to guide the pedestrians. The crosswalk in Figure 11D has a sign about accessibility, but there is no information about the crossing. In this case, there should be a sign for pedestrian crossings, and the sign for accessibility could be additional, as pedestrian crossings should be accessible in general.

The broader implications of these issues highlight a significant barrier to participation in normal life for wheelchair users. Effective signage and guidance are crucial for empowering WUs to navigate independently and confidently. In cities with a complex urban layout, the importance of accessible information cannot be overstated. The integration of detailed and clear route signs, along with comprehensive area information maps, is essential in creating an inclusive environment where wheelchair users can move freely and access various services and locations.

The lack of sufficient signage and area information is a critical issue affecting wheelchair users in urban walkways. To improve accessibility and enhance the quality of life for WUs, cities need to invest in clear and informative signage, comprehensive route diagrams, and effective guidance systems. Addressing these gaps will not only assist wheelchair users in navigating unfamiliar environments but will also contribute to a more inclusive and accessible urban infrastructure.

3.5. Traffic control and Safety

In the context of traffic control and safety for wheelchair users (WUs) navigating city walkways, several significant problems have been identified. These issues arise from inadequate planning, illegal practices, and malfunctioning infrastructure, leading to severe accessibility and safety concerns.

Parking issues are one of the main problems hindering accessibility for people with disabilities, as there is a chronic lack of designated on-street parking spaces. This lack of parking spaces causes vehicle owners to park illegally on sidewalks, impeding the essential flow of pedestrians. Furthermore, in some cases sidewalks are found to be used as part of controlled private parking areas. As a result, wheelchair users face significant barriers when trying to traverse these areas. Blocked sidewalks not only hinder mobility but also force wheelchair users to navigate dangerous street edges or seek alternative, often longer routes.

Malfunctions in traffic signals exacerbate the problem of pedestrian safety. For instance, traffic lights intended for pedestrian crossings often fail to operate correctly, causing confusion and unsafe conditions. A common issue observed is the simultaneous activation of pedestrian green lights with permissive signals for right-turning vehicles. This malfunction poses a particular risk to wheelchair users, who may be caught in the crossfire of turning vehicles and face challenges in quickly moving out of the way.

The effectiveness of sidewalk and road markings is crucial for guiding pedestrian flow and ensuring accessibility. However, many walkways suffer from poor or misleading pavement markings. For example, crosswalk markings may lead to blind walls or inaccessible areas, creating unnecessary obstacles. Additionally, some walkways are improperly

marked as bicycle parking areas or even transformed into parking spaces themselves, further obstructing wheelchair access.

Another problem is the illegal use of sidewalks by vendors and shop owners to display merchandise are prevalent in China. This practice significantly reduces the usable width of walkways, forcing wheelchair users into cramped spaces or onto the street. Such encroachments not only compromise accessibility but also present safety risks, as these vendors' setups can obstruct clear routes and create hazards.

The combination of illegal parking, traffic signal malfunctions, misleading pavement markings and vendor encroachments collectively contributes to a challenging and unsafe environment for wheelchair users. Addressing these issues requires a comprehensive approach involving better urban planning, strict enforcement of parking regulations, and improvements in traffic signal systems and walkway design to ensure equitable access and safety for all pedestrians.

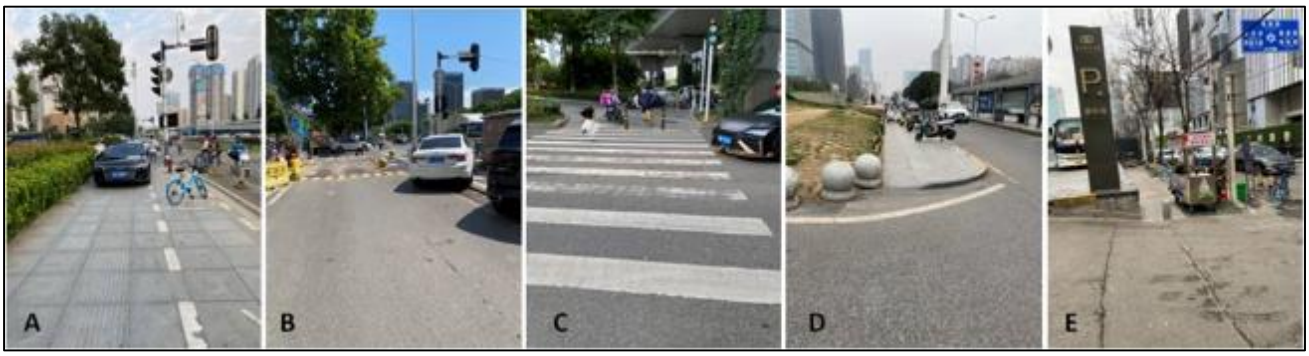

Figure 12 A) Vehicle illegally parked on the sidewalk, B) Use of sidewalk as part of private controlled parking, C) Permitted turning of vehicles during green pedestrian crossing signal, D) Marking of bicycle parking zones on sidewalk with limited width, E) Sidewalk use by vendor hindering pedestrian flow.

4. Conclusion

Based on the identified problems within the city's walkway network affecting the mobility of wheelchair users (WUs), several critical barriers have been highlighted. The primary issues found include uneven pavement surfaces, insufficient curb cuts, inadequate space on sidewalks, walkway gradients and access point slopes, which collectively hinder accessibility and smooth navigation. Uneven surfaces, such as cracked or poorly maintained pavements and surface openings, pose significant challenges, increasing the risk of accidents and making travel uncomfortable. The lack of or poorly designed curb cuts restricts access to and from sidewalks, often forcing WUs to navigate hazardous areas or seek alternate routes. In addition, overcrowded sidewalks and obstructive street furniture that are not placed properly further reduce manoeuvrability, contributing to a challenging travel experience.

Addressing these barriers is essential to creating an inclusive urban environment. Solutions such as regular maintenance of pavement, strategic placement of curb cuts, and thoughtful urban planning to avoid sidewalk congestion are crucial. By implementing these improvements, the city can enhance accessibility, ensure safety, and provide wheelchair users with a more equitable and pleasant experience while navigating walkways. A comprehensive and ongoing evaluation of walkway conditions is necessary to continuously address and mitigate emerging issues, ensuring sustained progress towards a fully accessible urban landscape.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] United Nations. (n.d.). Convention on the Rights of Persons with Disabilities (CRPD), Department of Economic and Social Affairs, Social Inclusion. https://social.desa.un.org/issues/disability/crpd/convention-on-the-rights-of-persons-with-disabilities-crpd

[2] United Nations. (n.d.). Article 9 - Accessibility. Division for Inclusive Social Development. https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities/article-9-accessibility.html

[3] Goldsmith, S. (2000) Universal design. Architectural Press

[4] U.S. Department of Justice Civil Rights Division. (n.d.). Introduction to the Americans with Disabilities Act. ADA.gov. https://www.ada.gov/topics/intro-to-ada/

[5] U.S. Department of Justice Civil Rights Division (n.d.) ADA standards for accessible design. ADA.gov. https://www.ada.gov/law-and-regs/design-standards/

[6] World Health Organization. (2007, October 5). Global age-friendly cities: A guide. https://www.who.int/publications/i/item/9789241547307

[7] World Health Organization. (2022, December 2). Global report on health equity for persons with disabilities. https://www.who.int/publications/i/item/9789240063600

[8] Bureau of Transportation Statistics. (2012, November 21). Transportation difficulties keep over half a million disabled at home.https://www.bts.gov/archive/publications/special_reports_and_issue_briefs/issue_briefs/number_03/entire

[9] Repository and Open Science Access Portal. (2018, September 1). Travel patterns of American adults with disabilities [Issue brief]. https://rosap.ntl.bts.gov/view/dot/37593

[10] Bureau of Transportation Statistics. (2024, April 18). Travel patterns of American adults with disabilities. https://www.bts.gov/travel-patterns-with-disabilities

[11] Johnson, E., Pennock, K., Strickland, C., Pathania, A., Stewart, M., Vogelmann, E. (2023) Barriers to transport for disabled people in 2023. Highlights Report. Transport for All. https://www.transportforall.org.uk/wp-content/uploads/2023/12/Are-we-there-yet_Highlights_PDF-web-compressed-more-compressed.pdf

[12] Sonenblum, S. E., Sprigle, S., & Lopez, R. A. (2012). Manual wheelchair use: Bouts of mobility in everyday life. Rehabilitation Research and Practice, 2012, 1-7. https://doi.org/10.1155/2012/753165

[13] Motability. (2022, March). The Transport Accessibility Gap: The opportunity to improve the accessibility of transport for disabled people. https://www.motabilityfoundation.org.uk/media/iwaidhxk/motability_transport-accessibility-gap-report_march-2022_final.pdf

[14] World Health Organization (2022, October 5) Physical activity. https://www.who.int/news-room/fact-sheets/detail/physical-activity

[15] Wahlgren, L., Stigell, E., & Schantz, P. (2010). The active commuting route environment scale (ACRES): Development and evaluation. International Journal of Behavioral Nutrition and Physical Activity, 7(1). https://doi.org/10.1186/1479-5868-7-58

[16] Ormerod, M. (2005). Undertaking access audits and appraisals: an inclusive design approach. Journal of Building Appraisal, 1(2), 140-152.

[17] Centre for Accessible Environments. (2023). The Access Audit Handbook: An inclusive approach to auditing buildings (3rd ed.). RIBA Publishing. https://doi.org/10.4324/9781003386292

[18] Han, S. S., & Wu, X. (2004). Wuhan. Cities, 21(4), 349–362. https://doi.org/10.1016/j.cities.2004.03.007

[19] Wang, L., Li, Z., & Zhang, Z. (2022). City profile: Wuhan 2004–2020. Cities, 123, 103585. https://doi.org/10.1016/j.cities.2022.103585

[20] Cheng, J., & Zhou, J. (2014). Urban Growth in a Rapidly Urbanized Mega City: Wuhan. In Advances in geographical and environmental sciences (pp. 301–322). https://doi.org/10.1007/978-4-431-55043-3_16

[21] Wuhan Municipal Bureau of Information Industry and Wuhan Municipal Information Center. (n.d.). Geography. Wuhan Municipal Government. https://english.wuhan.gov.cn/overview4of4wuhan/geography/202110/t20211026_1819195.shtml

[22] Wuhan Municipal Bureau of Information Industry and Wuhan Municipal Information Center. (n.d.). China's Wuhan sees permanent resident population grow by 1.2 mln. Wuhan Municipal Government. https://www.wuhan.gov.cn/wwwz/ywwz_1/H_1/NWP/202204/t20220413_1954911.shtml

[23] United Nations Partnership on the Rights of Persons with Disabilities. (2023). Situational Analysis of the Rights of Persons with Disabilities in China. Country Report. https://unprpd.org/new/wp-content/uploads/2023/12/CR-China-2023-70a.pdf

[24] China Disabled Persons' Federation. (2021, February 20). Total number of disabled people and number of people of different types and degrees of disability in China at the end of 2010. China Disabled Persons' Federation Information Center. https://www.cdpf.org.cn/zwgk/zccx/cjrgk/15e9ac67d7124f3fb4a23b7e2ac739aa.htm

[25] Hua, X. (2023, June 30). China Focus: Landmark legislation removes barriers for disabled, elderly. Xinhua. https://english.news.cn/20230630/b05a00d6e292405aa40a393f1533b69e/c.html

[26] World Health Organization. (n.d.). Ageing and health in China. https://www.who.int/china/health-topics/ageing#:~:text=402%20million%20by%202040,over%20the%20age%20of%2060.&text=Older%20man%20in%20hospital%20being%20assisted%20by%20nurse%20in%20China

[27] World Health Organization. (2015, February 15). China country assessment report on ageing and health. https://www.who.int/publications/i/item/9789241509312

[28] UN-Habitat. (2018). Assessment of Public Spaces in a Heritage District, Wuchang, Wuhan, China. https://unhabitat.org/assessment-of-public-spaces-in-a-heritage-district-wuchang-wuhan-china

[29] He, S., Yu, S., Wei, P., & Fang, C. (2019). A spatial design network analysis of street networks and the locations of leisure entertainment activities: A case study of Wuhan, China. Sustainable Cities and Society, 44, 880–887. https://doi.org/10.1016/j.scs.2018.11.007

[30] Li, T., Xu, H., & Sun, H. (2023). Spatial Patterns and Multi-Dimensional Impact Analysis of Urban Street Quality Perception under Multi-Source Data: A Case Study of Wuchang District in Wuhan, China. Applied Sciences, 13(21), 11740. https://doi.org/10.3390/app132111740

[31] Li, Y., Tao, Y., Qian, Q. K., Mlecnik, E., & Visscher, H. J. (2024). Critical factors for effective resident participation in neighborhood rehabilitation in Wuhan, China: From the perspectives of diverse stakeholders. Landscape and Urban Planning, 244, 105000. https://doi.org/10.1016/j.landurbplan.2023.105000

[32] Cui, H., Fang, H., Tian, Y., Zheng, W., Li, W., & Tian, W. (2022). Evaluation of Livability of Wuhan under Ecological Construction and Analysis of Its Spatial Pattern. Sustainability, 14(18), 11283. https://doi.org/10.3390/su141811283

[33] Ma, Y., & Jiao, H. (2023). Quantitative Evaluation of Friendliness in Streets' Pedestrian Networks Based on Complete Streets: A Case Study in Wuhan, China. Sustainability, 15(13), 10317. https://doi.org/10.3390/su151310317

[34] Zhang, Q., Zheng, Z., Kang, D., Zhou, Y., Zhang, Y., & Zhang, X. (2023). Prioritizing Neighbourhood Amenities to Enhance Neighbourhood Satisfaction: A Case Study in Wuhan, China. International Journal of Environmental Research and Public Health/International Journal of Environmental Research and Public Health, 20(4), 3528. https://doi.org/10.3390/ijerph20043528

[35] Yue, H., & Zhu, X. (2019). Exploring the Relationship between Urban Vitality and Street Centrality Based on Social Network Review Data in Wuhan, China. Sustainability, 11(16), 4356. https://doi.org/10.3390/su11164356

[36] Zhang, L. (2012, October 3). China: New Accessibility Regulations Passed. The Library of Congress. https://www.loc.gov/item/global-legal-monitor/2012-10-03/china-new-accessibility-regulations-passed/

[37] Ministry of Housing and Urban-Rural Development website. (2021, September 08). Announcement of the Ministry of Housing and Urban-Rural Development on the promulgation of the national standard "General Specification for Accessibility of Buildings and Municipal Engineering Projects". Housing and Urban-Rural Development, China Government Network. https://www.gov.cn/zhengce/zhengceku/2022-03/30/content_5682480.htm

[38] Hua, X. (2023, June 30). China Focus: Landmark legislation removes barriers for disabled, elderly. Xinhua. https://english.news.cn/20230630/b05a00d6e292405aa40a393f1533b69e/c.html

[39] Jing, J. (2023, October 10). New law adopted to facilitate the building of a barrier-free society. Beijing Review. https://www.bjreview.com/China/202307/t20230710_800336258.html