Humanities and Social Sciences
2025, Vol. 13, No. 3, pp. 254-263
https://doi.org/10.11648/j.hss.20251303.17

Research Article

Research on the Optimisation Strategy of Habitat Accessibility Design Under the Perspective of Resilient Cities

Xianpeng Liu*, Dongying Xiao

College of Architecture and Design, Jiangxi University of Science and Technology, Ganzhou, China

Abstract

Against the backdrop of accelerating urbanization and frequent natural disasters worldwide, the concept of resilient cities offers an important paradigm for urban systems to systematically address disaster challenges. As an essential carrier of inclusive urban development, barrier-free design in the built environment has a coupling relationship with resilient cities in terms of spatial planning mechanisms and dynamic adaptation of facilities. Although the concept of resilient cities provides a new perspective for dealing with urban complexity and uncertainty, its application in the field of barrier-free environment design remains to be further explored. This paper takes the theory of resilient cities as the core theoretical framework and focuses on the optimization paths and strategy innovations of barrier-free design in the built environment, aiming to systematically address key issues such as insufficient spatial accessibility and inadequate facility adaptability in current barrier-free environment construction. Based on this, this paper introduces the theory of resilient cities into the field of barrier-free design and proposes innovative strategies from four dimensions: spatial planning, facility upgrading, technological aspects, and social participation, to explore optimization plans for urban barrier-free environment construction. Future research can further expand the exploration of differentiated strategies for barrier-free design in different urban contexts to promote the continuous development of this field.

Keywords

Resilient Cities, Barrier-free Design, Ecological Human Settlements, Inclusiveness

1. Introduction

With the acceleration of global urbanization, cities are facing increasingly complex challenges, including population aging, climate change, and frequent natural disasters. Urban environments based on resilience thinking can maintain the integrity, livability, ecology, and functionality of the built environment under constantly changing environmental conditions. In October 2020, the government has proposed in the 14th Five-Year Plan to "enhance urban flood control and drainage capacity, and build sponge cities and resilient cities." Recently, the government has issued the "Opinions on Promoting the Construction of New Urban Infrastructure and Building Resilient Cities", pointing out the future direction of resilient city construction.

At the same time, the problem of population aging is becoming increasingly serious. With the development of social civilization, more and more cities around the world are be-

*Corresponding author: 465185395@qq.com (Xianpeng Liu)

Received: 25 April 2025; **Accepted:** 10 June 2025; **Published:** 22 June 2025

ginning to attach importance to the importance of barrier-free environment design to meet the travel, living and life needs of the elderly, the disabled and other special groups. Barrier-free design is not only about the improvement of facilities, but also an important indicator reflecting the degree of urban civilization, social fairness and inclusiveness. Especially in the event of urban disasters, the emergency evacuation of special groups is more difficult than that of normal people, and the current urban barrier-free facilities still have problems such as poor spatial accessibility, incomplete facility configuration and insufficient dynamic adaptability.

With the acceleration of urbanization, the deterioration of urban ecological environment and various natural disasters pose huge challenges to people's urban living environment. How to create a green, sustainable and livable city is an important issue that needs to be urgently solved in the current field of urban planning and construction. Resilient cities not only emphasize the physical resilience of infrastructure, but also include social inclusiveness and fairness, and pay attention to the needs of vulnerable groups. Barrier-free design, as a key approach to promoting social inclusiveness, is committed to eliminating physical and social barriers in the environment and ensuring that all groups, including the elderly and the disabled, can equally integrate into social life. Combining barrier-free design with ecological human settlements in the construction process of resilient cities can provide a safer, healthier, more convenient and sustainable living space for all groups, especially special groups (Figure 1)[1].

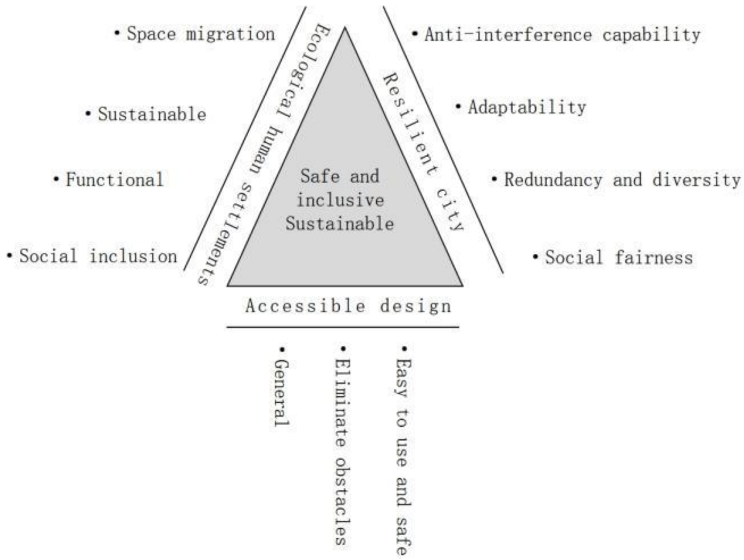

Figure 1. *Resilient Cities and Barrier-free Human Settlements.*

2. Theoretical Foundation of Resilient Cities and Barrier-free Design of Human Settlements

2.1. Resilient City

Since its introduction, the concept of resilience has been studied in various fields such as mechanical engineering, psychology, ecology, and sociology. In 1973, Canadian ecologist Holling first applied the concept of resilience to the field of ecology, extending the natural attributes of the concept of resilience [2]. It was later gradually applied to urban planning and management. Urban forms based on resilience thinking can efficiently maintain the integrity, livability, functionality, and ecological nature of the built environment under constantly changing environmental conditions, while reducing vulnerability [3]. In recent years, the theory of resilient cities has received extensive attention and research. Shi Longyu et al. defined urban resilience as "the ability of an urban system and its components to maintain or quickly restore the required functions in the face of multiple disturbances and achieve sustainable development through adaptation and transformation." This concept emphasizes the dynamics and complexity of urban systems, including not only physical infrastructure resilience but also social, economic, and ecological aspects [4]. In the research and development of resilient cities, scholars have promoted the development of resilient cities from multiple dimensions. Yan Wentao explored resilient cities from a theoretical perspective, proposing the concept of "people-oriented", with the goal of "ensuring the safety of residents and maintaining their normal living conditions", to enhance residents' sense of security, happiness, and gain [5]. Xu Xuesong, Chen Xiaohong, and others analyzed the challenges faced in building smart resilient cities from the perspective of smart resilient cities, and proposed a framework, ecology, path, and evaluation indicators for the construction of smart resilient cities [6]. However, existing research mainly focuses on climate, disaster response, urban renewal, and the economy, with less attention paid to social inclusiveness and the needs of vulnerable groups, especially in the field of barrier-free design.

2.2. The Theory of Barrier-free Design

The concept of barrier-free design originated in the early 20th century. The English word for "barrier-free" is a combination of "barrier" and "free", which literally means to remove barriers. The report of the "Expert Meeting on Barrier-Free Design of Urban Environments" held by the United Nations in 1974 proposed: "The city we aim to build is one where healthy people, patients, children, the elderly, and people with disabilities can all live and move freely without any inconvenience or obstacles." Barrier-free design is based on detailed research into human behavior, consciousness, and motor responses, and is dedicated to optimizing the design of all materials and environments used by people to provide the greatest possible convenience for users. By today's highly developed society, barrier-free design has become a global and cross-industry effort.

In recent years, with the progress of social civilization and the emphasis on inclusive development, barrier-free design not only focuses on the physical accessibility of buildings and public spaces but also emphasizes the inclusiveness of information, services, and society. The "Barrier-Free Environment Construction Law", which came into effect in September 2023, stipulates regulations in multiple aspects such as facility construction, information exchange, and social services, aiming to protect the rights and interests of special groups and promote social integration and development. Yin Limeng analyzed the necessity of barrier-free construction from the perspective of China's modernization process and pointed out the realization paths from three aspects [7]; Jin Yan, Liu Ziqi, and others, under the background of information accessibility, pointed out the existing problems of APPs and proposed optimization paths to help bridge the digital divide for the elderly [8]. Existing research mostly focuses on the design optimization of specific parts such as single spaces or facilities, lacking a systematic perspective to explore the connection between barrier-free design and the overall resilience of cities.

From the perspective of the concepts, goals, and practices of resilient cities and barrier-free design, there is a strong connection between resilient cities and barrier-free design in human settlements. First, in terms of concepts and goals, resilient cities focus on strengthening the city's ability to withstand disasters and emergencies to ensure its stability and recovery capacity, while barrier-free design aims to remove physical, information, and communication barriers, enhance the city's inclusiveness and accessibility, and improve people's quality of life. Both reflect a people-oriented urban development concept, aiming to create more livable, fair, and sustainable urban environments.

From a practical perspective, the concepts and methods of resilient cities and barrier-free design should be combined. For example, in strengthening the disaster resilience of urban infrastructure, the needs of barrier-free facilities should be considered to ensure their normal use after disasters; when planning urban green spaces and public spaces, the integration of barrier-free design should be emphasized to enhance the accessibility and inclusiveness of these spaces. Barrier-free design should also draw on the relevant concepts of resilient cities, such as enhancing the flexibility and recoverability of facilities to improve their adaptability to various disturbances (Figure 2).

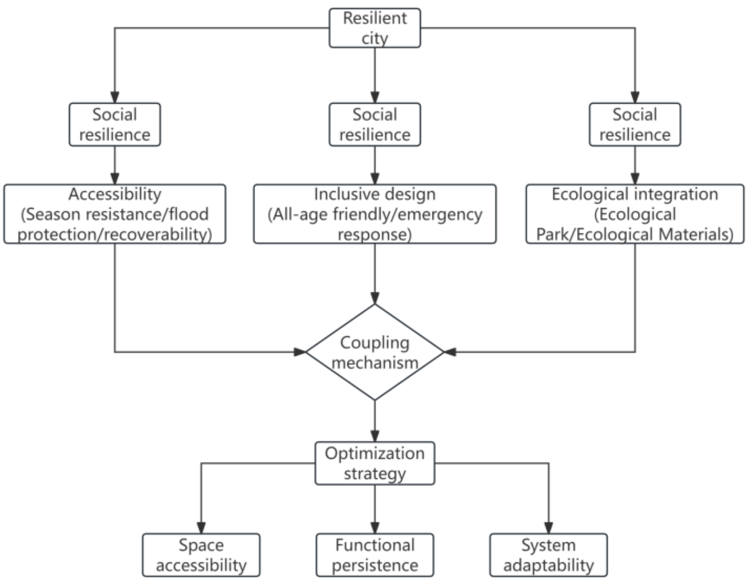

Figure 2. *The Coupling Relationship between Resilient Cities and Barrier-free Human Settlements.*

3. Analysis of the Current Situation of Barrier-free Design in Human Settlements from the Perspective of Resilient Cities

Globally, many cities are emphasizing barrier-free design while building resilient cities. Tokyo, Japan, located in the Pacific Ring of Fire, frequently faces natural disasters such as earthquakes and tsunamis. To enhance its disaster resistance and resilience, Tokyo has implemented a series of measures in urban infrastructure, resilient communities, public safety facilities, community transportation systems, and community social governance. These include strengthening the community governance system and its effectiveness, improving the level of public safety in communities, enhancing the community transportation network, reinforcing the level of social public services in communities, improving the safety of community housing, and enhancing the safety of residents' daily lives. Tokyo leads the world in barrier-free urban infrastructure, with most of its metro stations equipped with barrier-free elevators and ramps, and buses featuring low floors and wheelchair securement systems. Streets and buildings are also equipped with continuous barrier-free walkways and low automatic doors. Japan has also improved the seismic performance of facilities in public transportation, public places, and commercial services, significantly enhancing convenience and providing rapid evacuation routes in the event of natural disasters. These measures not only facilitate the daily lives of the elderly and people with disabilities but also enhance the city's resilience.

New York City, one of the largest cities in the United States, has an accessibility improvement initiative aimed at eliminating physical and informational barriers to ensure equal access for all. The initiative covers various projects such as public transportation, parks, and shopping centers. It includes installing wheelchair-accessible elevators and ramps, as well as low service counters. These changes have made the city more accessible to everyone and improved evacuation efficiency during emergencies. These improvements not only make the city more accessible and convenient but also enhance its resilience to various unexpected issues.

In China, first-tier cities like Beijing and Shanghai have adopted digital technologies to implement solutions for scenarios such as monitoring fire risks in non-motorized vehicle parking sheds, thereby enhancing the city's safety and resilience. They also focus on creating barrier-free living circles, especially in public transportation and public places, where barrier-free facilities are fully equipped, providing convenience for the elderly and people with special needs.

However, there are still issues in China's urban barrier-free design, such as low utilization of barrier-free facilities, weak awareness of barrier-free design, and a lack of integration with resilient city planning. These factors not only affect the quality and effectiveness of barrier-free environment construction but also hinder the development of urban resilience. Firstly, the low utilization of barrier-free facilities may prevent them from playing their intended role in emergencies. Secondly, weak awareness of barrier-free design limits the full potential of barrier-free facilities and their maintenance. Thirdly, the lack of integration with resilient city planning means that cities are ill-prepared to deal with natural disasters and other emergencies.

4. Optimization Design Strategies for Barrier-free Environments from the Perspective of Resilience

4.1. Principles for Optimizing Barrier-free Design from a Resilience Perspective

4.1.1. The Principle of Universality

Everyone will experience a sense of barrier, although the specific barriers vary from person to person. Everyone is at risk of illness or disability throughout their life, so all people are potential disabled individuals and have the same needs as those with disabilities. Barrier-free design should meet the needs of all people, including the elderly, children, pregnant women, people with disabilities, and ordinary citizens [9]. At the same time, barrier-free design also requires the principle of inclusiveness, not only focusing on people with physical disabilities but also including those with cognitive and psychological disabilities, and the design should fully meet the needs of different groups. In the context of resilient cities, the principle of universality is not only reflected in the convenience of facilities but also in the accessibility under extreme conditions.

4.1.2. The Principle of Sustainability

From an integrated perspective of resources and environment and urban sustainable development, the principle of sustainability requires the establishment of a full life-cycle resource management system. During the construction phase, materials that are recyclable, have low pollution and are durable should be given priority, such as blind path bricks made of recycled plastic. This can reduce energy consumption and pollution during the construction process. During the usage phase, through reasonable design and regular maintenance, the lifespan of facilities can be prolonged. This not only saves resources for later investment but also reduces environmental pressure, while bringing dual benefits of economy and environmental protection. Additionally, with social development and changes in population structure, barrier-free design should break away from the static paradigm and adopt methods such as reserved interfaces and modular design to achieve flexible adjustment and upgrading of facilities. For instance, emergency equipment pipeline interfaces can be installed in advance in barrier-free restrooms of public buildings, and detachable signboards can be used in subway stations, so as to adapt to the needs of different periods. Through this efficient use of resources and flexible adjustment approach, urban barrier-free facilities can maintain their basic functions even under conditions of resource scarcity or environmental changes. This not only enhances the city's ability to deal with sudden problems but also enables the elderly, the disabled and other special groups to equally enjoy the convenience and services of the city.

4.1.3. The Principle of Flexibility

In the context of resilient city construction, the principle of flexibility is the core strategy for optimizing barrier-free design. It requires that the design of barrier-free spaces and facilities break away from the single-function stereotype and adopt modular and reconfigurable design methods, enabling them to be flexibly adjusted according to usage scenarios, the needs of different groups, and special circumstances. This design approach offers two main benefits. Firstly, in daily use, it can better meet the needs of various groups, such as the elderly, pregnant women, or people with disabilities. Secondly, in the event of natural disasters, epidemics, and other emergencies, these facilities can be quickly transformed to serve new purposes. For instance, after an earthquake, barrier-free passages can be temporarily converted into medical aid stations; during a pandemic, by adjusting the spatial layout, it is possible to maintain safe distances while ensuring basic services for special groups. From the perspective of resilient city theory, this flexible design establishes a dynamic response mechanism, not only ensuring the continuous operation of barrier-free functions during emergencies but also enhancing the city system's ability to resist disturbances and recover efficiently in complex situations through functional reorganization and resource allocation. This strengthens the overall resilience of the city and provides safe and convenient living guarantees for people with disabilities and all citizens, embodying the inclusive and sustainable development concepts of urban space design (Figure 3).

Design principles	Specific Points	Explanation
The principle of universality	Meet everyone's requirements	Including seniors/children/people with disabilities, etc
	Pay attention to various groups with disabilities	Cover all physical/cognitive/mental disabilities
	Easy access under extreme conditions	Maintain basic functionality in times of disaster
The principle of continuity	Full life cycle resource management	Recycled materials/low-carbon construction
	Facilities are dynamically adjusted and upgraded	Reserved interfaces/modular design
	Guarantee basic service capabilities	Under resource constraints/keep running
The Flexibility principle	Modular reconfigurable design	Movable partitions/class adjustment facilities
	Adapt to everyday and emergent scenarios	Dual-use space conversion for peacetime and disaster
	Enhance the resilience of urban systems	Enhance resilience and resilience

Figure 3. *Principles for Optimizing Barrier-free Design from a Resilience Perspective.*

4.2. Optimization Strategies for Barrier-free Design from the Perspective of Resilience

4.2.1. Optimization Strategies at the Spatial Planning Level

(1) Build a Multi-level Barrier-free Spatial Network

The theory of resilient cities emphasizes the connectivity and redundancy of systems to enhance the city's ability to cope with potential shocks. In the construction of barrier-free travel networks, a continuous and unobstructed pedestrian system is a fundamental element for achieving urban spatial accessibility. Planning and design should follow dual standards: first, ensure that the width of sidewalks meets the smooth passage requirements of wheelchairs, walking aids, and other assistive devices, and reserve space for multiple people to walk side by side to meet the flow demands during peak hours; second, eliminate various obstacles on sidewalks, including steps, barriers, and narrow sections, to avoid disruptions in travel and maintain the continuity and stability of the travel network, in line with the requirements of resilient cities for the continuous operation of systems [10]. This design concept essentially builds a redundancy mechanism for travel routes. When a certain road is impassable due to construction or emergencies, people can choose other barrier-free routes. This significantly improves the reliability of the urban travel system, allowing everyone to reach their destinations smoothly, effectively enhancing the resilience of the urban travel system [11].

At the spatial layout level, it is necessary to break away from the traditional linear model and build an integrated multi-level barrier-free space system of "point-line-surface". Taking the community center as the core node, barrier-free walking paths connect residential areas, schools, medical institutions, and other functional zones, forming a barrier-free service network with a radiation effect. At the same time, different types of barrier-free passages should be set up: main passages should primarily meet the needs of wheelchair users, ensuring their width and slope comply with standard specifications; secondary passages should provide guidance for visually impaired people through blind paths, achieving precise matching of travel needs for different disabled groups.

Furthermore, enhancing the barrier-free connectivity between urban functional spaces is crucial. Currently, there is a problem of fragmented barrier-free spaces in China's urban construction, with a lack of continuous barrier-free transportation connections and clear guidance systems between functional zones such as business districts and residential areas. Therefore, it is necessary to plan continuous barrier-free transportation belts and establish systematic guidance signs to ensure the free movement of disabled people between different functional areas [12]. On this basis, ecological concepts can be integrated into the barrier-free space network. By using plant clusters to divide spaces and build ecological corridors to connect these barrier-free facilities, this design not only creates a comfortable and pleasant travel environment for the disabled but also promotes urban biodiversity conservation, achieving an organic unity of functionality and ecology [13].

(2) Reserve Some Flexibility

The theory of resilient cities emphasizes the core goal of maintaining urban functions and ensuring residents' safety during emergencies. This requires that urban planning and design reserve flexible space for barrier-free facilities to enhance their ability to cope with uncertainties. At the level of road construction, it is necessary to reserve adjustable elastic land and build a dynamic adaptation mechanism to combine peacetime and disaster response, so that it can be quickly transformed into temporary land when needed. On the one hand, in the planning stage, the expansion land for barrier-free facilities should be clearly defined to ensure that they can be flexibly added or upgraded according to future changes in population structure and technological innovation. On the other hand, implement differentiated design strategies based on disaster risk assessment: in areas with high-frequency natural disasters, "passive resilience design" can be adopted; in areas with medium and low-frequency disasters, "adaptive transformation" can be promoted; and in areas with low-frequency disasters, "functional redundancy" design should be emphasized (Figure 4).

Colour	Region	Design	Optimization Practice Cases
Red Zone	High-frequency disaster area	"Passive resilience" design	Adjustable curbstone system
Yellow Zone	Medium-risk area	Implement "adaptive transformation"	Optimize the path of the blind path to avoid structurally fragile areas
Blue zone	Low-risk area	Construction of "functional redundancy"	There are alternative or redundant solutions for barrier-free nodes

Figure 4. *The three-stage Response Mechanism under Differentiated Design.*

In the design of public building spaces, the concept of flexibility is reflected in the reconfigurability of spatial layout.

By adopting flexible and variable designs, using movable partition walls, and installing adjustable-height service counters, the spatial functions can be quickly adjusted according to the needs of different disabled individuals, achieving flexible functional transformation. Moreover, the construction of flexible spaces should follow the principles of green sustainability, giving priority to the use of recyclable and low-carbon emission building materials to reduce the environmental burden. At the same time, ecological functions should be integrated into the design of flexible spaces, such as converting reserved spaces into ecological planting areas or rainwater retention facilities, enhancing the flexibility of space usage while strengthening the ecological resilience of the city.

In response to the uncertainties of urban development, the planning of emergency flexible accessible spaces is particularly crucial. In public open spaces such as parks and squares, accessible spaces that can be rapidly converted into temporary shelters should be reserved, and necessary accessible facilities and emergency supplies should be provided. At the same time, the design of these spaces should focus on the integration with ecological technologies. By implementing measures such as ecological roofs and rain gardens, the organic unity of emergency functions and ecological benefits can be achieved, ensuring that in the event of emergencies, the basic living needs of the disabled population can be met while enhancing the stability and recovery capacity of the city's overall ecosystem [14].

4.2.2. Optimization Strategies at the Facility Function Level

(1) Enhance the Universality and Compatibility of Facilities

Adopting a universal design concept, the optimization of barrier-free facilities aims to comprehensively cover different types of disabled groups. In facility design practice, adjustable parametric design strategies are employed, such as height and angle adjustable bathroom handrails and the use of standardized components for easy replacement. This not only meets the needs of wheelchair users but also assists those who need standing support, enhancing the inclusiveness of the facilities. In the field of public transportation, convertible barrier-free seat systems should be promoted. These seats are designed with sliding rails and folding mechanisms to quickly switch between wheelchair parking areas and regular seats, effectively balancing the travel needs of special groups with the dynamic allocation of public transportation capacity resources.

At the level of urban infrastructure coordination, barrier-free facilities need to enhance compatibility with other systems. For instance, barrier-free elevators should be connected to fire control systems, equipped with emergency lighting and ventilation functions, and automatically switch to safety mode in case of fire or power failure to ensure the safe evacuation of disabled people. Pedestrian crossing signals should be integrated into the traffic control center to adjust waiting times based on real-time traffic flow, providing more accurate crossing prompts for the blind and ensuring the safe crossing of visually impaired people. Additionally, the selection of facility materials should follow ecological design principles, prioritizing the use of recyclable and biodegradable materials to reduce the environmental load throughout the life cycle. In terms of spatial form design, consideration should be given to promoting the organic integration of barrier-free facilities with the surrounding ecological environment, achieving a unity of functionality and environmental harmony.

(2) The Optimization and Upgrading of Public Transportation Facilities

Public transportation, as a key hub for urban operation, the renovation and upgrading of its barrier-free facilities is an important part of resilient city construction. By implementing low-floor modifications at bus stops to achieve seamless connection between the bus floor and the platform, the convenience of travel for wheelchair users has been greatly enhanced, effectively ensuring the continuity of the urban transportation system. Meanwhile, measures such as laying anti-slip and easy-to-clean materials on the platforms, installing blind paths, equipping buses with wheelchair fixation devices, adding barrier-free elevators and lift platforms in metro stations, and ensuring that automatic ticket vending machines and gates have barrier-free operation functions have been taken to enhance the adaptability of public transportation facilities to diverse groups of people [15].

Targeted optimization strategies are formulated based on the differences in regional risk characteristics. In areas prone to earthquakes, blind path materials with good seismic resistance are used to improve the structural stability of facilities and ensure they are less likely to be damaged during earthquakes. In flood-prone areas, floating modifications are made to facilities such as ramps to enhance their flood resistance. In some areas, modular component designs are promoted, allowing damaged parts to be quickly replaced, thereby shortening the post-disaster repair time and improving the travel efficiency of special groups. These optimization measures not only meet the travel needs of different groups in both normal and emergency situations but also effectively maintain the stable operation of the urban transportation system, strengthen the city's resilience in the face of uncertainties, and provide a solid guarantee for the continuous operation of the city's basic functions.

4.2.3. Optimization Strategies at the Technical Level

(1) Establish a Real-time Monitoring and Feedback Mechanism

One of the key points of a resilient city is timely perception and rapid response. Therefore, barrier-free design can be combined with intelligent technologies such as the Internet of Things, big data, and artificial intelligence. Sensors for pressure, displacement, etc. can be installed on barrier-free facilities to obtain information such as the flow of people, the wear and tear of facilities, and the occurrence of faults in a timely manner. This is equivalent to building a "sensing nerve" for the city's barrier-free environment, reducing the time for early warning response. Thus, it can achieve real-time and effective intelligent management and service of facilities, provide information to special groups in case of disasters, and help them effectively avoid risks. A user feedback platform based on mobile Internet can also be established to facilitate the public to report problems and make suggestions, building a bridge for interaction between the public and the management department. The management department can adjust, maintain or update barrier-free facilities based on this information and user feedback data, keeping the facilities in the best operating condition. This transforms the traditional passive maintenance into active maintenance, similar to the self-adaptive system of a resilient city, enabling barrier-free design to be timely optimized and adjusted along with urban development, and continuously enhancing the city's barrier-free environment's ability to respond to changes and dynamic adaptability [16].

(2) Suggestions for Revision of Standards

The theory of resilient cities emphasizes the dynamic adaptability, redundancy and sustainable development of systems. However, the current accessibility standards in China mainly focus on the static functional requirements of facilities, which shows obvious insufficiency in adapting to the complex and dynamic urban systems. From the perspective of resilient cities, it is urgent to systematically improve the existing accessibility standards and promote the transformation of accessibility facility construction from "compliance construction" to "resilient construction".

Firstly, in response to the current standards' insufficient consideration of the dynamic adaptability of accessibility facilities, a dynamic performance evaluation mechanism and flexible design standards should be established. By formulating a regular assessment system, the functional status, user adaptability and environmental compatibility of facilities during their usage can be evaluated periodically. At the same time, flexible design clauses should be added to the standards, clearly stipulating technical requirements such as reserved functional expansion interfaces and modular reconfigurability of facilities to cope with rapid urban development and emergencies.

Secondly, the current standards lack systematic consideration of the integrity and redundancy of accessibility systems, resulting in passage dead ends in some areas. This can be improved in two ways: first, establish a universal connectivity standard, clearly stipulating the minimum connectivity density of accessible paths between major urban roads and public facilities; second, refine the redundancy configuration standards for accessibility facilities.

Thirdly, the current standards' lack of consideration for the full life cycle management and environmental impact assessment of accessibility facilities restricts the achievement of sustainable development goals. In the revision, full life cycle design requirements should be supplemented, clearly stipulating the priority use of recyclable, low-carbon and long-life materials; formulate a full life cycle maintenance guide, including daily inspection cycles, replacement standards for key components and disposal procedures, and establish a facility service life prediction mechanism to provide a scientific basis for facility updates.

Fourthly, it is necessary to improve the multi-scenario integration and collaborative design standards. By establishing linkage standards between accessibility design and urban emergency management systems, integration standards between accessibility design and smart city construction, and collaborative standards between accessibility design and ecological city construction, the depth integration of accessibility facilities with various urban systems can be achieved, comprehensively enhancing the resilience level of the urban accessibility environment.

4.2.4. Optimization Strategies at the Social Level

(1) Strengthen Social Publicity and Promote Social Participation

Through multiple channels such as traditional media and new media, carry out extensive and in-depth social publicity activities. By creating vivid and interesting public service advertisements, promotional short videos, graphic and text posts, etc., popularize the knowledge and concepts of barrier-free design to the general public, introduce the importance of barrier-free design to everyone's life, especially that of people with disabilities, and how it promotes social fairness and inclusiveness. Enhance social awareness and guide them, especially special groups, to participate in the optimization and transformation. Only through the collaborative governance of multiple subjects can a better barrier-free environment be built.

(2) Establish a community co-construction and co-sharing mechanism.

At present, the elderly care model in China is mainly community-based, and the activity range of special groups is mostly within the community. Establishing a volunteer team for barrier-free community construction, organizing volunteers to participate in the investigation, assessment, supervision and maintenance of barrier-free facilities. Volunteers can regularly inspect the barrier-free facilities in the community, promptly report any problems to the relevant departments, and assist the departments in making rectifications. Encourage community residents to participate in the design and renovation process of barrier-free facilities, fully listening to their opinions and suggestions. Conduct disaster response drills at the community level, including simulating the use of blind paths under power outage conditions, the evacuation routes for special groups in various disasters, etc., and continuously optimize and improve them. Through the participation of residents, make barrier-free facilities more in line with the actual needs and usage habits of residents, and increase their satisfaction with barrier-free facilities (Figure 5).

Comparison dimensions	The traditional barrier-free design paradigm	Resilient optimization design paradigm	Advantages
Design Goals	Static compliance (conforming to the provisions of the regulations)	Dynamic adaptation (in response to uncertainty disturbances)	Risk response
Space organization	Layout of independent facilities	Point-line-surface multi-level network	Improving connectivity
Facility performance	Single-condition design	Multi-disaster coupling design (earthquake-resistant / flood-proof / modular)	Enhance post-disaster availability
Technology Application	Manual inspection and maintenance	Real-time monitoring and intelligent regulation	Reduce fault response time
Participation mechanisms	Expert-led	Multisubject collaborative governance	Improve acceptance and adaptability

Figure 5. *Optimizing Barrier-free Design from the Perspective of Resilience.*

5. Conclusions

Against the backdrop of global urbanization and frequent disasters, resilient cities represent a systematic approach to urban disaster response, while barrier-free design is an intrinsic need for promoting inclusive urban development. There is a significant coupling relationship between resilient cities and barrier-free human settlements in terms of spatial response and facility adaptation at the urban scale. Incorporating resilient city building into the design process of barrier-free human settlements breaks away from the traditional simple functional fulfillment of barrier-free design and offers a new path for on-site barrier-free design in human settlements. This can enhance the urban system's ability to resist and recover from sudden events and ensure that diverse groups in the city can equally share urban spaces and facilities. Although current research has proposed optimization strategies in terms of spatial planning and facility upgrading, there is still room for exploration in differentiated practices, technical integration systems, and assessment systems in specific urban contexts. Future research can be conducted in the following areas:

(1) Deepening differentiated barrier-free resilience strategies in urban contexts

Firstly, different cities are located in different regions and have distinct regional climates and disaster risk profiles. Secondly, different cities at various development stages have different barrier-free resilience needs, and the optimization of barrier-free design should be adapted to the development stage of the city. Finally, different cities have different regional cultures and social structures, and design should be combined with local population structure and cultural habits. Therefore, barrier-free design should be analyzed and adapted based on specific circumstances.

(2) Strengthening resident participation mechanisms and community resilience cultivation

Establish a multi-stakeholder collaborative platform, including the participation of government, design institutions, community organizations, and representatives of special groups, and attach importance to resident needs throughout the design process. Build barrier-free blocks at the community level and encourage resident participation.

(3) Promoting the deep integration of digital technology and barrier-free design

Digital technology, especially during disasters, can play a significant role for special groups. On the existing basis, actively introduce and develop technologies such as AI visual recognition that can be integrated with barrier-free facility usage scenarios, and build a barrier-free resilience digital twin model to enhance and optimize the living experience of special groups.

(4) Constructing a scientific barrier-free resilience assessment system

Build an assessment system that includes quantitative and qualitative indicators from multiple dimensions such as physical resilience, social resilience, ecological resilience, and economic resilience. Rely on big data platforms to regularly collect barrier-free-related data and form an "assessment-optimization-reassessment" mechanism. Actively promote the inclusion of barrier-free resilience indicators in urban planning and other assessment systems.

Through the deepening of these research directions, the theoretical coupling between resilient cities and barrier-free design can be further improved, promoting the implementation of the "people-oriented" urban development concept and providing more universal solutions for addressing global climate change and the challenges of an aging society.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Li CHEN, Xigang ZHU, Jie SUN. The Basic Concept, Mechanism and Planning Ideas of Resilient Cities [J], Modern Urban Research, 2017: 18-24. https://doi.org/10.3969/j.issn.1009-6000.2017.09.003

[2] Du Li. What is Urban Resilience? - An Analysis of the Basic Concepts of Resilient Cities [J]. Journal of Tianjin Administration Institute, 2022, 24(03): 46-56. https://doi.org/10.16326/j.cnki.1008-7168.2022.03.005

[3] Melika Amirzadeh, Saeideh Sobhaninia, and Ayyoob Sharifi. "Urban Resilience: A Vague or an Evolutionary Concept?", Sustainable cities and society 81(2022): 103853-103853. https://doi.org/10.1016/j.scs.2022.103853

[4] SHI L, ZHENG Q, YANG M, LIU L, et al. A review of definitions, influence factors and assessment of urban resilience [J], Acta Ecologica Sinica, 2022, 42(14): 6016-6029. https://doi.org/10.5846/stxb202107121874

[5] Yan Wentao. A Preliminary Exploration of the Theory of People-Oriented Resilient Cities [J]. City Planning Review, 2023, 47(11): 49-50. https://doi.org/10.11819/cpr20231108a

[6] Xu X, Yan Y, Chen X, Liu X, Su Y, Tang J, Peng J, et al. Framework System and Path of Smart Resilient City Construction [J], Strategic Study of CAE, 2023, 25(1): 10-19. https://doi.org/10.15302/j-sscae-2022.05.027

[7] Yin Limeng. Promoting High-Quality Development of Barrier-Free Environment Construction in the Process of Chinese-Style Modernization [J]. Disability Research, 2024(4): 52-58. https://doi.org/10.3969/j.issn.2095-0810.2024.04.007

[8] Jin Yan, Liu Ziqi, Bi Chongwu. Research on the Adaptation of APPs for the Elderly in the Context of Information Accessibility [J]. Modern Information, 2022, 42(8): 96-106. https://doi.org/ 10.3969/j.issn.1008-0821.2022.08.010

[9] Li Chen. Interpretation of the Marrakesh Treaty Based on the Human Rights Model of Disability Perspective [J]. Human Rights, 2022, (04): 1-13. https://doi.org/10.16696/j.cnki.11-4090/d.2022.04.004

[10] Ayyoob Sharifi. Resilient urban forms: A review of literature on streets and street networks [J], Building and Environment, 2019, 147(): 171.0-187.0. https://doi.org/10.1016/j.buildenv.2018.09.040

[11] Xiao S, Liu C, Gu G, Zhang H, Li X, et al. Barrier Free Design of Municipal Roads in Resilient Cities [J], Municipal Engineering Technology, 2022, 40(7): 101-106, 113. https://doi.org/10.19922/j.1009-7767.2022.07.101

[12] Xue-feng H, Jing X, Xing-ping W, Hong-sheng C, Jing X, et al. Study on Spatial Mismatch and Majorization of Barrier-free Facilities for Urban Community: A Case Study of Nanjing [J], Disability Research, 2019: 63-70. https://doi.org/10.3969/j.issn.2095-0810.2019.03.011

[13] Ayataç H. Accessibility in disaster-resilient cities [J]. Journal of Design for Resilience in Architecture and Planning, 2021, 2(3): 295-310. https://doi.org/10.47818/DRArch.2021.v2i3026

[14] Müller B, Shimizu H, Otto A. The Transition Towards Sustainable and Resilient Cities—Urban Challenges and Solutions in Germany and Japan [J]. Towards the Implementation of the New Urban Agenda: Contributions from Japan and Germany to Make Cities More Environmentally Sustainable, 2018: 1-20. https://doi.org/10.1007/978-3-319-61376-5_1

[15] Han J, Chan E H W, Qian Q K, et al. Achieving sustainable urban development with an ageing population: An “age-friendly city and community” approach [J]. Sustainability, 2021, 13(15): 8614. https://doi.org/10.3390/su13158614

[16] Joash M, Hossana T, Rose L, Siyabonga M, Kelvin B, Stella B, et al. Building Resilience into Smart Mobility for Urban Cities: an Emerging Economy Perspective [J], International journal of production research, 2024, 62(15): 5556-5573. https://doi.org/10.1080/00207543.2022.2139866