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Research on the Optimization of Spatial Service Systems Based on Barrier-Free Design Theory: A Case Study of the Immigrant Community in Hongguozi Town, Ningxia

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Abstract: With the rapid acceleration of urbanization in China, the continuous expansion of immigrant communities has gradually revealed significant deficiencies in their spatial service systems. Taking the immigrant community in Hongguozi Town, Ningxia as the research object and based on the theory of barrier - free design, this study adopts a comprehensive research method combining field visits, questionnaires, and interviews. It analyzes the existing problems in the community's physical environment, cultural adaptation, and service chains. Three - dimensional optimization strategies are proposed. In spatial design, the study reconstructs the matching relationship of "demand - behavior - space", aiming to create a more suitable spatial environment for residents. In service design, a system model of "tool - interface - process" is constructed to improve the efficiency and quality of community services. In cultural dissemination, the translation and narrative of "cultural symbols and design" are realized, which helps to promote cultural integration and identity among residents. The research aims to improve the living quality of residents in immigrant communities, especially for people with disabilities, and to promote social integration. Although limited by a relatively small sample size, this study provides valuable theoretical and practical references for the optimization of spatial service systems in immigrant communities. It is expected to contribute to the high - quality development of new - type urban and rural construction.

Keywords: Barrier-free design, immigrant community, spatial service systems, social integration.

1. Introduction

As China's urbanization process accelerates, the construction and development of immigrant communities have garnered increasing attention. As a special social group, immigrants face many challenges in the process of adapting to new environments, among which the perfection of spatial service systems directly affects their quality of life and social integration. Barrier-free design theory emphasizes the creation of equal and convenient living environments for all people, aligning closely with the goals of immigrant community development. This study examines optimization strategies for spatial service systems based on barrier-free design theory, using the immigrant community in Hongguozi Town, Ningxia, as a case study. The study seeks to provide theoretical and practical references for optimizing spatial service systems in immigrant communities, contributing to the high-quality development of new urbanization.

2. Research Background and Significance

Based on data from the National Bureau of Statistics, China's urbanization rate surged from 36.22% in 2000 to 65.22% in 2022. The seventh national population census revealed that the size of immigrant communities has surpassed 125 million. A 2023 assessment by the Ministry of Housing and Urban-Rural Development showed that the coverage rate of barrier-free facilities in immigrant communities in central and western China stood at only 58.7%, 21.5 percentage points lower than that in urban built-up areas. Hongguozhen in Ningxia, a national "new urbanization comprehensive reform" pilot by the National Development and Reform Commission, witnessed a 28.4% poverty incidence rate among disabled individuals in its immigrant communities, as reported by the Ningxia Academy of Social Sciences in 2022. This situation underscores the profound contradictions in implementing the "14th Five-Year Plan for the Protection and Development of Persons with Disabilities" at the grassroots level.

This study innovatively extends the application of barrier-free design theory from physical environment renovation to the "society-culture-system" framework of immigrant communities, aligning with the United Nations' "2030 Agenda for Sustainable Development" target of fostering inclusive cities. By employing space syntax modeling to uncover the topological features of service disruptions, it complies with the "precise identification" requirements outlined in the "Guiding Opinions on Promoting the Construction of Barrier-Free Environment for Urban Difficult Groups (2023)." Drawing on Jan Gehl's "public space life cycle theory," this research constructs a "space empowerment - social integration" double helix model, facilitating the realization of the "age-friendly community" objective stipulated in the "Barrier-Free Environment Construction Law (2023)." As such, it offers interdisciplinary methodological support to address the "semi-urbanization" challenge in the context of new urbanization.

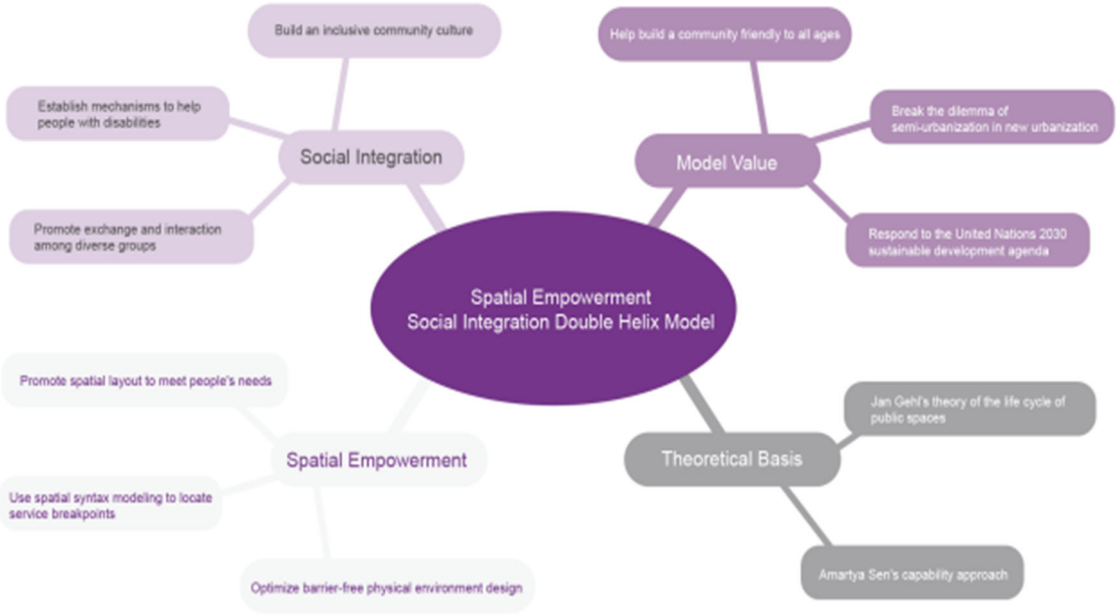

Figure 1. Spatial Empowerment - Social Integration" Double Helix Model Self-made by the author

3. Relevant Concepts and Definitions

3.1. Barrier-free design theory

Barrier-free design theory emerged in the mid-20th century, coinciding with the rapid industrialization and urbanization of developed Western countries, where the need for social integration of people with disabilities became increasingly urgent. In 1961, the United States issued the Accessible Building Standards, promoting the widespread application of wheelchair ramps, accessible restrooms, and other facilities in public buildings, significantly improving the living and mobility conditions of people with disabilities.With the advancement of human rights and societal progress, barrier-free design theory has evolved from solely addressing disability integration issues to becoming an inclusive design concept aimed at creating equitable, convenient, and sustainable living environments for all. The theory is structured around four core principles: accessibility, usability, safety, and comfort[1]. Accessibility ensures that spaces and facilities are equally accessible to all, providing passage and guidance facilities for wheelchair users and the visually impaired. Usability emphasizes accommodating the needs of different groups, such as installing wheelchair parking zones, pictorial signs, and auditory announcements in public transportation systems. Safety focuses on reducing risks through the use of safe materials and well-planned evacuation routes. Comfort enhances user experience by optimizing spatial environmental factors[2]. In the context of optimizing spatial service systems in immigrant communities, applying barrier-free design theory can significantly improve the living quality of people with disabilities and the elderly, optimize spatial resource allocation, and foster an inclusive community culture. Therefore, integrating this theory into immigrant community development holds significant practical and theoretical value.

3.2. Spatial Service System

The spatial service system developed in this study aims to overcome the traditional dichotomy between spatial design and service delivery. By integrating physical space renovation with digital service innovation, it addresses the specific needs of immigrant community members, particularly persons with disabilities and older adults. Guided by their requirements, the system promotes collaborative innovation between spatial design and service processes, establishing a hybrid physical-digital support framework. Space is reimagined as a service carrier, dismantling barriers across three dimensions—functional layout, facility configuration, and information interaction—to rebuild social participation mechanisms.

In functional layout, spatial analysis techniques are employed to plan community facilities based on user behavior patterns and needs, enhancing service accessibility. For facility configuration, physical environments are retrofitted to meet accessibility standards and integrated with multimodal sensing systems to accommodate diverse sensory capabilities. In information interaction, digital service platforms enable precise delivery of service information and two-way communication, facilitating residents' convenient access to services and assisting providers in optimizing strategies. Through resource reorganization and technological empowerment, the spatial service system converts spatial resources into high-quality social services, empowering persons with disabilities to transition from passive adaptation to active spatial participation and achieving a comprehensive upgrade of barrier-free service systems in immigrant communities.

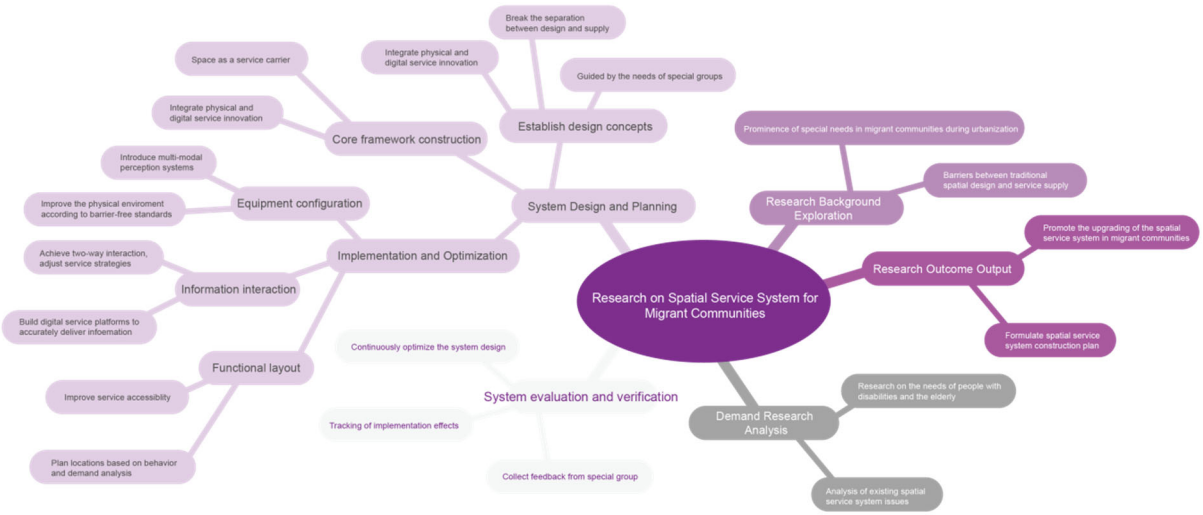

Figure 2. Research Framework

4. Project Overview and Research

4.1. Project Background

Established in 1984, the Hongguozhen Hui West Community spans a large area, divided into six grids and encompassing 39 residential zones. It serves 3,461 households, with a total population of 10,334. The community's population is diverse, including 335 immigrant households with 1,310 individuals, 1,610 elderly residents, and 217 people with various disabilities, among whom 25 are registered disabled immigrants. While the community has actively developed a "home for people with disabilities," offering various services, significant challenges remain in serving this vulnerable group. Infrastructure deficiencies are prominent: many public areas lack barrier - free amenities. For instance, residential area entrances and exits lack wheelchair ramps, and the surrounding public transportation is inaccessible, severely hindering mobility for people with disabilities.

In terms of service provision, rehabilitation resources are scarce, with a lack of necessary equipment and professional therapists. Boarding facilities are basic, and the skills of service staff vary widely. Employment opportunities are limited, and training programs are incomplete, leading to unstable job prospects. Resource integration is also subpar; there is minimal cooperation with external entities, funding is insufficient, and demand assessment is inadequate, undermining the precision of services. Addressing these issues promptly is crucial for improving the service system and enhancing the quality of life for people with disabilities in the community.

Figure 3. User Profile Analysis

4.2. Research Methods

This study adopts a multi-method approach, including field surveys, questionnaires, and interviews. First, field visits were conducted in immigrant communities such as the Hongguozhen Hui West Community to observe the construction of infrastructure, public service facilities, and barrier-free facilities, as well as the operation of the "home for people with disabilities," including its internal facilities, service content, and personnel management. This provided a direct understanding of the current status and existing problems of the community's spatial service system. Second, a questionnaire survey was administered. The questionnaire covered basic information of community residents, usage of community service facilities, satisfaction levels, awareness of barrier-free design, and related needs. Random sampling was used to widely collect feedback and expectations from residents regarding the spatial service system. Additionally, in-depth interviews were conducted with community workers, persons with disabilities and their families, and elderly residents to understand their actual service needs, usage experiences, evaluations of existing services, and suggestions for system optimization. Interviews with community managers and officials from relevant government departments provided insight into policy implementation challenges and obstacles in community development.

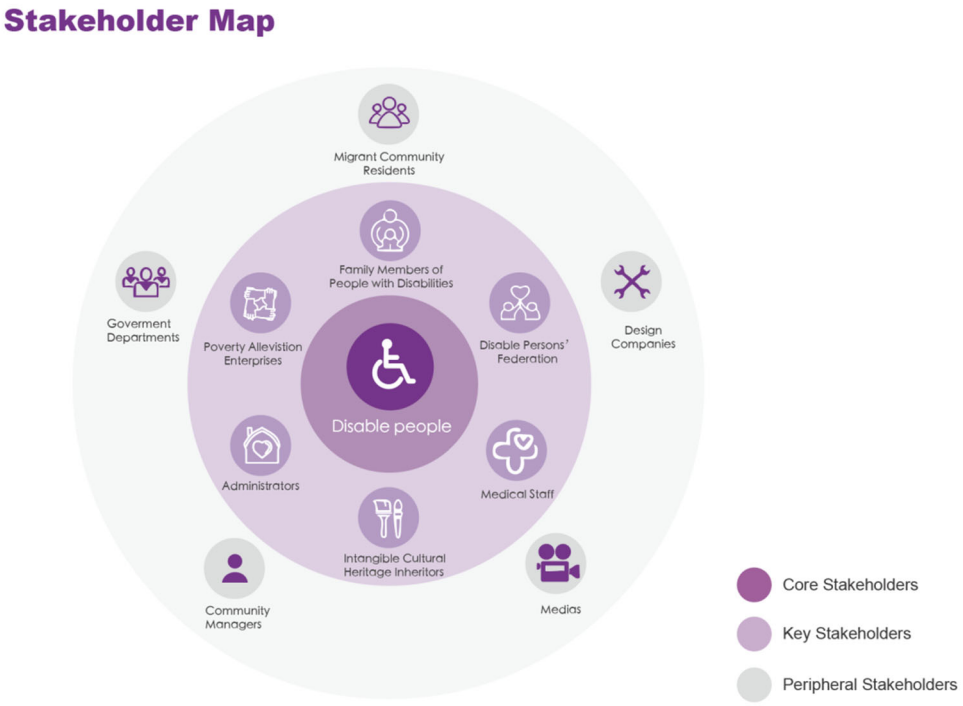

Figure 4. Stakeholder map

4.3. Current Project Status and Problems

4.3.1. Physical Environment Barriers: Lack of infrastructure adaptation

From the perspective of modern community planning and design theory, the degree of accessibility of infrastructure is a core indicator for measuring community inclusiveness and accessibility. However, significant shortcomings are evident in many communities.

From the standpoint of road design theory, unreasonable road slopes and widths severely violate basic barrier-free accessibility principles. According to internationally accepted accessibility design standards, the slope of a wheelchair-accessible ramp should not exceed 1:12 to ensure safety and manageable propulsion force, while road width should be at least 1.5 meters for two-way wheelchair traffic, with a turning space diameter of no less than 1.8 meters. However, many community roads are steep (up to 1:8 in some older neighborhoods) and narrow, barely accommodating a single wheelchair, severely restricting the mobility and social participation of wheelchair users.

Inside buildings, excessive steps and the lack of accessible passages and elevators betray the principle of user-centered design. According to Zhong's research, "refined and simplified design for different types of elderly users, combined with ergonomic furniture, sensory care features, and standardized safety measures, is key to effective barrier-free residential design[3]" a principle equally applicable to spaces for people with disabilities. For example, at the "Home for Persons with Disabilities," health and rehabilitation facilities are inadequate, failing to meet the basic needs for health maintenance and rehabilitation. Ideal design should comprehensively consider medical support and assistive facilities tailored to different disabilities, such as rehabilitation equipment for physical impairments and tactile or auditory navigation systems for the visually impaired.

Figure 5. Photographs of the current status of the home for the disabled

4.3.2. Cultural Adaptation Challenges: Conflict Between Minority Customs and Universal Design

Within the field of multicultural community design research, cultural adaptation is a critical factor for fostering community harmony and promoting cultural integration. In typical immigrant communities such as the Huixi Community of Hongguozi Town, minority residents, particularly Hui Muslims, constitute a significant portion of the population. However, their specific cultural and religious needs have been insufficiently considered during the universal design processes of the community, highlighting a serious lack of respect for cultural diversity.

From the perspective of social space design theory, public spaces and residential layouts in communities should serve as vital platforms for multicultural coexistence and exchange. However, current practices reveal a failure to adequately investigate and integrate the unique customs and religious practices of Hui residents. For instance, the absence of designated prayer rooms or quiet spaces in public areas neglects the spiritual needs of Hui Muslims, for whom regular daily prayers hold profound religious significance. The lack of such facilities severely impairs their ability to maintain cultural practices, weakens their cultural identity, and diminishes their sense of belonging and psychological integration within the community.

From the viewpoint of facility design theory, public service infrastructure should demonstrate a high degree of cultural sensitivity. For example, the absence of halal dining facilities catering to Hui residents in the community violates the principles of culturally adaptive design. A reasonable and well-rounded community design must account for the basic living needs of residents from diverse cultural backgrounds and provide culturally aligned services. Only by doing so can multicultural communities foster mutual respect, inclusive interaction, and a cohesive social environment.

4.3.3. Service Chain Disruptions: Lag in Response from Needs Identification to Service Provision

In community service design theory, building an efficient and smooth service chain is essential for enhancing residents' quality of life and ensuring the community's sustainable operation. However, in many communities, particularly concerning persons with disabilities, significant delays are observed between needs identification and service provision.

From the perspective of information interaction design, the timely and accurate feedback of resident needs and the prompt, effective response by service departments are fundamental to establishing a sound community service system. In practice, however, channels for communicating the needs of persons with disabilities are often underdeveloped or inefficient. Some communities lack specialized platforms for collecting the needs of people with disabilities, or, if available, suffer from cumbersome information processing procedures and prolonged feedback cycles, resulting in insufficient service responsiveness and accuracy.

Regarding the management model of the "Home for Persons with Disabilities," most communities adopt a structure where such centers are managed by general community workers without dedicated professional managers. From the standpoint of organizational management design, a specialized management team is crucial for ensuring service quality and standardizing service processes. Overburdened community staff cannot adequately supervise or manage the centers, leading to irregular service procedures, inconsistency in service quality, and a failure to meet the diverse needs of users. A scientifically designed service management system should clearly define the responsibilities of each department and role, employ professional managers and service personnel, and implement standardized service processes. This would ensure efficient operation and high-quality service delivery, ultimately enhancing the service experience of persons with disabilities and the overall effectiveness of community support.

5. Design Optimization Strategies

5.1. Spatial Design Level: Reconstructing the "Needs – Behavior – Space" Matching Relationship

From the perspective of environmental behavior theory, spatial environments and human behaviors and psychology are closely interconnected, dynamically influencing each other. For special spaces such as the Home for Persons with Disabilities, achieving a precise match between users' perceptual needs, behavioral patterns, and spatial characteristics is crucial. Creating a low-stimulation, highly inclusive sensory-friendly environment aims to alleviate environmental stress for groups such as individuals with autism, thereby comprehensively enhancing their quality of life—a core concept aligned with environmental behavior theory. According to Xu's research, scientifically rational zoning of functional areas is foundational for effective spatial design[4]. Based on functional zoning theory, the Home for Persons with Disabilities should be clearly divided into learning areas, calming areas, and hygiene areas.In designing the learning area, light blue tones, known from color psychology to enhance concentration, are adopted, combined with hardwood desktops to meet the ergonomic stability requirements of learning environments, thus creating a focused and secure study atmosphere. In the calming area, beige tones are employed to create a soothing and peaceful ambiance. According to tactile design theory, soft carpets provide relaxing tactile experiences, perfectly matching the area's purpose of calming emotions. Prominent signage is installed based on wayfinding design principles, enhancing the area's visibility and facilitating quick and accurate spatial recognition. Transitional spaces are designed following spatial experience theory to reduce users' anxiety during spatial transitions. Sensory integration theory is applied through the creation of felt cabins and ball pits, offering rich tactile and visual stimuli to assist emotional regulation during

transitions. Careful circulation design is also essential. Rehabilitation, social interaction, and resting spaces are strategically connected according to behavioral path planning theory, minimizing users' cognitive load during movement and ensuring smooth, natural navigation through the space.

In terms of multi-dimensional environmental control:

Visual Design: Neutral cool colors such as light gray and pale blue are selected to create a comfortable, non-glare visual environment, fully adhering to visual comfort theories. Color-coded wayfinding is employed, such as using yellow signs to indicate hygiene areas, aiding orientation for users with visual impairments or cognitive difficulties.

Auditory Control: Techniques such as double-layer hollow glass and cork flooring are used to control sound levels. Dynamic classrooms are maintained at ≤45dB, and collective activity rooms at ≤55dB, ensuring appropriate acoustic environments based on acoustic design theory.

Tactile and Proprioceptive Design: Materials such as wool felt, silicone-edged furniture, and EPDM rubber flooring are used, coupled with rounded corners and the elimination of steps to maximize safety and comfort in accordance with safety and comfort design principles.

Flexibility and Safety: Modular furniture such as movable partitions and height-adjustable desks are introduced, following space flexibility design theory[5]. Fixed recessed seating is also provided, based on psychological safety design concepts, offering users stable psychological support.

Lighting Design: A balance between natural lighting (window-to-floor area ratio ≥ 1:6) and adjustable artificial lighting (LED light sources with dimmable switches) is ensured, complying with coordinated natural and artificial lighting design standards to meet varied lighting needs across different activities and times.

5.2. Service Design Level: Constructing the "Tools–Interface–Process" System Model

Guided by service blueprint theory, this study systematically reorganizes and integrates the frontstage, backstage, and support processes of the Home for Persons with Disabilities service system. By organically combining digital tools, interaction interfaces, and standardized procedures, the aim is to create a tightly connected and efficiently operated closed-loop service system, breaking down barriers between service stages and significantly enhancing the service experience for persons with disabilities. In the development of digital tools, advanced IoT and mobile Internet technologies are incorporated to establish an intelligent call system equipped with real-time positioning and emergency rescue functions. In emergencies, users can issue alerts with one click, transmitting precise location data to management terminals to ensure rapid response and maximum safety. A comprehensive service reservation platform is also developed, covering rehabilitation training, psychological counseling, and daily care services[6]. Leveraging big data analysis, the platform recommends services tailored to users based on their service history and personalized preferences, significantly improving service precision and effectiveness.

In interface design, a simple and accessible design principle is maintained. Features such as large icons, high-contrast colors, and voice prompts are adopted to facilitate use by visually impaired, low-vision, and cognitively impaired individuals. The interaction logic is optimized to minimize operational steps, improving service accessibility and convenience. In service process standardization, the Home for Persons with Disabilities is staffed with highly qualified professional managers. Detailed service procedures covering reception, needs assessment, service delivery, and feedback are established, with clearly defined responsibilities, strict service standards, and precise timeframes to ensure service quality and consistency. A comprehensive service quality supervision mechanism is implemented, including regular user feedback collection and data-driven analysis for continuous service process optimization and improvement of service quality and user satisfaction.

5.3. Cultural Communication Level: Translating "Cultural Symbols into Design Narratives"

Based on semiotics theory, this study systematically explores local culture through field research and literature reviews, deconstructing it into material, behavioral, and spiritual symbols. Through the processes of "decoding–reconstruction–re-encoding," these cultural symbols are integrated into the design of the Home for Persons with Disabilities, promoting both cultural heritage and the social integration of persons with disabilities. In Hongguozi Town, for instance, the design team incorporated the typical Hui architectural element of arches into the entrance design. The archway's height and width strictly follow accessibility standards, ensuring convenient passage while showcasing regional cultural features. Moreover, traditional Hui plant patterns are laser-engraved onto handrails and signage. The patterns' dimensions and clarity were tested by visually impaired users to ensure that the designs could be appreciated through touch, thereby enhancing cultural experience for all users. User feedback indicates that the integration of cultural elements significantly enhances users' sense of cultural identity[7].

Additionally, a "Traditional Craft Workshop" was established within the Home for Persons with Disabilities, offering handicraft courses such as paper cutting and Helan stone carving in collaboration with local intangible cultural heritage inheritors. Project-based learning methods were adopted, enabling disabled participants to engage in the full design and creation process—for example, crafting locally themed paper-cut greeting cards for festival celebrations. To further foster a culturally rich environment and promote community interaction, "Folk Culture Experience Days" were organized, recreating traditional festivals such as Eid al-Fitr and Eid al-Adha, allowing participants to experience local customs immersively. Furthermore, "Co-Painting Our Hometown" activities invited disabled and non-disabled residents to collaboratively create large-scale murals depicting the life transformations of immigrant communities. These activities significantly strengthened cultural confidence among persons with disabilities, enhanced the community’s acceptance of them, and substantially promoted interaction between disabled and non-disabled groups[8].

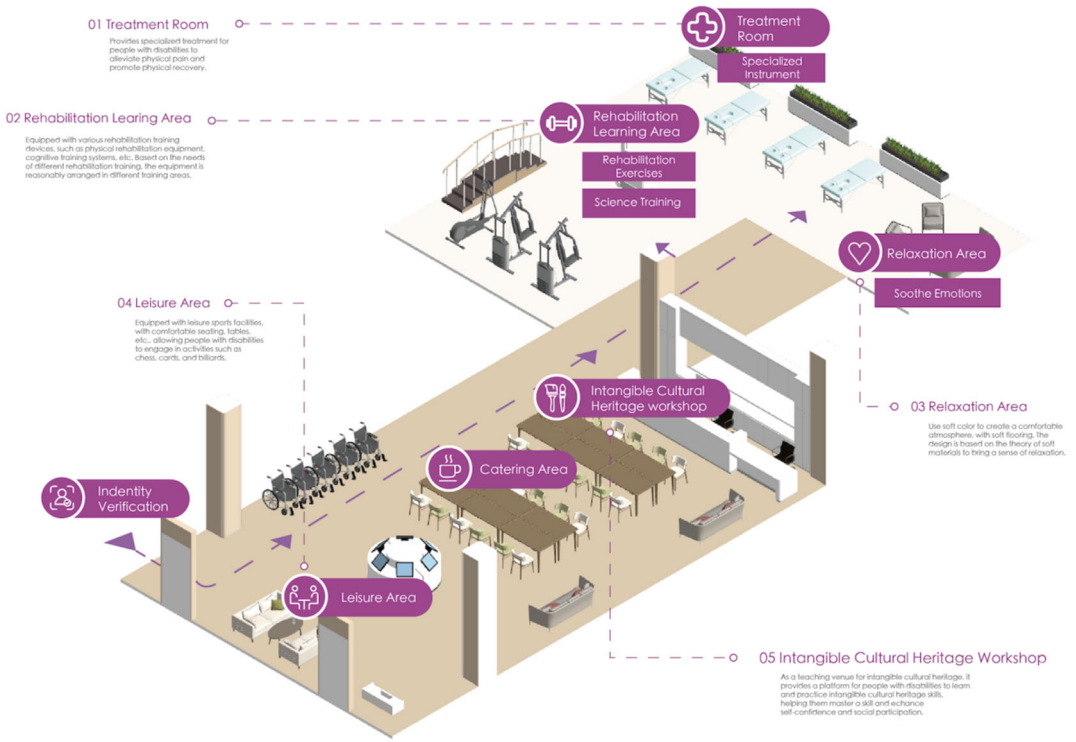

Figure 6. Conceptual map of the environment

6. Conclusion

This study, grounded in barrier-free design theory, conducted an in-depth investigation into the spatial service system of the immigrant community in Hongguozi Town, Ningxia, and systematically proposed a series of targeted optimization strategies. The research addressed multiple dimensions—including spatial planning, service provision, and cultural communication—with the goal of enhancing the quality of life for community residents, particularly persons with disabilities, and promoting social integration.

However, this study is subject to certain limitations. Constraints in sample collection and the partial immaturity of some research methodologies have affected the comprehensiveness of the findings. In the future, it will be necessary to expand the research scope, include a broader range of samples, and strengthen interdisciplinary collaboration to build a more comprehensive research perspective. Moreover, continuous tracking and evaluation of the effectiveness of the proposed optimization strategies are required to refine theoretical guidance and practical approaches for the long-term development of immigrant communities. Such efforts are crucial for providing more robust and scientific support to improve the living conditions and promote the sustainable and inclusive development of immigrant communities.

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