Research on pedestrian accessibility of urban parks and green spaces in Yantai city center based on GIS

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Abstract: I This study aims to evaluate the walking accessibility of urban park green spaces in the central area of Yantai using GIS-based network analysis. Parks are classified into two categories: (1) community parks and recreation gardens, and (2) comprehensive and specialized parks, with 15-minute and 30-minute walking thresholds applied respectively. The results indicate that the 15-minute accessibility of community parks is limited and spatially fragmented, with Laishan District showing relatively higher accessibility and Muping District exhibiting the lowest accessibility. In contrast, comprehensive and specialized parks demonstrate higher accessibility within a 30-minute walking range, with Muping and Fushan Districts having broader service coverage, while Zhifu District shows relatively low accessibility. Overall, urban park green spaces in Yantai exhibit uneven spatial distribution, insufficient alignment with population density, and disparities in service coverage. These findings provide a scientific basis for optimizing the spatial layout of urban green spaces and improving residents' well-being.

1 Background

1.1 Concept of Park City

With the acceleration of urbanization and the continuous improvement of living standards, the demand for high-quality urban green spaces has increased significantly. More residents expect to enjoy accessible and pleasant green environments while benefiting from urban convenience. In urban planning and development, it is essential to integrate urban growth with environmental protection, aiming to create a livable and sustainable urban environment. The concept of "Park City" was proposed in the report of the 19th National Congress of the Communist Party of China, which emphasizes that the entire city should be developed as an integrated park system, providing residents with a nature-oriented living environment. This concept highlights the importance of ecological civilization and promotes a shift in urban development from economic growth-oriented planning to ecologically sustainable and people-centered development, thereby guiding the future construction of urban park and green space systems [1].

1.2 Importance of Urban Park Green Space

The urban green space system consists of various types of green spaces, including parks, green belts, squares, and street greenery, and urban park green spaces represent one of the most important and widely distributed components. From an ecological perspective, urban park green spaces support natural ecosystem functions, enhance biodiversity, and contribute to environmental protection and improvement. Vegetation in green spaces plays an important role in air purification and microclimate regulation, such as temperature and humidity control. In addition, urban parks serve as essential public spaces for recreation, social interaction, and leisure activities. They provide facilities for outdoor activities, such as running tracks, fitness equipment, and children's playgrounds, which not only reflect the overall landscape character of a city but also indicate the quality of life of urban residents [2]. Furthermore, urban parks contribute to residents' physical and mental well-being and help strengthen community cohesion and social connections.

2 Related Research

2.1 International Research Progress

2.1.1 Urban Park Green Space Accessibility

Research on accessibility originated earlier in foreign countries. The concept was first proposed by Hansen in 1959, who introduced the gravity model to analyze spatial interactions among different elements [3]. Subsequently, the concept of accessibility was further developed and widely applied. In 1970, Torsten proposed a method for calculating accessibility [4], which established accessibility as an important analytical

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perspective in spatial studies. In 1990, accessibility was incorporated into the U.S. Disability Regulations, which promoted extensive discussions on universal design and social equity. In 2003, Herzele used human comfort as an indicator to evaluate accessibility differences among various outdoor spaces [5]. I In 2015, Calvin conducted questionnaire-based research and found that park accessibility significantly affects residents' usage and perception. In 2021, Li Xin applied the two-step floating catchment area method to urban road networks to propose optimization strategies for public green spaces [6].Overall, existing studies indicate that increasing attention has been paid to the service efficiency and accessibility of urban park green spaces.

2.1.2 Application of GIS in Accessibility Studies

The application of GIS in accessibility research began in the early 1990s. In 1991, Miller used GIS to evaluate public service facilities in urban park green spaces [7], marking the initial integration of GIS into accessibility analysis. Subsequently, Nicholls applied GIS to analyze service radius and accessibility indicators, further exploring their impacts on residents. In 2007, Kyushik incorporated travel cost into accessibility analysis to examine the spatial distribution of urban park green spaces and their service coverage. In 2019, Artmann focused on the accessibility of urban parks for the elderly based on GIS methods. With the rapid development of geospatial technologies, GIS-based accessibility research has increasingly focused on methods such as buffer analysis and network analysis, leading to more refined and comprehensive evaluations.

2.2 Domestic Research Progress

2.2.1 Accessibility of Urban Park Green Spaces in China

Compared with international studies, research on urban park green space accessibility in China started relatively late. However, with the rapid urbanization process, issues related to spatial equity and green space provision have become increasingly prominent, which has attracted growing academic attention. Since the 1990s, Chinese scholars have gradually focused on urban green space planning and accessibility evaluation. In 1999, Yu Kongjian and his colleagues conducted early research on green space accessibility [8], which is widely regarded as a pioneering study in this field in China. Although a formal definition was not explicitly proposed, this work laid the foundation for subsequent research on urban green space accessibility. In 2008, Yin Haiwei introduced GIS-based methods to construct an accessibility model from the perspective of spatial equity [9], using cities such as Shanghai and Qingdao as case studies, thereby promoting the application of accessibility theory in urban park green space research. In 2022, Wen Shiya used Baidu Maps data and selected Shenyang as a case study to analyze residents' travel time to parks under different transportation modes, providing a more detailed evaluation of accessibility. Overall, domestic studies have gradually evolved from conceptual exploration to quantitative analysis, with increasing emphasis on spatial equity and practical applications.

2.2.2 Application of GIS in Domestic Accessibility Studies

The application of GIS in accessibility research in China began in the late 20th century. Yin Haiwei applied the cost-weighted distance method based on 3S technology to conduct dynamic analysis of urban green space accessibility in Shandong. In 2012, Qinhua used GIS network analysis methods, taking Chongqing urban park green space as a case study, and selected park entrances as analysis points to evaluate spatial accessibility, thereby improving methodological approaches in accessibility research. With the continuous development of GIS technologies, their application in accessibility studies has become increasingly mature. By integrating multi-source data, applying spatial analysis techniques, and providing visualization tools, GIS offers strong technical support for the evaluation and optimization of urban park green space accessibility.

3 Research Purpose and Significance

3.1 Research Purpose

This study aims to evaluate the accessibility of urban park green spaces in the central urban area of Yantai using GIS-based methods. Specifically, travel time, distance, and transportation modes are analyzed to assess the accessibility levels across different areas. By examining the spatial distribution of accessibility, this study identifies disparities and imbalances in park green space provision, thereby revealing areas where residents face difficulties in accessing parks. These findings provide a scientific basis for optimizing the spatial layout of urban park green spaces. In addition, this study analyzes key factors influencing accessibility, including transportation networks, land use structure, population distribution, and public transport facilities, **i**n order to determine their relative impacts on accessibility levels [10].

Based on the analytical results, targeted planning strategies are proposed to improve accessibility, such as optimizing park location and distribution, enhancing transportation connectivity, and improving park service facilities. These measures aim to support decision-making in urban planning and enhance residents' overall well-being. Overall, this study focuses on evaluating accessibility conditions, identifying spatial inequalities, analyzing influencing factors, and proposing optimization strategies to improve urban park green space accessibility and residents' quality of life.

3.2 Research significance

First, this study provides scientific support for urban planning by evaluating the accessibility of park green spaces in Yantai. By identifying spatial disparities in accessibility, it helps to reveal deficiencies in the current layout of park green spaces and supports the optimization of their spatial distribution, thereby improving coverage and accessibility.

Second, this study contributes to improving residents' quality of life by promoting equitable access to urban green spaces. As important places for leisure and recreation, urban parks play a key role in enhancing residents' well-being and social participation. Evaluating accessibility facilitates a more balanced distribution of park resources, reducing spatial inequalities and improving service levels.

Third, diversify the uses of park green space. Research can also provide thoughts on the diversification of uses of park green space. By studying accessibility, we can understand the needs and usage habits of residents in different areas for park green spaces, so that diverse uses can be considered in planning. Parks with different functions can provide residents with different places for leisure, culture, education, sports and other activities to meet the needs of different levels and groups.

4 Accessibility Concepts and Methods

4.1 Concept of Accessibility

Accessibility is a widely used concept in urban and transportation planning, referring to the ease with which a location can be reached from other locations [11]. It reflects both the connectivity of spatial elements and the convenience of movement between them. In urban planning, accessibility is an important indicator used to evaluate the effort, time, and cost required for people to reach specific destinations. It is commonly understood as the degree of spatial resistance that must be overcome to access a given location [12]. In studies related to urban park green space layout, accessibility serves as a key analytical tool for evaluating spatial distribution and service capacity.

4.2 Accessibility Evaluation Methods

In planning practice, accessibility evaluation methods are generally selected based on operability, accuracy, and applicability. Such methods typically have the following characteristics: (1) ease of implementation, (2) repeatability across different study areas [13]and (3) the ability to reflect the relationship between park green spaces and user groups [14]. Accessibility evaluation methods can be classified into different types depending on research objectives. For example, indicator-based evaluation methods use metrics such as per capita park green space area, green space ratio, and green coverage rate to assess the relationship between green space supply and population demand. In contrast, spatial accessibility methods focus on the spatial relationship between residential areas and parks. Common approaches include grid-based analysis, nearest-neighbor distance analysis, and buffer analysis, which are used to measure spatial proximity and accessibility levels [15].

5 Overview of the study area

Yantai City is located in the northeastern part of the Shandong Peninsula, bordering the Bohai Sea to the east and neighboring Qingdao to the north and Weihai to the south. The geographical coordinates range from 37°25′ to 38°23′ N and 119°10′ to 121°57′ E. The terrain of Yantai is characterized by a combination of hills, mountains, and plains, with elevations generally higher in the east and lower in the west. Mountainous areas are mainly distributed in the western and southern regions, including Baxian Mountain and Yungang Mountain. In addition, the coastal landscape features beaches and bays due to its long shoreline along the Bohai Sea. Yantai has a relatively well-developed transportation network, including expressways, national and provincial highways, as well as urban arterial and local roads, which provide good connectivity between different urban areas (Figure 1).

In recent years, with rapid urban development, indicators such as vegetation coverage, greening rate, and per capita park area have shown a continuous upward trend. Based on collected data, more than 70 urban parks have been identified in Yantai, including 18 comprehensive parks and 17 specialized parks, forming the basic structure of the urban green space system. These characteristics provide a suitable basis for analyzing the spatial accessibility of urban park green spaces in the study area.

Figure 1. Geographic location of Yantai City (Source: Author's own work)

6 Data Processing

The data used in this study were primarily obtained from the Yantai City Master Plan (2022–2023), which provides information on the location, area, and classification of urban parks. In addition, Baidu Maps was used as a supplementary data source for verification and spatial reference. Park green space data were categorized into point data and polygon data, including

information on park entrances, locations, names, areas, and types. Park entrances were defined as source points for accessibility analysis, based on the assumption that residents access parks through these entrances. All spatial data were processed using GIS-based tools. Geographic data of Yantai City were imported into Google Earth Pro for spatial referencing, and park boundaries were manually digitized using polygon tools. Attribute information was then assigned to the corresponding spatial features to construct a complete geospatial dataset. These processed data provide the basis for subsequent accessibility analysis using GIS methods (Figure 2).

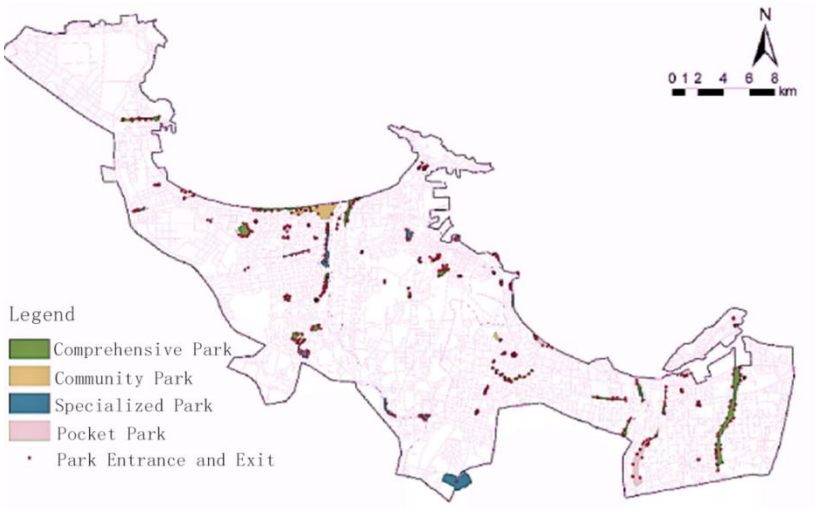

Figure 2. Distribution of urban park green space in Yantai downtown (Source: Author's own work)

6.1 Walking Accessibility Analysis

Walking accessibility refers to the ease with which residents can reach destinations based on walking travel mode, reflecting the degree of spatial resistance between locations [16].In this study, walking accessibility is used to evaluate the equity of access to urban park green spaces and the rationality of their spatial distribution[17]. Considering variations in individual walking behavior, an average walking speed of approximately 4–5 km/h (about 80 m/min) is adopted. Based on common urban planning standards, a 15-minute walking threshold is used to represent the optimal service range of community parks, while a 30-minute threshold is applied to larger parks with wider service areas. Accordingly, parks are classified into two categories: (1) community parks and recreation gardens, which mainly serve nearby residents within a 15-minute walking distance, and (2) comprehensive and specialized parks, which have larger service areas and are typically accessed within 30 minutes. Accessibility analysis was conducted using the ArcGIS Network Analyst tool. Park entrances were defined as source points, and the urban road network was used to generate service areas based on walking time thresholds (15 and 30 minutes).

6.1.1 Community Parks and Recreation Gardens

The 15-minute walking accessibility of community parks and recreation gardens was analyzed using the ArcGIS service area method (Figure 3). The results show that accessible areas are relatively limited and spatially fragmented, while a large proportion of urban areas remain outside the 15-minute service range. In terms of spatial distribution, the 15-minute walking accessibility rates are 5.49% in Zhifu District, 14.21% in Laishan District, 7.88% in Fushan District, and 7.78% in Muping District. Among these, Laishan District demonstrates the highest accessibility level, whereas Muping District exhibits the lowest accessibility. Overall, the distribution of community parks in Yantai is uneven, with insufficient coverage in several areas, which limits the formation of a comprehensive urban green space service system. This imbalance indicates that existing park resources are not adequately matched with residential demand, resulting in reduced accessibility for a significant portion of residents.

6.1.2 Comprehensive and Specialized Parks

The 30-minute walking accessibility of comprehensive and specialized parks was analyzed using the ArcGIS service area method (Figure 4). The results indicate that the overall accessibility level is relatively high compared to that of community parks. Specifically, the 30-minute walking accessibility rates are 24.37% in Zhifu District, 24.98% in Laishan District, 32.87% in Fushan District, and 40.21% in Muping District. Among these, Muping District and Fushan District exhibit higher accessibility levels, indicating a broader service coverage, while Zhifu District shows the lowest accessibility level. The relatively high accessibility in Muping and Fushan Districts can be attributed to the larger size and wider distribution of comprehensive parks, which expand their service areas. In contrast, the lower accessibility in Zhifu District is mainly due to the limited number and uneven distribution of parks, making it difficult for nearby residents to access them within walking distance.

Compared with the 15-minute accessibility results, the 30-minute accessibility shows a significant improvement in spatial coverage, indicating that large-scale parks play an important role in compensating for the insufficient service capacity of community parks.

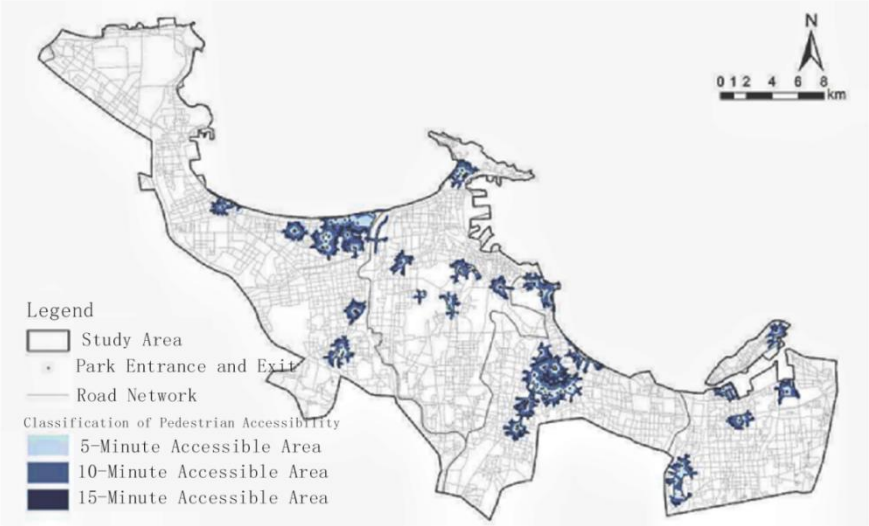

Figure 3. Pedestrian accessibility map of community parks and recreation gardens (Source: Author's own work)

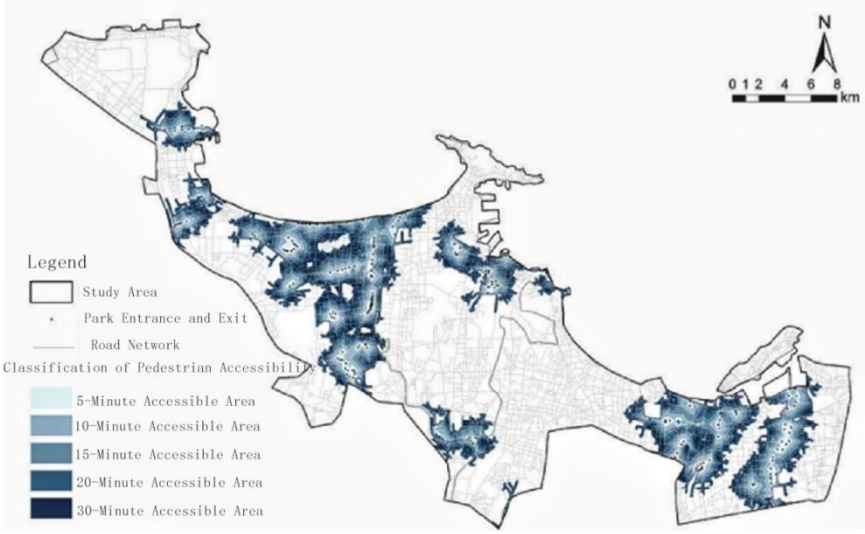

Figure 4. Pedestrian accessibility map of comprehensive and specialized parks (Source: Author's own work)

7 Conclusions and Suggestions

7.1 Conclusions

This study applies the ArcGIS network analysis method to evaluate the walking accessibility of urban park green spaces in the central area of Yantai, using 15-minute and 30-minute walking thresholds. The main conclusions are as follows:

(1) Accessibility varies significantly among different types of parks. The 15-minute walking accessibility of community parks and recreation gardens is generally low and spatially fragmented. Laishan District shows relatively higher accessibility, while Muping District exhibits lower accessibility levels. In contrast, the 30-minute walking accessibility of comprehensive and specialized parks is relatively high, with Muping and Fushan Districts demonstrating broader service coverage, while Zhifu District shows relatively limited accessibility.

(2) The spatial distribution of park green spaces is uneven and does not adequately correspond to population distribution. Some high-density residential areas lack sufficient nearby green spaces, resulting in inequitable access to park resources among residents.

(3) The overall service efficiency of park green spaces is limited. Differences in accessibility lead to an imbalance in resource allocation, with oversupply in some areas and insufficient provision in others, thereby reducing the overall effectiveness of park services in meeting residents' daily needs.

Overall, the accessibility of urban park green spaces in Yantai exhibits clear spatial disparities, indicating the need for further optimization of spatial layout and resource allocation.

7.2 Recommendations

(1) Optimize the spatial layout of park green spaces by increasing the provision of community parks and pocket parks in areas with low accessibility, such as Zhifu District, in order to improve local service coverage. This strategy should consider land availability, planning constraints, and financial costs to ensure practical feasibility.

(2) Improve the pedestrian network by enhancing slow-traffic systems, optimizing sidewalk connectivity, and increasing walking safety and convenience. Since accessibility directly affects residents' use of park green spaces, these improvements should be implemented in conjunction with existing urban infrastructure to reduce construction costs and maximize efficiency [18].

(3) Enhance service capacity through differentiated planning strategies. Comprehensive and specialized parks should expand their service coverage, while community parks should improve facility provision and usability. This hierarchical approach can optimize resource allocation under limited urban land and financial resources.

(4) Establish a dynamic monitoring and evaluation mechanism for park green space accessibility. By continuously updating data on population distribution and land use, planning adjustments can be made in a timely and cost-effective manner, thereby improving the equity and efficiency of green space services.

Overall, the implementation of these strategies should balance accessibility improvement with economic cost, land constraints, and long-term urban development goals.

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