

Article

Rethinking Cultural Ecosystem Services in Urban Forest Parks: An Analysis of Citizens' Physical Activities Based on Social Media Data

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Abstract: Urban forest parks play a vital role in promoting physical activities (PAs) and providing cultural ecosystem services (CESs) that enhance citizens' well-being. This study aims to reevaluate CESs by focusing on the physical activity experiences of park visitors to optimize park management and enhance citizen satisfaction. This study utilized social media data and employed natural language processing techniques and text analysis tools to examine experiences related to physical activities in Beijing Olympic Forest Park, Xishan Forest Park, and Beigong Forest Park. A specialized sports activity dictionary was developed to filter and analyze comments related to PA, emphasizing the impact of natural environments on enjoyment and participation in PA. The importance–performance analysis (IPA) method was used to assess the service characteristics of each park. The findings reveal that urban forest parks are highly valued by citizens, particularly for their natural landscapes, leisure activities, and the emotional fulfillment derived from PA, with 82.58% of comments expressing positive sentiments. Notably, appreciation for natural landscapes was exceptionally high, as evidenced by the frequent mentions of key terms such as 'scenery' (mentioned 2871 times), 'autumn' (mentioned 2314 times), and 'forest' (mentioned 1439 times), which significantly influence park usage. However, 17.11% of the reviews highlighted dissatisfaction, primarily with the management of facilities and services during sports and cultural activities. These insights underscore the need for performance improvements in ecological environments and sports facilities. This study provides a novel perspective on assessing and optimizing urban forest parks' functions, particularly in supporting active physical engagement. The rich CESs offered by these parks enhance physical activity experiences and overall satisfaction. The findings offer strategic insights for park managers to better meet citizens' needs and improve park functionality.

Keywords: urban forest park; cultural ecosystem services; physical activities; social media data; importance–performance analysis



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1. Introduction

Urban green spaces, as the primary venue for substantial interaction between urban citizens and nature [1], provide a variety of cultural ecosystem services (CESs), which are essential for maintaining urban ecological balance [2]. CESs include intangible benefits such as aesthetic experiences [3], cultural identity reinforcement [4], spiritual fulfillment [5], and the expanding of social spaces [6]. These services significantly influence citizens' lifestyles, physical health, and quality of life by encouraging physical activities (PAs). Regular exercise in urban forest parks has been shown to promote endocrine and neurochemical regulation, effectively mitigating common urban stresses and anxieties [7].

The United Nations Human Settlements Programme estimates that, by 2035, over 62.5% of the global population will reside in urban areas [8]. Rapid urbanization has led to higher residential densities in large cities to meet the increasing housing demands. This urban environment presents challenges to citizens' emotional health and psychological well-being. Research indicates that urban youth experience higher levels of sadness, closely associated with the built environment's density [9]. Older adults in central cities are more prone to psychological health issues such as loneliness, anxiety, and depression [10]. Additionally, many urban professions are sedentary, necessitating PAs to counteract the inactive nature of their work [11].

This study focuses on urban forest parks, which are some significant providers of CESs and cater to various PAs. Urban forest parks offer multifunctional environments through diverse natural and manufactured features such as water bodies, viewing platforms, educational paths, and interactive art installations, creating comprehensive cultural experience. These parks are vital venues for PAs and centers for vibrant cultural and social interaction, profoundly influencing citizens' lifestyles and social interactions. Participation in PAs within urban forest parks allows citizens to enjoy natural beauty [12], socialize [13], and engage in entertainment experiences [14], enhancing their subjective well-being [15]. Thus, urban forest parks play a crucial role in improving the quality of life for urban residents.

Traditionally, researchers have relied on interviews and questionnaire surveys to understand how citizens perceive and engage in CESs in urban forest parks and their impact on PAs. These methods, while informative, are often resource-intensive and context-specific, limiting the generalizability of the results. However, technological advancements have enabled access to a vast amount of user-generated data from social media and mobile applications, offering unique insights into individual behaviors and emotional responses in real-time natural settings [16]. Existing research has leveraged social media data to explore new dimensions in analyzing urban forest parks. Platforms such as X, Flickr, Instagram, Dianping, Mafengwo, Weibo, and Wikiloc are some rich sources of user experiences, including running, hiking, and cycling [17]. The text and images on such sites provide valuable references for exploring how CESs enhance these experiences [18]. Advances in natural language processing (NLP) technologies have made it possible to transform large volumes of unstructured social media texts into structured information. Techniques such as Latent Semantic Analysis (LSA), Word2Vec, and GloVe allow researchers to construct various low-dimensional vector representations of vocabulary, revealing deep semantic content [19,20]. These vectorized expressions capture semantic associations between words, enabling the identification of themes based on semantically similar vocabulary. This technology is widely applied in analyzing comments on social media, gaining insights into people's PA experiences and environmental perceptions in urban green spaces [21]. Although automated NLP technologies efficiently process vast amounts of data, human review is necessary to accurately capture the natural environment's true impact on people [22].

To better understand the CES experiences of citizens engaging in PAs in urban forest parks, the importance–performance analysis (IPA) method provides an insightful framework. The IPA method has effectively depicted non-linear relationships in user preferences across the tourism [23], business management [24], and public health sectors [25]. Applying the IPA method to CES analysis in urban forest parks can identify which attributes are crucial for enhancing citizens' perceptions and PA performance. Elements such as natural landscapes, including plants and water bodies, have a positive impact on citizens visiting green spaces for visual aesthetic experiences and outdoor exercises [26]. A survey in Belgium identified these as key qualities of urban green spaces [27]. Therefore, applying the IPA method can help park managers to optimize resource allocation and improve services or facilities that impact citizens' experiences.

This study aims to analyze social media data, using the CES theory and the IPA method to assess the CES experiences of citizens engaging in PAs in the urban forest parks of Beijing. The goal is to provide support for the optimization of park functional layouts and enhance management service quality. The specific research questions are as follows:

- (1) Which CES elements are most important to citizens engaging in PAs in urban forest parks?
- (2) What is the emotional tendency of citizens engaging in PAs in urban forest parks, as expressed on social media?
- (3) Based on the IPA model, which factors influence citizens' experiences in urban forest parks?

2. Materials and Methods

2.1. Research Area and Data Sources

This study focuses on Beijing, the capital of China, which serves as a political, cultural, and environmental model city. By the end of 2023, Beijing had a permanent population of 21.858 million and an urbanization rate exceeding 87.8% [28]. The city's green space, which covers 99,000 hectares, includes 36,000 hectares of park green space, with a per capita green space target of 16.89 square meters. The Beijing Municipal Landscaping and Greening Development Plan for the 14th Five-Year Period aims to achieve a forest coverage rate of over 45% by 2035 [29].

Data for this study were collected from the Chinese social media platform Dian Ping (<http://www.dianping.com>, accessed on 1 February 2024), which hosts detailed user reviews with pictures about local services. The three most reviewed and representative urban forest parks from Dian Ping's 'Surrounding Tour' channel under the 'Natural Scenery—Forest Parks' category were selected: Beijing Olympic Forest Park, Xishan Forest Park, and Beigong Forest Park (Figure 1). Beijing Olympic Forest Park, established for the 2008 Olympics, covers 680 hectares and integrates sports, culture, leisure, and ecological protection. Xishan Forest Park, located in the western suburbs, spans 900 hectares and is known for its natural landscapes and historical relics. Beigong Forest Park, in the northwest, covers 500 hectares and is renowned for its diverse forest resources and wildlife. These parks play a significant role in Beijing's ecosystem services and green space planning.

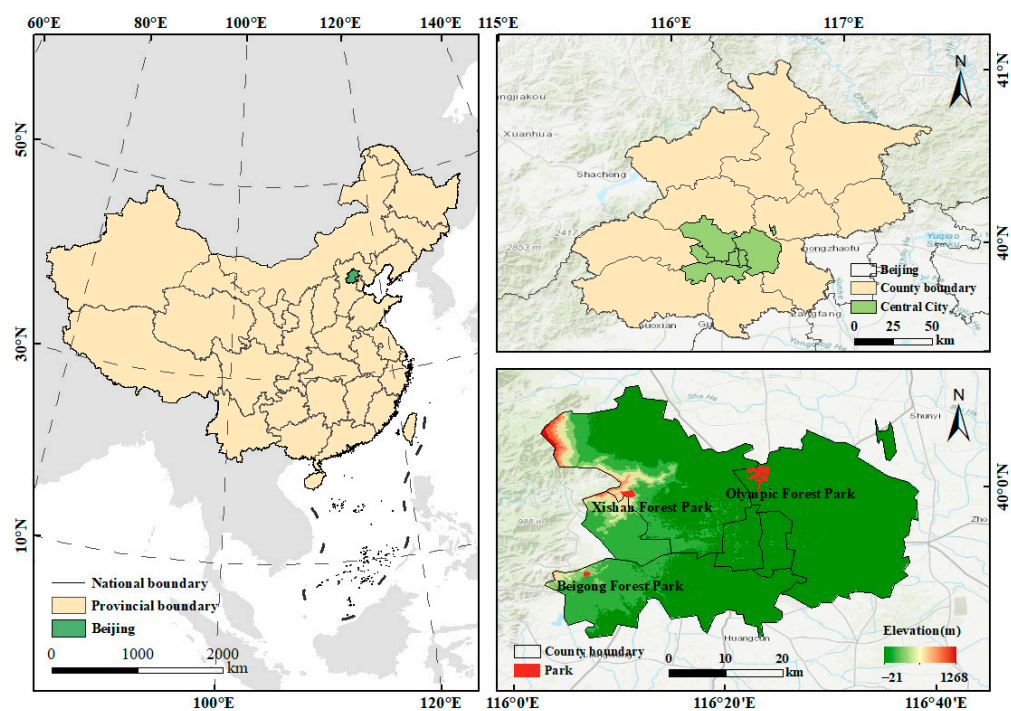


Figure 1. Study area.

2.2. Data Collection and Processing

A Python-based web crawler was used to extract comment data from 1 January 2019 to 1 February 2024. Collected information included park name, user ID, comment text, star

ratings (1 to 5 stars), and evaluation dates. The text data were cleaned using a PA dictionary, merging or removing duplicates and blank entries. Emojis lacking emotional expression were excluded to avoid data processing interference. This process yielded 22,012 comments, totaling 3,223,100 characters, providing a robust dataset for evaluation. Data analysis and processing are shown in Figure 2.

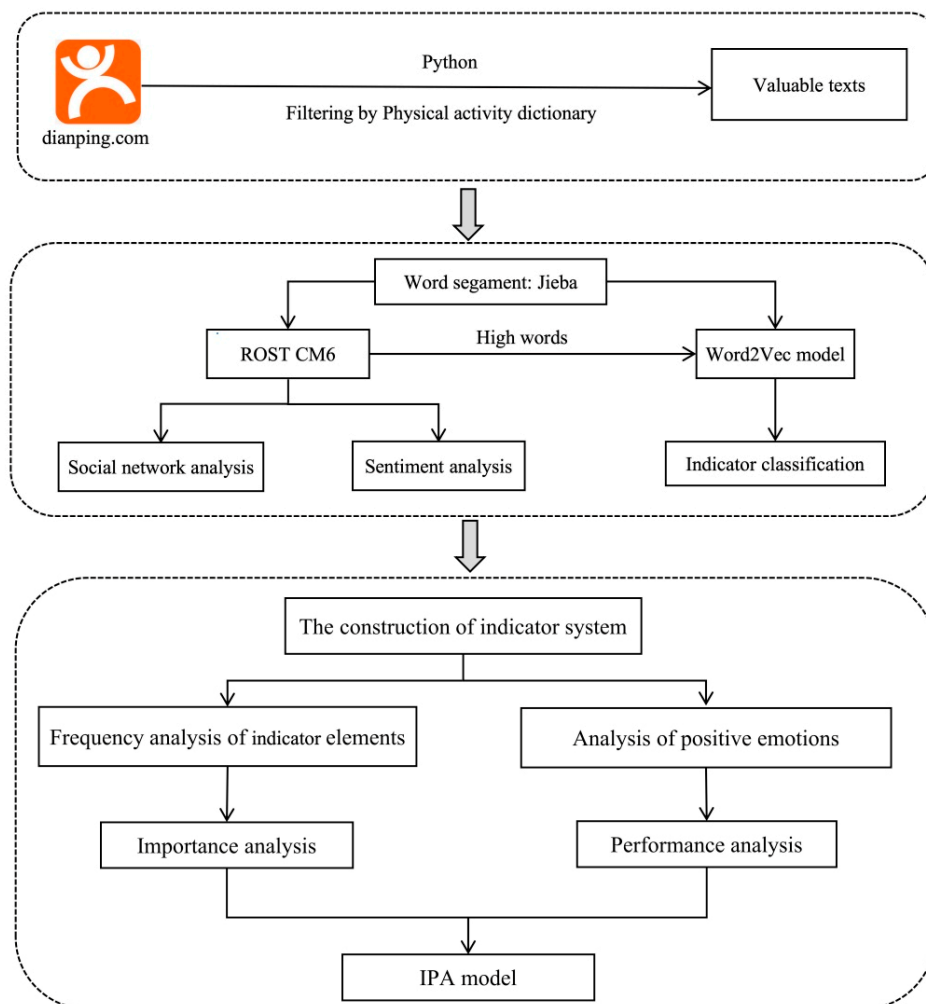


Figure 2. Research technical roadmap.

2.2.1. Data Preprocessing

The Python-based jieba package was utilized for text segmentation due to its accuracy and efficiency with large-scale data. Jieba supports custom segmentation dictionaries and features part-of-speech tagging and callable codes [30]. Additional Chinese dictionaries, including the sentiment dictionary from Dalian University of Technology [31], were used to enhance segmentation. Redundant or neutral words without clear connotations were removed. The HowNet dictionary identified transitional words, adverbs, and negations [32]. To eliminate irrelevant stopwords, stopwords dictionaries from Harbin Institute of Technology, Baidu, and Sichuan University’s Machine Intelligence Lab were integrated [33], resulting in a comprehensive stopwords dictionary that included emotional expressions, negations, and degree expressions.

2.2.2. Text Analysis

ROST CM6, developed by Professor Shen Yang from Wuhan University, was used for text preprocessing. This platform is widely recognized for its efficiency in handling large volumes of text data and supporting Chinese language analysis [34]. Functions such

as word frequency analysis, social network analysis, and semantic network analysis were employed to quantify and visualize the text data, constructing high-frequency vocabulary and semantic network analysis graphs based on the comments.

2.2.3. Dictionary Construction and Indicator Selection

Text vectorization was performed using the word2vec model, known for its low dimensionality, fixed vector dimensions, low computational cost, and effective word similarity representation [35]. Word2vec includes Skip-gram and CBOW (Continuous Bag-of-Words) models [36]. Skip-gram was chosen for this study due to its context prediction capabilities. High-frequency words from ROST CM6 were imported into the word2vec model, and the combined data were used to identify key evaluation factors, forming a comprehensive evaluation system.

By constructing a sports activity dictionary, comments involving PAs were filtered, and high-frequency words from online comment texts regarding PA factors in forest parks were extracted from the literature. This process recorded the issues of focused concern, combining them to determine evaluation factors, and, after encoding each factor, a related evaluation system was formed.

2.2.4. Construction of IPA Model

The IPA method was employed to assess the status and development potential of Beijing's urban forest parks in enhancing citizens' PA experiences. Proposed in 1977 by Martilla and James, the IPA method evaluates discrepancies between consumer expectations and actual experiences. Survey participants rated various CES characteristics based on importance and satisfaction. The IPA matrix divided the data into four quadrants: Quadrant I (Keep Up the Good Work) with high importance and performance; Quadrant II (Concentrate Here) with high importance but low performance; Quadrant III (Possible Overkill) with low importance and performance; Quadrant IV (Low Priority) with low importance but high performance.

The importance of each evaluation factor was assessed using the frequency of word occurrence in the texts, while satisfaction was measured by the proportion of positive emotional texts, which were defined as texts rated 4 stars and above. First, a frequency count of words for each indicator was conducted according to the established indicator system. Following this, satisfaction ratings were evaluated using the Likert scale method (1 star = very dissatisfied, 2 stars = dissatisfied, 3 stars = neutral, 4 stars = satisfied, 5 stars = very satisfied). The total number of positive texts for each indicator was then calculated, and their proportion relative to all texts was used to measure users' satisfaction with each element. This combined methodological approach provided valuable insights for park management and optimization, aiming to enhance urban citizens' health and well-being.

3. Results

3.1. Word Frequency and High-Frequency Words

The word frequency analysis of social media comments about Beijing's three forest parks extracted the top-200 high-frequency words, reflecting citizens' experience of CES while engaging in PAs in urban forest parks. Using the "Word Segmentation" and "Word Frequency Statistics" functions of ROST CM6 software, these high-frequency words were categorized into nouns, verbs, adjectives, and adverbs.

Nouns (58%) primarily relate to the park's natural landscapes, activity facilities, cultural elements, and ecological environment. For example, words like "park", "forest", "zoo", and "red leaves" reflect citizens' attention to natural landscapes. Verbs (22%) reflect the main types of activities of the citizens, such as "hiking", "running", "photographing", and "exercising", indicating active participation in various PA within the parks. Adjectives (12%) represent the citizens' perceptions of their experiences, such as "good", "free", "nice place", and "beautiful", showing some overall positive evaluations of the park experiences.

Adverbs (8%) represent the frequency and depth of the citizens' visits, such as "usually", "again", and "particularly", reflecting the ongoing use of and satisfaction with the parks.

By analyzing the top-200 high-frequency words in the comments, we gain a deeper understanding of the citizens' experiences with CESs. These focal points mainly concentrate on landscapes, activities, facilities, and management. Natural landscapes are the most concerning aspect for the citizens, accounting for 40% of the high-frequency words. Words like "scenery", "seasons", "flowers", and "trees" not only express citizens' appreciation for seasonal natural beauty but also reflect their profound understanding of ecological diversity and the natural environment, highlighting the significant role of CESs in providing aesthetic and spiritual enjoyment. Activity experiences are also a focus as citizens engage in activities such as hiking, running, and picnicking, not just for entertainment and leisure but also to improve health, showcasing the core value of forest parks in promoting physical health and social interaction. Facilities and safety, with about 10% of attention focused on words like "subway", "parking", and "safety", emphasize the importance of park infrastructure in enhancing visitor satisfaction and ensuring a safe experience. Although management services attract relatively less attention, words like "information", "service", and "maintenance" indicate that citizens have clear expectations for park operations and maintenance, expecting not only transparency but also efficiency, directly related to their overall experience quality.

This analysis reveals the focal points of citizens' attention towards forest parks and highlights the key role of CES in satisfying citizens' needs for aesthetics, health, safety, and information. By optimizing these services, urban forest parks can better serve the citizens, enhancing their quality of life and well-being.

3.2. Emotional Analysis

In this study, we conducted an emotional analysis of the citizens' experiences related to PAs in forest parks (Figure 3). We collected 22,012 comments from social media and review platforms, categorized into three emotional tendencies: positive, neutral, and negative. Specifically, comments rated as "4" and "5" were classified as positive emotions, totaling 18,178 comments, accounting for 82.58%. These comments indicate that most residents are satisfied with their experiences and the CESs provided by the forest parks. For example, residents highly rated the parks' landscapes, PAs, and public service facilities, with common words such as "comfortable", "charming", and "convenient." Comments rated as "3" were classified as neutral emotions, totaling 68 comments, accounting for 0.31%, reflecting citizens' neutral views on their experiences in forest parks. Comments rated as "1" and "2" were classified as negative emotions, totaling 3766 comments, accounting for 17.11%, showing that a portion of the residents had negative attitudes when participating in PAs and enjoying cultural services in forest parks. Common issues in negative comments were categorized into facilities, management, and services, with frequent terms such as "crowded parking", "outdated facilities", "unclear directional signage", and "poor service attitude."

The results of the emotional analysis reveal the main problems and potential areas for improvement in citizens' experiences in urban forest parks. Although most citizens are satisfied with the overall environment, atmosphere, and abundance of activities in the forest parks, some hold negative attitudes towards facility maintenance, service quality, and management levels. This feedback provides valuable suggestions for park managers; improving facility maintenance, enhancing service quality, and strengthening management can enhance the quality of experiences in urban forest parks, better meeting citizens' needs.

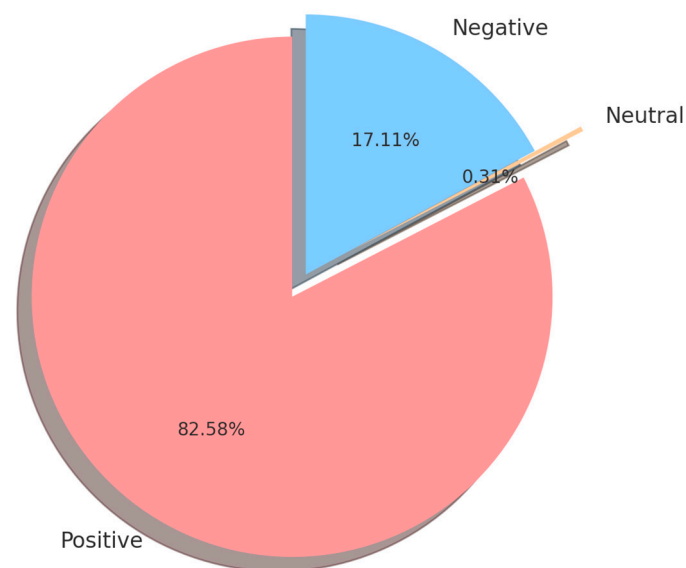


Figure 3. Emotional analysis chart of urban forest park reviews.

3.3. Cluster Analysis

Using the 200 high-frequency words and the word2vec model, cluster analysis identified four major clusters: natural landscapes, activities, infrastructure, and management, each centered around CESs in forest parks. The natural landscape cluster focuses on the aesthetic and ecological attributes that define the essence of forest parks, with sub-categories like natural landscape, ecological environment, and seasonal variation enhancing the visual and ecological diversity, which are crucial for a rich visitor experience. The activity cluster captures the variety of engagements possible within the parks, from active pursuits such as sports and fitness to more relaxed leisure activities and social interactions, all of which significantly contribute to the physical and emotional well-being of park visitors. The infrastructure cluster addresses the fundamental facilities and services that support accessibility and usability of the park, such as transportation and public amenities, which are vital for accommodating a wide range of visitor needs. Lastly, the management cluster deals with the operational aspects that ensure that the park is maintained efficiently, covering everything from management services to consumer expenditure and strategic planning layout, crucial for optimizing both the visitor experience and park sustainability. Each of these clusters, detailed in Figure 4, plays an integral role in defining the character and functionality of urban forest parks, influencing how visitors interact with and benefit from the park environment.

The natural landscape cluster highlighted rich natural resources in forest parks (Figure 5), such as “red leaves” (mentioned 2200 times), “forest” (mentioned 1439 times), and “ginkgo” (mentioned 906 times). These elements provide visual enjoyment and a natural backdrop for PA such as hiking and running. Additionally, the ecological environment cluster further emphasized the importance of “scenery” (mentioned 2871 times) and “landscape” (mentioned 2737 times), revealing how environmental quality impacts citizens’ health and well-being, especially air quality (“air” mentioned 1644 times) and lighting conditions (“sunlight” mentioned 627 times) affecting outdoor activities. The seasonal changes cluster explored the impact of temporal transitions on the use of forest parks, from the colorful “autumn” (mentioned 2314 times) to the vibrant “spring” (mentioned 1237 times), where the change of seasons not only alters the park’s landscape aesthetics but also redefines the types of activities and participation, such as water activities and resting in the shade during “summer” (mentioned 1171 times).

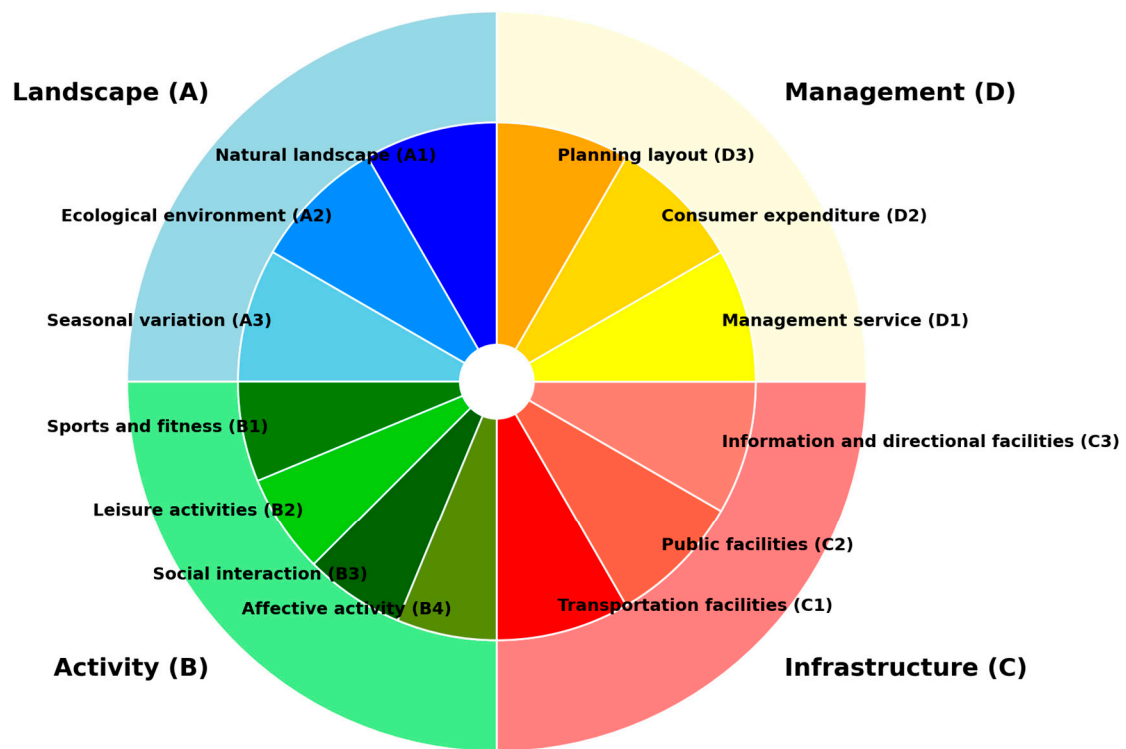


Figure 4. Comprehensive cluster analysis of urban forest park elements.

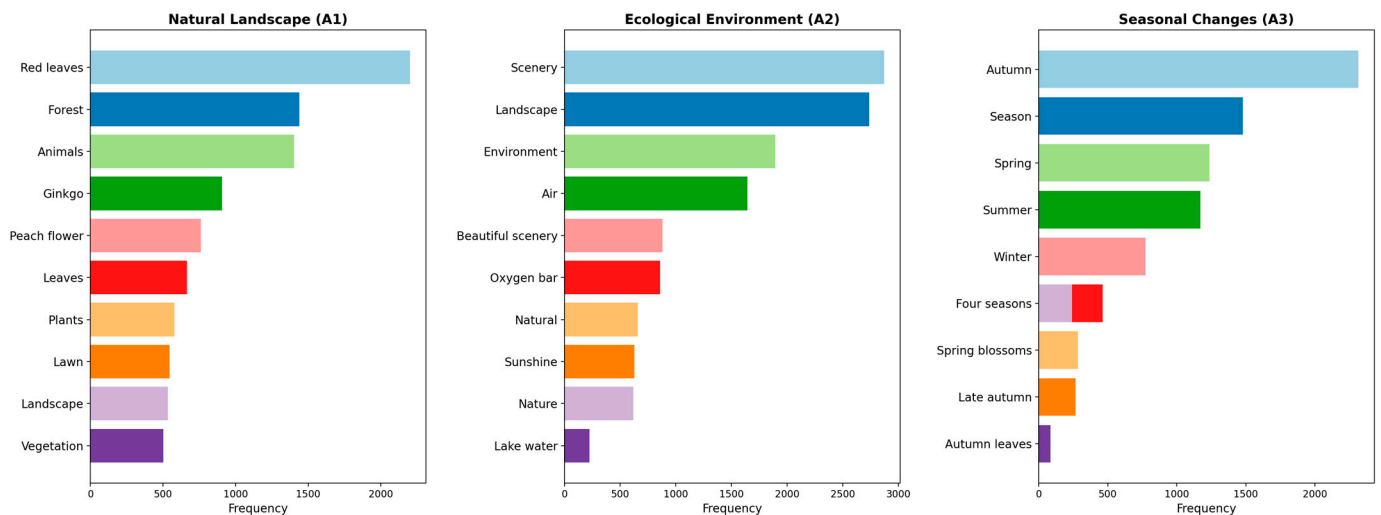


Figure 5. Top-ten words related to landscapes with their frequencies of occurrence.

The activities cluster, constituting 23% of the total comments, encompasses sports fitness, leisure activities, social interaction, and emotional activities (Figure 6). The sports fitness cluster showed the enthusiasm of citizens for engaging in various PAs in forest parks, with “hiking” (mentioned 6470 times) and “running” (mentioned 4582 times) emerging as the most popular activities. These findings underscore the park’s role as a vital venue for physical exercise, promoting personal health, fitness, and a deeper connection with the natural environment, thereby enhancing their overall quality of life for citizens. The leisure activities cluster covered more relaxed activities, such as “photographing” (mentioned 2911 times) and “picnicking” (mentioned 2439 times), showcasing the park’s function as a space for leisure and relaxation. These activities offer citizens opportunities to relieve daily stress and engage with nature, thereby improving their emotional quality of life. The social interaction cluster emphasized the function of forest parks as venues for community

interaction. Social media comments frequently mention gatherings from “friends” (mentioned 1929 times) to “families” (mentioned 320 times), highlighting the role of forest parks in fostering community cohesion and supporting family and friendship relationships. The emotional activities cluster focused on citizens’ emotional responses in their experiences in forest parks, with words like “suitable” (mentioned 5196 times) and “good” (mentioned 4873 times), indicating the significance of forest parks in enhancing citizens’ mood and psychological well-being.

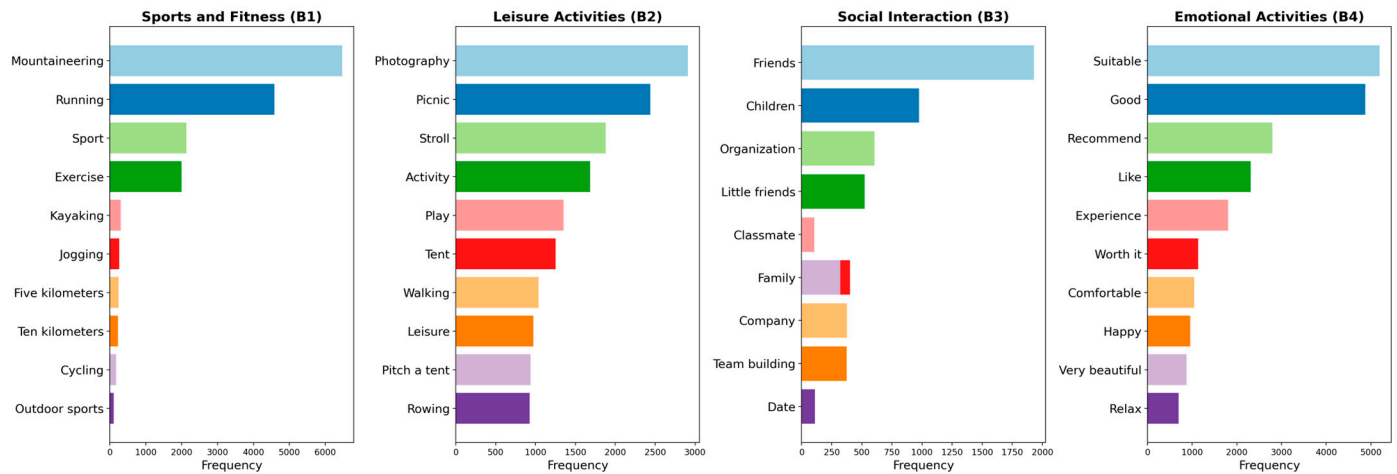


Figure 6. Top-ten words related to activity with their frequencies of occurrence.

The infrastructure cluster was particularly critical, as it directly affects citizens’ ability and willingness to engage in PAs in the parks (Figure 7). In this study, the infrastructure cluster accounted for 36% of the total clusters, including transport convenience, public service facilities, and information and guidance facilities, which are important factors in enhancing park accessibility and user experience. The transport convenience cluster showed that the physical accessibility of the park is key to attracting visitors, with “parking” (mentioned 4462 times) and “transport” (mentioned 3429 times) highlighting the importance of convenient transport connections for promoting citizen participation in park activities. Additionally, mentions of “subway” (mentioned 2068 times) and “bus” (mentioned 389 times) revealed the role of public transportation in enhancing park accessibility. The public service facilities cluster focused on the park’s internal facilities, such as “trails” (mentioned 1317 times) and “tracks” (mentioned 1131 times), which not only facilitate various forms of physical exercise but also enhance the park’s appeal as a venue for PAs. Meanwhile, facilities such as “children’s playgrounds” (mentioned 465 times) and “amusement parks” (mentioned 372 times) indicated that parks serve as recreational spaces suitable for families and children. The information and guidance facilities cluster covered the park’s internal signage and information systems, like “reservations” (mentioned 965 times) and “navigation” (mentioned 865 times), with the design and layout of these facilities directly impacting visitors’ navigation experience and the overall usability of the park. Clear “signs” (mentioned 240 times) and “road signs” (mentioned 59 times) help citizens to explore the park more effectively, ensuring that they can easily find the activities or attractions they wish to participate in.

The management cluster encompasses management services, consumer spending, and planning layout, reflecting park management’s efficiency and public participation quality (Figure 8). Keywords in the management services cluster include “queueing” (mentioned 896 times) and “opening” (mentioned 739 times), which highlight strategies for controlling visitor flow and ensuring park accessibility. Additionally, frequent mentions of “crowded” (mentioned 519 times) and “congested” (mentioned 286 times) indicate the challenges in managing the park during peak periods, while terms like “security” (mentioned 181 times) and “maintenance” (mentioned 136 times) emphasize the importance

of safety and facilities upkeep. These management measures directly impact visitors' experiences and their sense of security. The consumer spending cluster focused on the economic accessibility of the park. Keywords such as "tickets" (mentioned 3473 times) and "free" (mentioned 2335 times) highlighted the impact of access costs on park usage. Pricing strategies, including "fee" (mentioned 884 times) and "parking fee" (mentioned 691 times), are some critical components of park management that directly affect citizens' willingness to participate in park activities. The planning layout cluster is illustrated by terms like "north park" (mentioned 2253 times) and "routes" (mentioned 1607 times), showcasing the spatial configuration and utilization efficiency of the park. These planning decisions affect both the functionality and aesthetics of the park and determine its capacity to support a variety of sports and leisure activities. For instance, mentions of "area" (mentioned 916 times) and "hectares" (mentioned 306 times) highlighted the park's scale and its ability to accommodate large-scale public events.

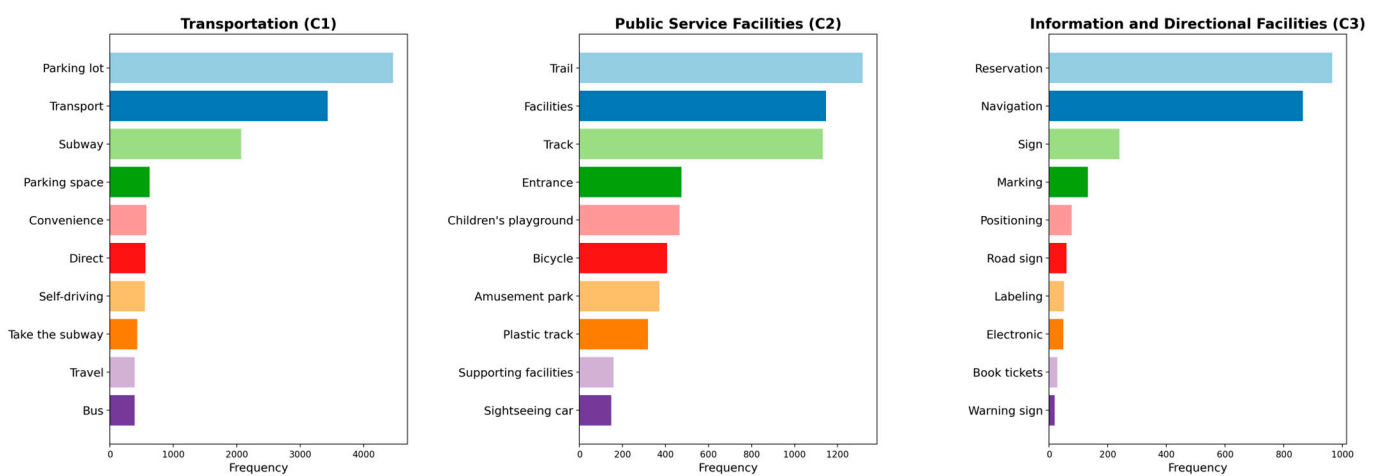


Figure 7. Top-ten words related to infrastructure with their frequencies of occurrence.

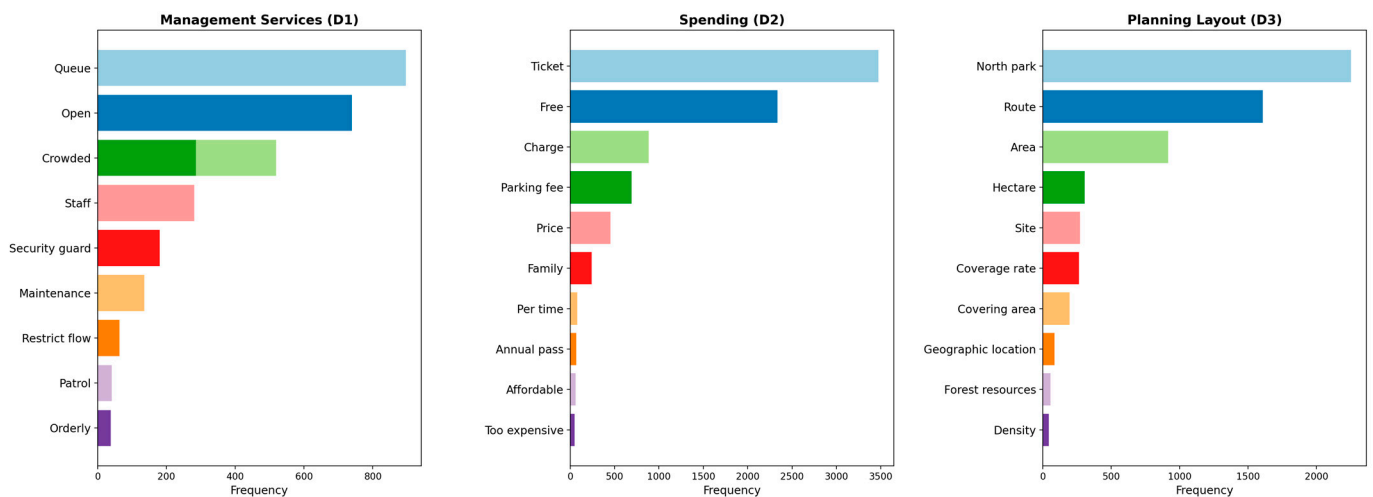


Figure 8. Top-ten words related to management with their frequencies of occurrence.

By analyzing the clustering of high-frequency words, this study identified four main categories of concern for citizens visiting urban forest parks: natural landscapes, activities, infrastructure, and management services. The emphasis on natural landscapes and activities indicates citizens' needs for PAs and visual enjoyment in the park, while the attention to infrastructure and management highlights their requirements for park convenience, safety, and service quality. The cluster analysis results offer clear guidance for the design,

management, and optimization of parks, providing important references for enhancing citizens' experiences with CESs.

3.4. Semantic Network Analysis

To further comprehend the elements influencing both positive and negative evaluations of participants' experiences in forest park PAs, this study employed semantic network analysis. This method revealed key experience elements frequently mentioned in the comments and their co-occurrence relationships, which are essential for understanding the factors that significantly enhance or reduce citizens' satisfaction.

3.4.1. Positive Semantic Network Analysis

This study conducted a positive semantic network analysis to explore the factors contributing to residents' positive experiences while participating in PAs in urban forest parks. Comments rated "4" and "5", which represent citizens' positive experiences, were analyzed. Through this analysis, a network diagram was created, where nodes represent frequently mentioned experience elements in resident feedback (Figure 9). The density of connections between nodes indicates the co-occurrence frequency of these elements, reflecting their importance in enhancing citizens' satisfaction.

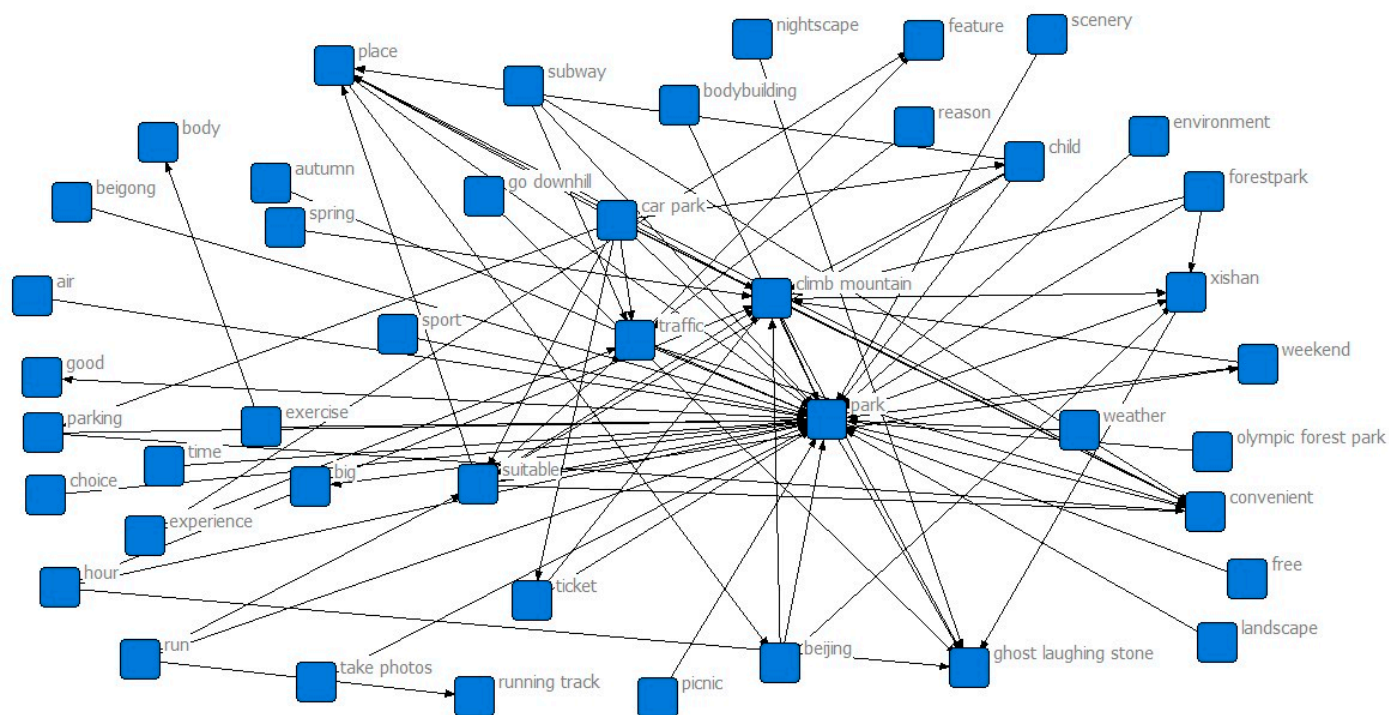


Figure 9. The semantic network of positive evaluations.

In the resulting positive semantic network diagram, several core nodes and their related connections can be observed, revealing multiple dimensions of citizens' positive experiences in forest parks. For instance, terms such as "scenery", "nature", and "green" are closely associated with "forest parks", highlighting the central role of natural beauty in citizens' experiences. Seasonal changes, particularly in "autumn" and "spring", make the natural landscape of forest parks a major attraction. Geographical locations such as "Xishan" and "Beijing" also appear in the network diagram, emphasizing the importance of natural resources in these areas and their role in positive resident evaluations. In terms of activities, terms like "fitness", "running", and "hiking" indicate the main PAs in which residents engage at the parks, while "picnicking" and "photography" reflect more leisurely activity choices. These activities not only contribute to physical health but also promote

social interaction and mental satisfaction. Additionally, terms such as “transport” and “convenience” point to the accessibility of the parks. Discussions about “parking facilities” and subway access highlight the importance of transport convenience as a factor in choosing to visit the parks. Nodes like “tickets” and “night scenes” also frequently appear, where ticket issues relate to the cost of access and night scenes represent the unique experiences offered by forest parks at night.

3.4.2. Negative Semantic Network Analysis

Conversely, the negative semantic network was constructed based on lower-rated comments (i.e., ratings of “1”, “2”, and “3”), to reveal factors leading to the negative experiences of residents. Through the negative semantic network diagram (Figure 10), we can identify some core nodes and their connections with other concepts, all of which highlight the negative aspects of citizens’ experiences in forest parks.

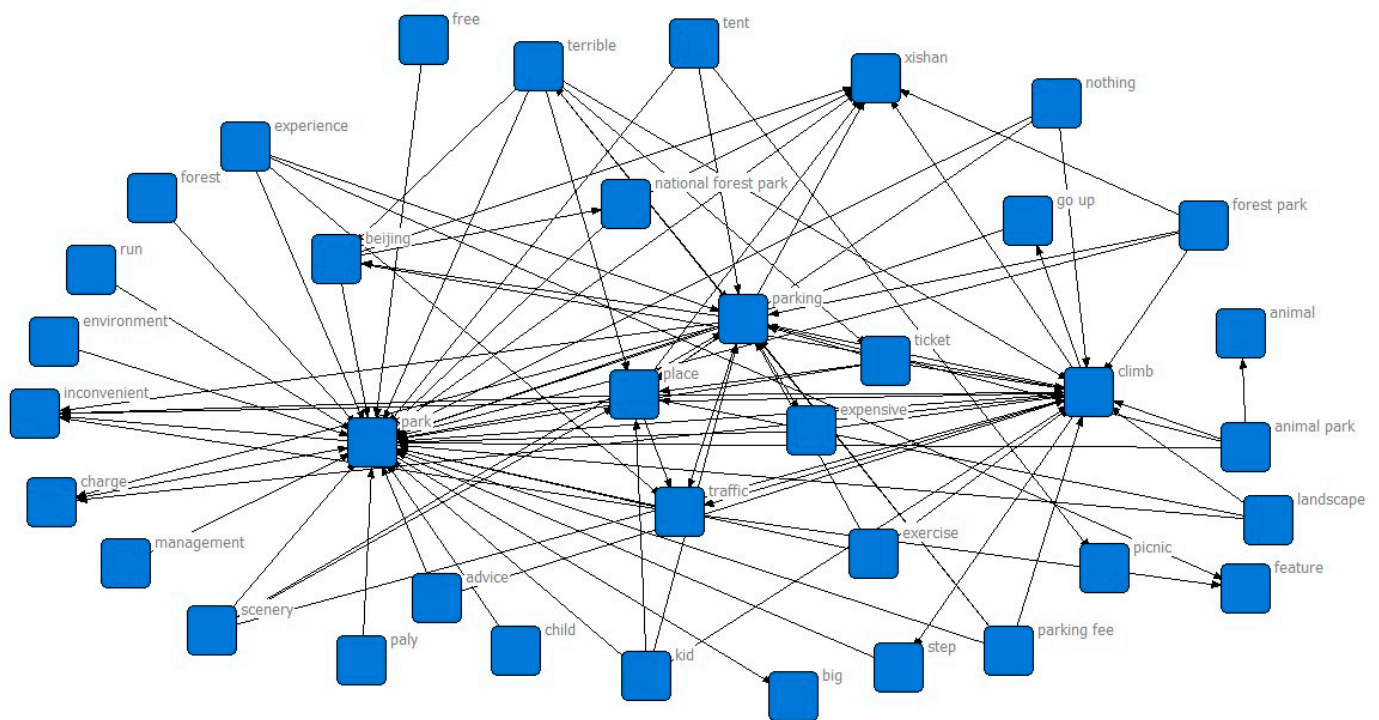


Figure 10. The semantic network of negative evaluations.

In this network, “management” and “service” serve as central terms, directly related to multiple negative experiences, highlighting the core role of management quality and service levels in resident dissatisfaction. Residents expressed strong dissatisfaction with poor management, such as a lack of effective guidance, inadequate security services, and poor service attitudes. In terms of transport and facilities, keywords “traffic” and “parking” demonstrate problems with providing convenient access, especially on “weekends”, when congestion is more severe. This indicates that residents particularly feel the challenge of accessing and parking in the park during peak times. At the same time, “fees” and “tickets” become some hot topics of discussion among residents, pointing out dissatisfaction with potentially high charges or a lack of transparency in park fees. Additionally, the occurrence of the term “environment” in the negative network reflects citizens’ concerns about the poor maintenance of the park’s internal environment, such as improper garbage disposal or inadequate protection of natural landscapes. Residents also express their expectations for improving the park environment and services through the term “suggestions”, showing their desire to see improvements. This information is crucial for park managers, helping

them to identify the key areas of concern and take measures to address these issues, thereby enhancing overall resident satisfaction and optimizing the park experience.

3.5. Construction of Resident Experience Elements for CESs in Urban Forest Parks Based on PAs

This study summarized the elements from the literature related to forest parks and evaluated the frequently mentioned words in the evaluation texts, integrating specific elements of interest in urban forest parks. Based on classifications from the Millennium Ecosystem Assessment [7], the Economics of Ecosystems and Biodiversity [37], and the Common International Classification of Ecosystem Services [38], as well as related urban green spaces studies, an evaluation index system for forest park experiences based on PAs was developed, consisting of 4 main indicators and 13 factors.

Table 1 shows the evaluation index system for resident experiences of CESs in urban forest parks based on PAs. The four main indicators include landscape, activities, infrastructure, and management, each with three to four specific factors.

Table 1. Evaluative indexes of citizen experience with urban forest park in terms of PA.

Evaluation Term	Indicators	Connotation
Landscape (A)	Natural landscape (A1)	Natural or artificial flora and fauna and wetland landscape.
	Ecological environment (A2)	The overall ecological environment, including air quality, water quality, etc.
	Seasonal variation (A3)	Seasonal changes are reflected in landscapes, such as the blossoming of flowers in spring and the falling leaves in autumn.
Activity(B)	Sports and fitness (B1)	The type and quality of PAs supported by the forest park.
	Leisure activities (B2)	Describe the leisure experience.
	Social interaction (B3)	Embodies the role as a social place.
	Affective activity (B4)	Highlights the emotional experiences and well-being facilitated by the forest park.
Infrastructure (C)	Transportation facilities (C1)	Geographical accessibility and parking.
	Public facilities (C2)	Forest park internal facilities and service quality.
	Information and directional facilities (C3)	The various information and directional aids provided by the park.
Management (D)	Management service (D1)	Management effectiveness and maintenance level.
	Consumer expenditure (D2)	Tickets, meals, and other expenses.
	Planning layout (D3)	Route planning, reasonable planning, etc.

3.6. IPA Analysis of PA in Forest Parks Based on Citizen Participation

In the IPA conducted on the Olympic Forest Park, Xishan Forest Park, and Beigong Forest Park, we systematically evaluated each park's performance in providing forest park experiences and their importance.

3.6.1. IPA Analysis of Olympic Forest Park

In the IPA analysis of Olympic Forest Park, we identified several key areas that are crucial for enhancing citizens' overall satisfaction (Figure 11). Located in the first quadrant

(high importance–high performance) are natural landscapes (A1), recreational activities (B2), and emotional activities (B4), which are widely praised for their excellent performance and significant contributions to citizens’ quality of life. In the second quadrant (low importance–high performance) are information and guidance facilities (C3). Although they perform well, their core importance is relatively low, suggesting that optimizing these non-core services could potentially enhance the overall visitor experience. In the third quadrant (low importance–low performance) are seasonal changes (A3) and social interaction (B3), both showing lower satisfaction and importance, but they could subtly enhance the park’s appeal and functionality with appropriate enhancements. In the fourth quadrant (high importance–low performance) are ecological environment (A2), sports fitness (B1), and transportation facilities (C1). These critical areas are underperforming but are extremely important for citizens’ well-being. For these areas, a series of priority improvement strategies need to be implemented to ensure that the park maximizes its role in enhancing citizens’ health and satisfaction.

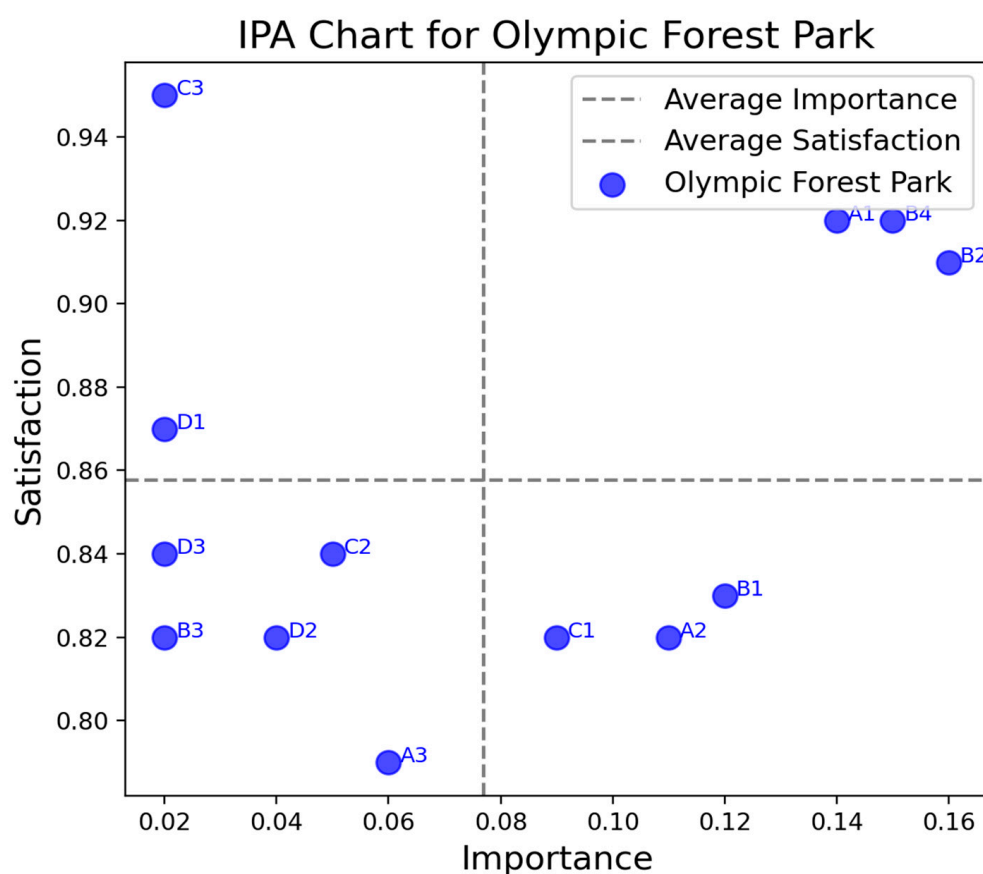


Figure 11. IPA diagram of citizen experience with Olympic Forest Park in terms of PAs.

3.6.2. IPA Analysis of Xishan Forest Park

In the IPA analysis of Xishan Forest Park, sports fitness (B5), emotional activities (B8), and transportation facilities (C4), located in the first quadrant, perform excellently and are considered highly important, significantly fostering citizens’ PAs and emotional health (Figure 12). Maintaining and further enhancing these services is recommended to preserve the park’s role as a community activity center. Natural landscapes (A4), seasonal changes (A6), social interaction (B7), management services (D4), consumer spending (D5), and planning layout (D6), located in the second quadrant, perform well but are considered of relatively low importance by residents. This finding suggests that, although these elements currently meet basic expectations, there is still room to optimize resource allocation to improve efficiency and responsiveness. Public service facilities (C5) and information

and guidance facilities (C6) in the third quadrant have low importance and performance, indicating that these areas are not urgent priorities, but appropriate improvements could enhance visitors' navigation experiences and overall satisfaction. The ecological environment (A5) and recreational activities (B6) in the fourth quadrant are critical areas needing focused improvement, particularly as ongoing enhancements to the ecological environment not only relate to biodiversity conservation but also directly affect citizens' leisure experiences and health. Strengthening investment and management in these areas is key to enhancing the overall functionality of the park and citizens' satisfaction.

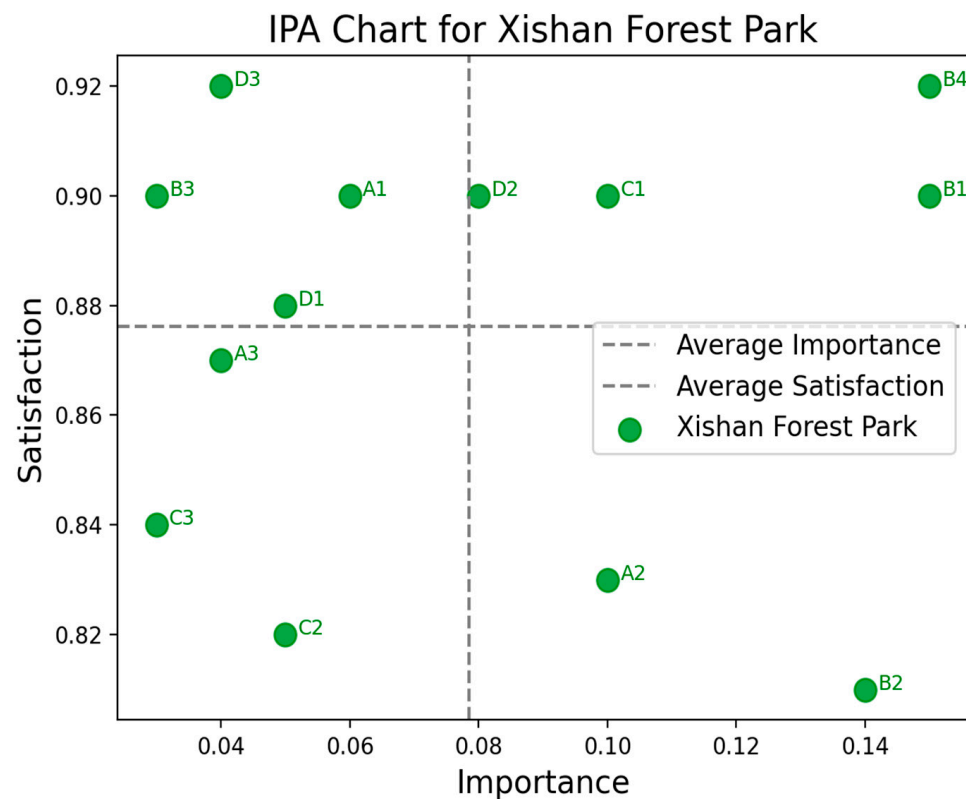


Figure 12. IPA diagram of citizen experience with Xishan Forest Park in terms of PAs.

3.6.3. IPA Analysis of Beigong Forest Park

In the IPA analysis of Beigong Forest Park, natural landscapes (A7) and ecological environment (A8), located in the first quadrant, perform well, reflecting the park's success in natural conservation and ecological maintenance, and highlighting the importance of these elements in providing spaces for PAs (Figure 13). The second quadrant includes seasonal changes (A9), sports fitness (B9), social interaction (B11), public service facilities (C8), management services (D7), consumer spending (D8), and planning layout (D9). Although these elements are of relatively low importance in citizens' lives, their good performance provides services that exceed citizens' basic expectations, especially sports fitness (B9) and social interaction (B11). Information and guidance facilities (C9), in the third quadrant, showing low importance and performance, indicate that, while not urgent, appropriate improvements could still enhance overall satisfaction. Leisure activities (B10), emotional activities (B12), and transportation facilities (C7) in the fourth quadrant are of high importance to citizens' PAs and emotional health but perform poorly, urgently requiring significant improvements.

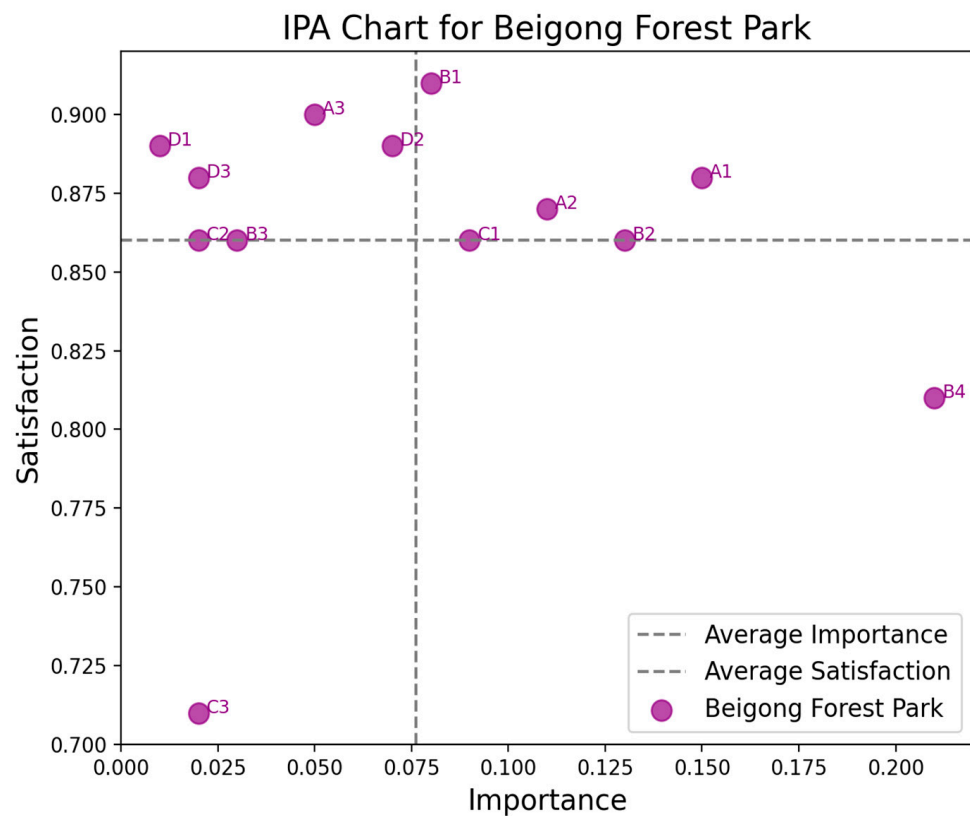


Figure 13. IPA diagram of citizen experience with Beigong Forest Park in terms of PAs.

In summary, these analyses reveal the strengths and weaknesses of each park in meeting citizens' expectations (Figure 14). Olympic Forest Park excels in natural landscapes, recreational activities, and emotional activities, all positioned in the first quadrant, indicating high resident satisfaction and importance. However, the ecological environment, sports fitness, and transportation facilities fall into the fourth quadrant, highlighting that, despite their critical importance to residents, their performance has not met expectations and needs priority improvement. Xishan Forest Park also performs outstandingly in sports fitness, emotional activities, and transportation facilities, indicating that it meets citizens' high expectations in these areas. However, deficiencies in the ecological environment and leisure activities located in the fourth quadrant show that these key areas urgently need strengthening to enhance overall resident satisfaction. Beigong Forest Park performs well in natural landscapes and ecological environments, marking highlights in the first quadrant, indicating that these infrastructures are well maintained. At the same time, leisure activities, emotional activities, and transportation facilities require focused attention and improvement, as their placement in the fourth quadrant indicates their high importance but poor performance. Additionally, in terms of regional differences, Olympic Forest Park emphasizes modern sports facilities and urbanized recreational activities, while Xishan Forest Park focuses on its rich natural and cultural heritage, attracting a broader range of ecological and cultural experience seekers. In contrast, Beigong Forest Park is characterized by its excellent ecological management and environmental conservation, offering a distinct natural experience compared to other parks. These differences reflect the differentiated strategies of urban forest parks in meeting the diverse needs of visitors and provide important references for future park management and planning.

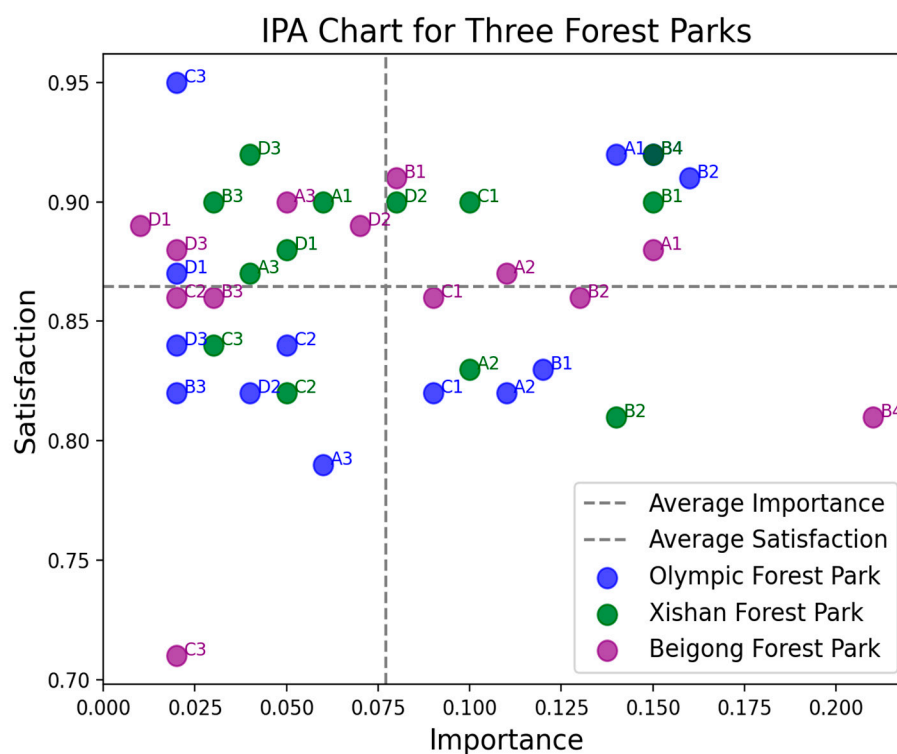


Figure 14. Comprehensive IPA of citizen experience in urban forest parks in terms of PAs.

4. Discussion

This study explores an innovative approach, using social media data to assess CESs in urban forest parks. By analyzing the spatial and semantic patterns of PAs and the associated CESs, we identified that natural landscapes, activities, infrastructure, and management services are the most valued elements by residents. Moreover, our findings indicate a predominantly positive emotional response towards urban forest parks. Natural landscape elements, such as plants and water bodies, significantly enhance citizens' PAs, supporting the results of the IPA. This study underscores the vital role of urban forest parks in promoting health and well-being, providing evidence-based recommendations for park management.

4.1. Construction of a Resident Evaluation Indicator System for CESs in Urban Forest Parks Based on PAs

This study has developed an evaluation index system for CESs in urban forest parks based on real-time social media data. Emphasizing the importance of PAs for health, social interaction, and psychological recovery, the index system includes four major areas: landscape, activities, infrastructure, and management. These areas encompass 13 factors such as natural landscapes, ecological environments, seasonal changes, sports activities, leisure activities, social interactions, emotional activities, transportation facilities, public facilities, information and guidance facilities, management services, consumer spending, and planning layout. The establishment of this index system is based on an in-depth analysis of social media data and the existing literature, aimed at capturing and assessing the specific role of CESs in promoting citizens' PAs.

Previous studies primarily utilized GIS to explore CESs, focusing on spatial-temporal characteristics and the connection between urban nature, PAs, and health [39]. However, they have overlooked citizens' actual experiences and the specific impacts of sports activities on well-being and the role of management and service [40]. Our study fills this gap by concentrating on residents' daily experiences and activities, particularly the relationship between sports activities and CESs. The evaluation system aligns with standards from the

Millennium Ecosystem Assessment [7], The Economics of Ecosystems and Biodiversity [37], and the Common International Classification of Ecosystem Services [38]. Social media data provide broader, immediate feedback, compensating for the limitations of traditional surveys and offering a scientific basis for optimized park management.

This evaluation index system allows us to identify and strengthen key indicators that most affect resident experiences, enhancing its practical value. It provides data support for urban planners and park managers to allocate resources effectively and optimize park design and services.

4.2. CESs and PAs in Urban Forest Parks

This study elucidates the mechanisms through which CESs enhance PAs. Urban forest parks, with their diverse natural landscapes and facilities, stimulate citizens' enthusiasm for engaging in various PAs, positively impacting their health and well-being. These findings highlight the crucial role of CESs in increasing urban citizens' participation in activities and overall well-being. Social media data capture real-time citizens' perceptions of CESs during PAs, revealing that urban forest parks support a range of PAs, from high-intensity exercises like running and hiking to more tranquil activities like walking and yoga. Research confirms that this diversity meets the health and fitness needs of different residents and provides opportunities for intimate nature connection [41]. PAs serve as a crucial link between green spaces and mental health.

We need to recognize that the importance and satisfaction of CESs in urban forest parks for visitors are not static but exhibit dynamic characteristics that vary over time, space, and external conditions. Firstly, seasonal factors and weather changes significantly influence park usage frequency and satisfaction, especially as vegetation conditions vary across seasons, altering visitors' experiences and perceptions of CESs [42]. Secondly, the renewal, maintenance, and management of park facilities play a crucial role in the long-term dynamic changes in visitor satisfaction, where improvements in facilities continuously enhance visitors' leisure and exercise experiences [43]. Thirdly, the visitors' perceptions of crowding and the resultant emotional fluctuations affect their evaluations of park services, while adaptive management strategies can mitigate these negative impacts [44]. Moreover, individual background differences such as age, culture, and past experiences lead to varied perceptions and preferences towards the same CESs, which evolve with changes in visitors' personal experiences [45]. Additionally, changes in the surrounding urban environment, such as traffic and construction developments, significantly impact the park visitors' sense of safety, convenience, and overall experience, thereby influencing their evaluations of cultural services [46]. Lastly, as the ecological environment, landscape, and biodiversity change, visitors' perceptions of the park's aesthetic and restorative functions also shift, further intensifying the dynamics of their experiences [47]. Future research should aim to systematically capture and track the key factors affecting visitors' importance and satisfaction with CESs in urban forest parks through social media data analysis or long-term observational studies. Furthermore, park managers should adopt proactive management strategies, conduct regular visitor satisfaction surveys, and utilize flexible, data-driven decision-making to dynamically optimize park facilities and service planning.

Our findings indicate that the relationship between CES experiences and PAs in different urban forest parks exhibits both representativeness and limitations due to regional variations. First, the representativeness of the study is reflected in the varying emphases on CESs in different regions. For instance, visitors to the Olympic Forest Park are attracted by its abundant sports facilities and high greening rate, aligning with European studies that have demonstrated a positive correlation between park facility quality, accessibility, and residents' participation in sports and their satisfaction [2]. Major events also enhance the park's status as a center for sport and recreation [48]. The Xishan Forest Park attracts ecotourists due to its historical cultural heritage and natural landscapes, a phenomenon also observed in Asia's Ugam-Chatkal National Park and Europe's Pulin National Park, showcasing the high attractiveness of cultural heritage and natural landscapes [49,50].

Beigong Forest Park draws eco-tourists through ecological conservation, similar to studies supported in parks in South Africa and Berlin, which underscore the positive effects of ecological management on cultural services and visitor experiences [51,52]. Moreover, the limitations of the study become apparent when considering the variations across different regions, influenced by disparate socio-cultural backgrounds, natural environments, and management strategies. These differences imply that findings from specific parks or regions may not be universally applicable. This underscores the need for future research to consider regional characteristics and local factors when extending and applying findings across different areas.

Our analysis shows that factors such as the physical environment, ecological quality, and provided services shape the CESs' impact on citizens' experiences. Beautiful natural landscapes enhance participation in PAs by improving psychological states and boosting emotional positivity [53]. The multifunctionality of PAs in urban forest parks, encompassing leisure, entertainment, health, social interaction, and psychological recovery, allows residents to pursue physical health, social interactions, and psychological relief. These activities help residents appreciate the park's cultural and ecological values, solidifying its role as an essential part of the urban ecosystem and enhancing its contribution to the quality of life for urban residents.

Incorporating PAs into CESs and treating urban forest parks as health-promoting environments align with global health promotion trends and sustainable urban development. Urban green spaces reduce public health costs by providing low-cost PA venues to prevent lifestyle-related diseases such as cardiovascular diseases, obesity, and diabetes [54]. This multifunctionality allows urban forest parks to respond comprehensively to residents' needs, enhancing their overall value in the urban ecosystem.

4.3. Recommendations for Enhancing the Resident Experience of CESs in Urban Forest Parks

This research utilizes keyword extraction and an analysis of user-generated content from urban forest parks to elucidate the varying needs and preferences among diverse demographic groups engaged in PAs, influenced by variables such as gender, cultural context, professional role, identity, and age cohort. The extant literature corroborates these observations. For instance, gender disparities are evident in the requisition of CESs, with males predominantly inclined towards leisure and aesthetic appreciation, whereas females demonstrate a heightened interest in historical and cultural significance [55]. Cultural context significantly influences park utilization patterns, with the cultural milieu of various cities shaping visitors' demands for amenities and recreational engagements. In Berlin and other European cities, usage patterns among visitors display marked cultural distinctions [2]. Professional roles and socio-economic status markedly dictate preferences for ecosystem services, with agriculturalists prioritizing hydrological resources and agromonic production, whereas administrative officials concentrate on governance and cultural services [56]. Divergences in priorities between specialists and the general populace are apparent in the provisioning of park services, specialists predominantly address managerial and operational challenges, while the general populace places a premium on natural gratification and leisure pursuits [57]. Furthermore, tourists and local inhabitants exhibit distinct requisites, with tourists predominantly focused on aesthetic and recreational experiences, whereas local inhabitants emphasize the multiplicity of ecosystem services and their pertinence to everyday living [58]. Age-related variances are characterized by older adults prioritizing comfort and rehabilitative health benefits, while younger cohorts favor athletic and social engagements [59].

Our analysis also reveals that convenient transportation connections and well-maintained infrastructure are critical for park usage. Research shows that good transportation connections significantly enhance park attractiveness, making parks ideal for leisure and sports activities [60]. Additionally, the richness of green spaces and proximity increase their usage rates [61]. Expanding parking facilities, optimizing walking paths and signage, and strengthening public transportation connections can improve park accessibility. These improvements

ensure barrier-free access, allowing everyone, including people with physical disabilities and the elderly, to use the parks effectively, thus enhancing citizens' health and well-being.

4.4. Limitations of the Study

Despite its merits, several limitations of this study should be noted. First, the reliance on a specific theoretical framework may not cover all social, environmental, and economic impacts associated with urban forest parks. Future research should validate this framework in various geographical and cultural contexts to enhance its universality and accuracy. Second, data from a single social media platform may limit representativeness. Future research should use data from multiple platforms and design supplementary surveys for populations not covered by social media data, such as older adults, to enhance data representativeness. Third, while text analysis and NLP technology are powerful, their accuracy and interpretative abilities are limited. Future research should employ more advanced NLP technologies to improve data analysis accuracy. Fourth, the subject of this study is the urban forest parks in Beijing. While these findings are representative to some extent, the results may vary due to differences in national regions, cultures, climates, and economic backgrounds. Future research could extend to a broader range of geographical and cultural contexts, particularly through similar studies in other cities or countries. Finally, the study focuses less on the connection between park environments and specific physiological health outcomes. Future studies should use device-based methods to assess PAs and systematically explore the specific impacts of urban forest parks on physiological health, providing comprehensive evaluation and guidance for park design and management.

5. Conclusions

This study explores citizens' experiences with CESs while engaging in PAs in urban forest parks by analyzing social media data. The findings indicate that urban forest parks provide a rich array of CESs, particularly excelling in promoting PAs. Specifically, the natural landscapes, diverse activity spaces, and other ecological services of forest parks collectively enhance the quality of citizens' experiences and satisfaction. This enhancement is confirmed through positive feedback on social media, highlighting the unique role of forest parks in providing spaces for psychological recovery and social interaction. Additionally, this study incorporates advanced text analysis technology that is capable of extracting and analyzing key information from vast amounts of social media data, offering a scientific basis for park management and policy-making. This approach aids in optimizing the functional layout and service provision of parks. Additionally, it is essential to recognize that the importance of CESs in urban forest parks and visitor satisfaction are dynamic rather than static. These aspects fluctuate with changes in time, space, and external conditions. Seasonal and weather variations, the updates and maintenance of facilities, and differences in visitors' individual backgrounds all influence their experiences within the parks. At the same time, the perceptions of crowding and changes in the urban environment further shape visitors' evaluations of park services. Additionally, this study reveals variations in the focus of CESs across urban forest parks. For example, the Olympic Forest Park, with its sports facilities and high greening rate, attracts many sports enthusiasts. In contrast, Xishan Forest Park, known for its rich historical and cultural heritage and natural landscapes, has become a hotspot for eco-tourism. Beigong Forest Park draws environmentally conscious visitors due to its exemplary ecological conservation efforts. These differences underscore the uniqueness of each region and park in providing CESs. We recommend enriching sports facilities in urban forest parks, including outdoor fitness equipment, bicycle trails, and multipurpose sports courts, to meet the needs of different age and interest groups. Regularly organizing fitness activities and educational seminars, such as yoga, running clubs, and healthy living workshops, can increase citizen participation and enhance community interaction. This strategy benefits physical health and promotes overall community harmony and development. Research from other countries and regions, such as Europe and Africa, supports our findings, indicating that this study has a certain degree of representativeness.

However, as the research is limited to Beijing, future studies should expand the scope to explore how key factors perform across different cultural and geographical contexts. Employing data from multiple social media platforms and integrating advanced analytical methodologies would significantly strengthen the verification of the study's outcomes.

Author Contributions: H.Z. and J.S. were responsible for the conceptualization of the study. H.Z. and J.Y. undertook the data curation. X.D. was in charge of the methodology and project administration. H.Z. handled the writing of the original draft. Both J.S. and X.Z. were involved in the review and editing of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: Data will be made available on request.

Conflicts of Interest: We confirm that the submission is original research and that neither the manuscript nor any parts of its content are currently under consideration or published in other publications. We declare no conflicts of interest.

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