A FRAMEWORK FOR ASSESSING VITALITY OF LEISURE URBAN SPACES IN NANJING, CHINA

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

January 2025

FBSB 2025 4

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Urban planning research examines the link between urban sustainability and urban space quality, emphasizing leisure's significant impact on social welfare and residents' life quality. In response to growing leisure demands, China has significantly expanded the provision of urban spaces with leisure functions. However, these spaces exhibit significant variations in attractiveness and utilization: some are overcrowded, while others remain underused or neglected due to inadequate maintenance. Vitality theory introduces a new approach to evaluating leisure urban spaces (LUS) quality, which is crucial for meeting leisure needs. Moreover, the adoption of big data analytics has transformed the analysis of urban dynamics, providing deeper insights into spatial and behavioral patterns. Therefore, the study aims to develop a multidimensional vitality evaluation framework to comprehensively identify the characteristics of leisure urban spaces through big data analysis.

The study explores key dimensions and factors influencing LUS vitality, integrating theories of urban leisure, leisure geography, vitality, urban space systems, spatiotemporal behavior, and behavioral change. It defines LUS and categorizes them into four types: parks, squares, waterfront spaces, and leisure blocks. Through narrative and systematic literature reviews, it identifies research gaps and trends, establishing a theoretical framework and evaluation indicator system for LUS vitality. The vitality of LUS is evaluated using multi-source data from systemic and individual perspectives. Systemically, GIS spatial analysis examines LUS distribution within Nanjing's Central Urban Area (CUA). Individually, big data and field surveys measure key indicators across 11 selected spaces, employing GIS analysis, word frequency analysis, text sentiment analysis, and statistical analysis. Pearson's correlation coefficient validates the theoretical framework, analyzing the relationship between crowd activity and the built environment. The final evaluation framework uses entropy and CRITIC weighting methods to calculate indicator weights. System-level analysis revealed stark differences in LUS distribution between the densely packed old city area (OCA) and the sparser newer urban areas, mirroring the concentrated distribution of population activities. Notable differences were found in the distribution and provision of different types of LUS. Individual-level analysis highlighted imbalances in space utilization and attractiveness. Crowd activity density and diversity of internal facilities emerged as critical indicators of LUS vitality. Each type of LUS exhibited unique temporal activity patterns, user group characteristics, and distributions of various leisure facilities. Users' preferences extend beyond nature to encompass historical, cultural ambience, and social and consumption facilities. Multiple aspects of crowd activity, including density, persistence, diversity, and feedback, were significantly influenced by the built environment's external and internal factors. These findings were also validated through expert surveys.

To bridge theory and practice, the study proposes strategic recommendations to enhance LUS vitality, including optimizing spatial configurations, improving connectivity and functional diversity, and increasing leisure facilities. These align with broader urban development goals, guiding policymakers and planners to achieve balanced leisure resource distribution and create vibrant, inclusive environments.

Keywords: vitality, leisure urban spaces, crowd activity, built environment, multi-source big data analysis

SDG: GOAL 11: Sustainable Cities and Communities

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

RANGKA KERJA UNTUK MENILAI DAYA HIDUP RUANG BANDAR BERMAIN DI NANJING, CHINA

Oleh

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Januari 2025

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Penyelidikan perancangan bandar mengkaji hubungan antara kemampanan bandar dan kualiti ruang bandar, menekankan impak signifikan masa lapang terhadap kebajikan sosial dan kualiti hidup penduduk. Menjawab permintaan masa lapang yang semakin meningkat, China telah memperluaskan penyediaan ruang bandar dengan fungsi masa lapang. Walau bagaimanapun, ruang ini menunjukkan variasi yang ketara dalam daya tarikan dan penggunaan: sesetengahnya terlalu sesak, manakala yang lain kurang digunakan atau diabaikan kerana penyelenggaraan yang tidak mencukupi. Teori vitaliti memperkenalkan pendekatan baru untuk menilai kualiti ruang bandar masa lapang (LUS), yang penting untuk memenuhi keperluan masa lapang. Selain itu, penggunaan analisis data besar telah mengubah analisis dinamik bandar, memberikan pemahaman yang lebih mendalam tentang corak ruang dan tingkah laku. Oleh itu, kajian ini bertujuan untuk membangunkan rangka kerja penilaian vitaliti multidimensi untuk mengenal pasti ciri-ciri ruang bandar masa lapang secara komprehensif melalui analisis data besar.

Kajian ini meneroka dimensi dan faktor utama yang mempengaruhi vitaliti LUS, menggabungkan teori masa lapang bandar, geografi masa lapang, vitaliti, sistem ruang bandar, tingkah laku spatiotemporal, dan perubahan tingkah laku. Ia mentakrifkan LUS dan mengkategorikannya kepada empat jenis: taman, dataran, ruang tepi air, dan blok masa lapang. Melalui ulasan naratif dan sistematik literatur, ia mengenal pasti jurang dan trend penyelidikan, mewujudkan rangka kerja teori dan sistem penunjuk penilaian untuk vitaliti LUS. Vitaliti LUS dinilai menggunakan data pelbagai sumber dari perspektif sistemik dan individu. Secara sistemik, analisis spatial GIS mengkaji pengedaran LUS dalam Kawasan Bandar Pusat (CUA) Nanjing. Secara individu, data besar dan tinjauan lapangan mengukur penunjuk utama merentasi 11 ruang terpilih, menggunakan analisis GIS, analisis kekerapan perkataan, analisis sentimen teks, dan analisis statistik. Pekali korelasi Pearson mengesahkan rangka kerja teori, menganalisis hubungan antara aktiviti orang ramai dan persekitaran binaan. Rangka kerja penilaian akhir menggunakan kaedah pemberat entropi dan CRITIC untuk mengira pemberat penunjuk. Analisis peringkat sistem mendedahkan perbezaan ketara dalam pengedaran LUS antara kawasan bandar lama (OCA) yang padat penduduk dan kawasan bandar baru yang lebih jarang, mencerminkan pengedaran tumpuan aktiviti penduduk. Perbezaan ketara juga diperhatikan dalam penyediaan dan ciri spatial pelbagai jenis LUS. Pada peringkat individu, analisis menonjolkan ketidakseimbangan dalam penggunaan ruang dan daya tarikan, dengan kepadatan aktiviti orang ramai dan kepelbagaian kemudahan dalaman muncul sebagai penunjuk kritikal vitaliti LUS. Setiap jenis LUS menunjukkan corak aktiviti temporal yang unik, ciri kumpulan pengguna, dan pengedaran kemudahan masa lapang. Keutamaan pengguna melampaui elemen semula jadi untuk merangkumi suasana sejarah dan budaya, serta kemudahan sosial dan penggunaan. Pelbagai aspek aktiviti orang ramai—seperti kepadatan, ketekalan, kepelbagaian, dan pengalaman—dipengaruhi secara signifikan oleh faktor luaran dan dalaman persekitaran binaan. Penemuan ini disahkan lagi melalui tinjauan pakar.

Untuk menjembatani teori dan amalan, kajian ini mencadangkan saranan strategik untuk meningkatkan vitaliti LUS, termasuk mengoptimumkan konfigurasi spatial, meningkatkan ketersambungan dan kepelbagaian fungsi, serta menambah kemudahan masa lapang. Ini selaras dengan matlamat pembangunan bandar yang lebih luas, membimbing pembuat dasar dan perancang untuk mencapai pengedaran sumber masa lapang yang seimbang dan mewujudkan persekitaran yang meriah dan inklusif.

Kata Kunci: kecergasan, ruang rekreasi bandar, aktiviti orang ramai, persekitaran binaan, analisis data besar pelbagai sumber

SDG: MATLAMAT 11: Bandar dan Komuniti Mampan

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest gratitude to my research supervisory committee for their invaluable guidance and unwavering support throughout this academic journey. I am particularly grateful to my supervisor, Dr. Marek Kozlowski, whose constructive feedback, intellectual guidance, and trust in granting me the freedom to explore have been pivotal in shaping this research. I also extend my sincere appreciation to Associate Professor Sumarni Binti Ismail and Dr. Sarah Abdulkareem Salih for their insightful comments and thoughtful suggestions, which have greatly enriched this work.

To my dearest parents, Li Guojun and Wang Xuejia, I owe my deepest appreciation for their unconditional love, endless support, and profound understanding. Their lifelong dedication to my education and personal growth has been the foundation of my academic pursuits. It is their unwavering encouragement and sacrifices that have enabled me to complete this endeavor.

I am eternally grateful to my beloved husband, Wang Yiming, whose steadfast support, patience, and encouragement have been my constant source of strength throughout this challenging yet rewarding journey. His unwavering belief in my abilities has made this achievement possible.

To all of you, I hope I have made you proud. This accomplishment is as much yours as it is mine

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

LUS	Leisure Urban Spaces
UPS	Urban Public Spaces
RTUD	Tencent Real-Time User Location Data
MSD	Mobile Signaling Data
MD	Meituan-Dianping
BHMD	Baidu Heat Map Data
POI	Point of Interest
CUA	Central Urban Area
OCA	Old City Area
NNI	Nearest Neighbor Index
SDE	Standard Deviation Ellipse
KDE	Kernel Density Estimation

CHAPTER 1

INTRODUCTION

1.1 Study Background

i. Leisure Functions and Demands in Urban Spaces during Rapid Urbanization

The city is a product of modern human civilisation and is a complex, multi-functional, huge, and open complex system. In the 21st century, cities have witnessed rapid economic and technological development, accelerating urbanisation. In demographic terms, urbanisation refers to the growth of the urban population as a proportion of the national population (Carlucci et al., 2020). The UN Department of Economic and Social Affairs states that 55% of the world's population lived in urban areas in 2018, and this proportion is expected to increase to 68% by 2050 (United Nations, 2018). The future growth of urban populations is expected to be concentrated in a few countries, notably China. The scale and speed of urbanisation in China are unparalleled, making its future particularly significant nationally and globally. When economic reforms were introduced in the late 1970s, China's urbanisation rate was less than 20% (Yeh & Chen, 2020). However, by 2022, China's urbanisation level will reach 64.72%, surpassing the global average (GOV.CN, 2022). China's population is approximately double that of the United States and 1.5 times that of the European Union. Over 100 Chinese cities have populations exceeding 1 million (Hamnett, 2020). As urbanisation continues, urban planners and designers face significant challenges. These challenges include balancing the growing demand for resources and the desire for a higher standard of living in the 21st century.

The United Nations adopted *The 2030 Agenda for Sustainable Development*, emphasising sustainable city communities and the need for universal accessibility to inclusive green and public spaces (United Nations, 2015). Historically, Urban public spaces (UPS) have fulfilled bare subsistence, communication, and leisure needs. These spaces, crucial for social interaction and community focus, play a vital role in sustainable development and in meeting the demands of inhabitants (Andersson, 2021). As Jacobs (1961) argues, urban spaces thrive when they encourage active community engagement, fostering both social connections and safety within neighborhoods. However, the ongoing urbanisation makes sustainable development increasingly dependent on effective urban growth management (GOV.CN, 2022). There is a growing interest in UPS and a demand for vibrant urban living, promoting health and safety outcomes (Jennings & Bamkole, 2019; Kondo et al., 2018). As an essential component of urban sustainability, public space needs to be urgently renewed and adapted to meet the needs of modern urban dwellers (Carmona, 2021). Urban space, often referred to as the 'living room' of a city, plays a vital role in the functioning of the urban system. By providing functions for living, working, transportation, and leisure, the availability of public space becomes fundamental to the well-being of contemporary urban populations (Mouratidis, 2021). As Lynch (1960) asserts, the legibility of urban spaces is key to ensuring that residents can easily navigate and access these spaces, making them integral to daily life and urban vitality.

Leisure is considered a core function of urban spaces, reflecting the level of urban life quality (Corbusier & Eardley, 1973). Since the 19th century, governments have sought to enhance the quality of life by providing leisure services and facilities (Lloyd & Auld, 2003). This paper suggests that leisure, whether as individual or group behaviour, involves activities freely chosen based on personal preferences during free time, primarily aimed at relaxation and rejuvenation. With rising living standards and evolving lifestyles, the demand for urban leisure is increasing, becoming a significant aspect of modern life (Carlino & Saiz, 2019). As Gehl (2010) highlights, spaces that are designed to encourage active participation—whether through walking, sitting, or social interaction—become essential to the well-being of residents and the vitality of the city. Leisure urban spaces (LUS) are not only vital components of the urban ecological and social systems, but their effective allocation also indicates a city's environmental, social, and economic development level (Lubowiecki-Vikuk et al., 2021). These spaces provide venues for entertainment and social interaction and play a critical role in enhancing urban vitality (Chen & Ma, 2023; Wang et al., 2022), improving residents' health and well-being (Kondo et al., 2018; White et al., 2020), and strengthening social cohesion (Jennings & Bamkole, 2019; Wan et al., 2021). More vibrant LUS are safer, desirable, and attractive, providing more social and cultural exchange options (El-Kholei & Yassein, 2022). The development and planning of LUS must cater to users' evolving leisure needs, as people are not only the creators but also the beneficiaries of these spaces.

ii. Development Status of Leisure Urban Spaces in China

Previous studies have shown that many Chinese people prefer spending tranquil time outdoors, immersing themselves in nature to achieve genuine relaxation, and experiencing a sense of harmony between their inner spirit and the external world. These activities are not just leisure pursuits but also promote positive emotions and a sense of well-being within the unique cultural context of China. Experiencing tranquillity, inner peace, and harmony between one's spirit and the external world has deep connotations in Chinese culture, involving aspects of life's control (Parker, 2021). Additionally, apart from tourism, which accounts for 44.4%, the favourite outdoor leisure activities among Chinese people include walking in parks (27.8%) and engaging in sports activities (17.0%) (M. Chen et al., 2018).

In response to rapid urbanisation and the growing leisure demands of residents, Chinese cities are evolving new forms of urban space development. Recent urban regeneration and redevelopment initiatives promote vitality, favouring multi-use, mixed-function areas over traditional, single-use zones. In 2019, China introduced the concept of "territorial spatial planning," emphasising high-quality development, avoiding sprawling patterns, and prioritising residents' well-being and participatory planning in urban development (GOV. CN, 2019). Controlling urban expansion or, at the same time, improving the developed urban space brings a challenge to urban planning, which is to enhance the quality and revitalise the city in this development pattern (Gavrilidis et al., 2019). In China, the supply of leisure spaces often falls short. This is due to the growing demands for leisure activities (H. Liu et al., 2020). Leisure research in China is still in its nascent stages, focusing on shifting from a scale-oriented to a quality-oriented model, emphasising people-centric principles, which involve prioritising residents' well-being and participatory planning in urban development (Y. Liu et al., 2020). In response, the Chinese government proposed elevating urban leisure development to a national strategic level in 2014, aiming to enhance the quality of life and meet the increasing demands for tourism and leisure (GOV.CN, 2014).

Moreover, the government emphasises improving cultural and leisure consumption quality and enhancing people's well-being through high-quality leisure offerings (GOV. CN, 2019). As primary venues for leisure activities, urban spaces need dynamic and attractive configurations to meet contemporary usage needs (Y. Liu et al., 2020). It follows that, In China's urban policies, the development of urban spaces has shifted from a phase of rapid quantity increase to a phase of high-quality development. As a result, the design of LUS has entered a phase of stock optimisation, evaluating the current quality and utilisation of local resources in urban spaces, an indispensable issue in urban construction and regeneration.

iii. Application of Vitality Theory and Big Data in Evaluating Leisure Urban Spaces

In this context, vitality theory provides a new perspective for evaluating the current quality and usage status of LUS, offering a basis for future urban renewal and construction. Esteemed scholars in urban studies highlight vitality as a critical indicator of urban space quality and a core objective of urban development. This theory facilitates the development of planning principles that aim to harmonise human activities with the urban environment (Yue et al., 2019). Evaluating the vitality of LUS is pivotal in determining whether the existing configurations and provisions of urban spaces align with the needs and actual usage patterns of contemporary residents. Such evaluations play a vital role in detecting and resolving discrepancies, which is fundamental to enhancing urban space quality (J. Zhu et al., 2020).

Moreover, a scientific appraisal of LUS vitality is integral to verifying if current urban planning and design fulfil today's population's leisure demands and expectations. This process is crucial for pinpointing and resolving issues, subsequently aiding in optimising urban spaces and supporting strategic planning decisions. Although scholars offer varying definitions of vitality, they generally agree that it hinges on three main elements: people, activities, and spaces. Human needs drive these activities, serving as crucial indicators of vitality, while space not only provides the physical setting but also underpins the mechanisms for these activities. Such evaluation helps in problem-solving, provides robust data support, and provides a rationale for urban planning decisions.

Additionally, evaluating UPS vitality has progressed to a new stage with the evolution of novel theoretical approaches. The emergence of smart city theories has catalysed network and geospatial big data for analysing and understanding urban spatial vitality's characteristics and dynamic trends (Oh, 2020). Big data, which refers to the large and complex datasets gathered through digital tools and platforms, unveils novel insights into human behaviours and patterns (S. Liu et al., 2020). These emerging theories and technological methods deepen our understanding of UPS's vitality features and their dynamic shifts and expose the multidimensionality and complexity in the development of UPS. An in-depth analysis of vitality can provide essential guidance for creating vibrant, livable, and intelligent urban environments.

Advancements in geographic information science and the emergence of new data sources have enabled the application of spatial big data mining and GIS analysis techniques in urban space research (S. Liu et al., 2020). The proliferation of urban big data collection, visualisation, and analysis technologies provides comprehensive support for urban planning (S. Liu, Long, et al., 2021). The application of urban big data in evaluating the vitality of LUS offers a novel approach to understanding and optimising urban spaces. By gathering information from various sources, these data enable urban planners to analyse and comprehend how urban spaces are used more accurately, thus more effectively assessing their vitality and efficiency (S. Liu et al., 2020; S. Liu & Lai, 2019; Y. Yang et al., 2021). Using big data analytics, the usage of LUS can be monitored in real-time. For instance, by analysing big data with location information and social media data, researchers can observe how people congregate in urban areas, identify peak activity periods and patterns of temporal distribution, and collect feedback on their activities (Bao et al., 2023; S. Liu et al., 2020; J. Zhu et al., 2020). As of December 2020, 99.7% of people in China accessed the Internet via cell phones, averaging 3.7 hours of daily Internet use (CNNIC, 2021). Big data will increasingly support urban planning and development, especially in China. Overall, urban big data provides powerful tools for evaluating the vitality of LUS, enabling urban planners to understand the usage of urban spaces from multiple perspectives, thereby making more informed decisions. The application of this technology can not only improve existing urban spaces but also support the sustainable development of future cities. However, integrating and refining big data technology in urban planning practice remains essential for sustainable city development.

iv. Overview of Nanjing's Background and Public Spaces

Nanjing, the capital of Jiangsu province in eastern China, is located in the Yangtze River Delta Economic Zone. It is a sub-provincial city and a megacity. It covers an area of 6,598 square kilometres and comprises 11 districts. According to the 2020 national census, Nanjing's permanent population was 9.31 million, with an urbanisation rate of 86.9% (Nanjing GOV, 2021a). Nanjing is significant in Chinese history and culture, having served as the capital of various dynasties and republics from the 3rd century to 1949.

Consequently, it has long been a significant centre of culture, education, research, politics, economics, and tourism and is also home to one of the world's largest inland ports. Nanjing is rated as a Beta (second-tier global) city by the Globalization and World Cities Research Network (GaWC, 2020) and is listed among the top 100 cities worldwide in the Global Financial Centers Index (CDI, 2020). Like most of Eastern China, Nanjing is predominantly Han Chinese (98.56%), with 50 other officially recognised ethnic groups. Currently, the economy of Nanjing is primarily service-oriented, accounting for about 60% of the city's GDP, with finance, culture, and tourism being the top three sectors. Densely populated and highly urbanised, residents face significant work stress. They also have an urgent need for relaxation and physical fitness improvement through leisure activities. This naturally increases the demand for LUS. Therefore, selecting Nanjing as a case study to evaluate the vitality of LUS is significant.

This choice is based on Nanjing's urban construction background, tourism development strategies, and its leisure spaces' current state and developmental needs. As a historical and cultural city, Nanjing attracts millions of visitors with its rich cultural resources and unique heritage, drawing over 10 million tourists in 2019 alone (S. Liu, Long, et al., 2021). The government is transforming it into a top-tier international tourist destination by preserving cultural heritage and enhancing leisure facilities and urban spaces. These initiatives have bolstered Nanjing's competitiveness as an international tourism hub and enriched its urban leisure facilities, providing a rich context for studying the vitality of LUS.

The Territorial Spatial Master Plan of Nanjing (2021-2035) aims to transform the city into an international destination distinguished by its unique cultural characteristics, beautiful living environment, and vibrant atmosphere (NMPG, 2022). Urban vitality is reflected in economic growth, the flourishing of cultural activities, and the richness and accessibility of leisure and entertainment facilities. The plan enhances leisure coverage areas and improves the quality and accessibility of UPS, which are key factors in assessing the vitality of LUS. The plan emphasises meeting residents' recreational needs, intending to achieve a 95% coverage rate of green and public spaces within a five-minute walk in the central urban area.

In recent years, Nanjing has made significant progress in planning and constructing LUS. The city has continually enhanced and expanded leisure facilities such as parks, green areas, and water systems, significantly improving the quality of life for its residents. Located in the lower Yangtze River Plain, Nanjing boasts a unique geographical landscape and a robust natural ecosystem, which provide a foundation for developing a rich and diverse urban leisure space system. As of the end of 2020, Nanjing's forest coverage rate reached 31.61%, and its natural wetland protection rate was 68.6%. Its built-up area green coverage rate stood at 45.16%, with the per capita park green space area at 15.7 square meters, all of which rank among the top in similar cities nationwide (Nanjing GOV, 2021b). Nanjing's abundant water resources and developed water systems, which account for 11.4% of the city's land area, are also significant features and developmental advantages (Nanjing GOV, 2023). Ensuring the sustainable use of these resources and their widespread benefits to all citizens is a crucial goal of urban planning.

The development of LUS in Nanjing has profoundly influenced the environment, residents, and tourists. Environmentally, the expansion of green spaces has reduced air pollution, alleviated the urban heat island effect, and enhanced biodiversity, although rapid urbanisation and tourism growth have also caused ecological degradation and overcrowding in popular areas(Guan & Guo, 2022). For residents, LUS promotes physical and mental well-being, fosters social interactions, and improves urban livability, yet the uneven distribution of LUS across districts limits access for some communities, exacerbating social inequities (Xu & Wang, 2024). For tourists, LUS enhances the experience of exploring historical and cultural sites, such as the Confucius Temple, by integrating leisure spaces with attractions, but peak-season overcrowding reduces visitor satisfaction and challenges the sustainability of these spaces (Wu & Chen, 2021).

In summary, with its rich historical and cultural resources, unique geographical location, and proactive advancements in urban planning and leisure space development, Nanjing provides an ideal scenario for evaluating the vitality of LUS. These research findings not only enhance our understanding of Nanjing but also offer strategies and experiences that can assist other cities globally in effectively enhancing urban vitality and improving the quality of life for their residents amidst rapid globalisation and urbanisation.

1.2 Definition of Terms

The following statements explain the definition of the basic terms of this study:

i. **Leisure**: An individual or group behaviour defined as activities in which people freely choose to participate according to their personal preferences during leisure time, primarily relaxing and restoring physical and mental energy.

ii. **Leisure Activity**: This paper focuses on outdoor leisure activities of the non-self-supplied type, including sightseeing leisure, cultural leisure, sports leisure, and consumption leisure.

iii. **Leisure Urban Spaces**: public spaces within the urban built-up area that provide individuals and groups with a relaxing, comfortable, and easy-going environment for leisure activities. This can be understood as a regionalization of the concept of leisure.

iv. **The Classification of Leisure Urban Spaces**: This study focuses on spaces with characteristics of leisure complexes, which include parks, squares, waterfront spaces, and leisure blocks. Each type of LUS in China offers unique characteristics and contributes differently to the urban fabric:

   a. Parks: Green spaces with a significant land area, an excellent ecological environment, and service facilities for public recreation.

   b. Squares: Large Open spaces in urban areas, surrounded by buildings, roads, or green zones, serving as centres for leisure and social interactions, reflecting the city's historical culture and artistic appearance.

   c. Waterfront Spaces: Urban spaces adjacent to natural water bodies, characterized by a mix of natural and artificial features, provide commercial and recreational functions.

   d. Leisure Blocks: Urban public spaces that concentrate cultural, entertainment, retail, and dining activities, designed to be pedestrian-friendly and foster social interaction and leisure.

v. **Vitality:** Vitality in UPS is the dynamic interplay of people, activities, and places, characterized by high activity density and frequency, reflecting a space's ability to meet human needs and support diverse social interactions.

vi. **Vitality of Leisure Urban Spaces:** The extent to which urban space supports the basic needs of urban leisure, drives diverse leisure activities, and generates sustained crowd clustering, crowd activity and built environment serve as its external representation and internal mechanism, respectively.

vii. **Big Data**: This refers to the large and complex datasets gathered through digital tools and platforms, unveiling novel insights into human behaviours and patterns.

1.3 Problem Statement

Rapid urbanisation and technological development have led to a significant spatial imbalance between supply and demand in LUS, resulting in varying vitality levels across different areas and spaces (Sun et al., 2024). Despite government efforts to create more urban spaces and provide residents with leisure opportunities, the number of parks, squares, and other urban spaces has increased considerably. However, there is a wide disparity in the supply and use of LUS in different areas of the city, with some high-quality spaces being overcrowded and others being sparsely populated. This disparity arises partly because some spaces are under-utilized and poorly maintained, making them unattractive to residents, while others are overcrowded due to high demand. As Jane Jacobs (1961) suggested, urban spaces should encourage social interaction and community life, making them essential to the vibrancy of a city. Well-designed and enjoyable urban spaces are not effectively utilized, leading to their neglect and decay (J. Zhu et al., 2020). This leads to significant variations in the vitality of urban spaces across different areas. Figure 1.1 illustrates different types of

LUS based on their utilization levels. Low-utilization spaces (A, B) show underutilized and neglected areas, indicating inefficient urban planning or maintenance issues. Overcrowded spaces (C, D) highlight high-density urban areas where leisure spaces are insufficient to meet demand. Balanced spaces (E, F) demonstrate well-designed and properly maintained urban leisure environments that support social interactions and sustainability."

Figure 1.1 : Example Images of Different Urban Leisure Space Utilization: Underutilized Spaces (A, B); Overcrowded Spaces (C, D); Balanced Leisure Spaces (E, F).
(Source: Author 2024)

In addition to the quality factors of the space itself, there are several other social contextual influences. With the advent of the digital age, the rise of online activities has reduced residents' use of physical space. The attraction of more diverse online activities, such as online socializing, gaming, and consumption, has gradually reduced leisure activities in physical spaces (Hampton et al., 2021; Thulin & Vilhelmson, 2019). Urban physical spaces' functional value and social attractiveness are facing severe challenges (Guo et al., 2022).

The specific impacts of insufficient or unevenly distributed LUS on special groups, such as low-income residents and older adults, deserve closer attention. Elderly residents, especially in Nanjing's outer suburbs, rely on local green spaces for social interaction and physical activity. However, these spaces are often insufficient or poorly maintained, increasing the risk of social isolation and health issues (Xu & Wang, 2024). Similarly, low-income residents in peripheral urban areas face barriers to accessing quality LUS due to transportation and spatial disparities (Peel et al., 2021). In Nanjing, research shows that 28.7% of leisure activities occur outside immediate residential quarters, indicating a spatial imbalance in LUS distribution (Zhang & Wu, 2022). Gehl's (2010) theory of human-centered design emphasizes the need to create spaces that encourage human interaction and active participation, suggesting that such spaces can reduce the feeling of exclusion in underserved communities. If these disparities remain unaddressed, they could worsen social inequalities and harm the health and well-being of special groups (Peel et al., 2021; Xu & Wang, 2024).

Therefore, it is crucial to conduct a scientific evaluation and develop targeted optimization strategies for distributing and utilising LUS. Such strategies are essential for effective urban planning and promoting social equity and sustainable development, ensuring that urban spaces serve the diverse needs of all city residents effectively. Integrating urban design principles that prioritize accessibility, engagement, and inclusivity is key to ensuring the sustainability and vitality of LUS in the face of rapid urbanisation.

1.4 Research Gap

i. Insufficient Multidimensional Analysis of Urban Spaces from a Leisure Perspective

The level of development of urban leisure directly affects the quality of life and the subjective well-being of urban residents (Mouratidis, 2021). However, few scholars have studied and discussed urban space from the multidimensional leisure perspective. Most scholars have focused on urban space from a single perspective of leisure research. On the one hand, from the standpoint of geography, urban space is the 'heart' for urban residents to accommodate leisure activities in their spare time and is a subset of UPS (Kendall, 2019). On the other hand, from a sociological point of view, urban space is a part of the urban leisure system, which provides ways and resources to meet the demand of residents for leisure activities (Y. Liu et al., 2020). This paper argues that LUS can be understood as the regionalization of leisure, encompassing both the physical and social attributes of leisure subjects' perceptions and behaviours within a specific geographical area (city). Therefore, this paper aims to provide an in-depth understanding of urban spaces from a multidimensional leisure perspective.

ii. Lack of Comprehensive and Systematic Evaluation

Although vitality has been recognized as one of the key indicators for evaluating the quality of urban spaces, the extent to which it has been applied to the evaluation of

LUS is still limited. Despite the existing literature on vitality in specific types of LUS, such as urban parks (Banchiero et al., 2020; Mu et al., 2021; J. Zhu et al., 2020), waterfronts (L. Chen & Ma, 2023; S. Liu, Lai, et al., 2021; Y. Niu et al., 2021; F. Wang et al., 2020), and night leisure spaces (M. Long, 2017), there is a lack of comprehensive and systematic studies on the evaluation of LUS from the perspective of vitality. This gap in the literature highlights the importance and urgency of conducting a comprehensive evaluation of LUS in China. Such an evaluation can shed light on their current status and identify potential areas for improvement. Furthermore, such an evaluation can contribute to formulating more effective policies and strategies for the sustainable development of LUS, which can benefit both the residents and the broader society. Therefore, this study aims to fill the research gap by comprehensively evaluating LUS in China from the perspective of vitality and providing practical recommendations for policymakers and practitioners.

iii. Insufficient Understanding of Vitality Formation Mechanisms

The current understanding of the mechanisms that generate vitality in LUS is insufficient, with limited research on the internal and external factors contributing to vitality formation. While some scholars view vitality as reflecting human activities in various places and times (Mu et al., 2021; T. Niu et al., 2022; F. Wang et al., 2020), others argue that it depends mainly on the physical space's support and attraction (Molavi et al., 2017; Y. Niu et al., 2021; T. Wang et al., 2022; F. Zhang et al., 2022; X. Q. Zhu et al., 2013). However, this paper supports that the vitality of LUS depends on the interaction between the users of the space and the role of urban spaces, which can generate different leisure activities (Navarro et al., 2021). Residents can influence the provision of leisure facilities in specific urban spaces, while the spatial design can encourage people to access these spaces and engage in activities. In turn, the urban space should provide the appropriate spatial configuration to support the users for completing the leisure activity. Considering the changing trends in urban space development, a single perspective of physical space can no longer cope with the new trend in urban space development. Instead, a multidimensional method for evaluating the vitality of LUS based on the interaction between space and people is needed. Thus, a multidimensional research perspective is necessary to study the vitality of LUS. This includes introducing relevant theories, such as environmental behaviour, to explain the processes and elements of leisure activity in urban spaces. This approach will enable researchers to accurately identify the current state of vitality and provide targeted guidance for choosing a technical path for creating and enhancing the vitality of urban spaces.

iv. Limitations of Research Methods and Data Analysis

Traditional research methods are limited by the difficulty in obtaining data, making it difficult to conduct extensive and in-depth research on urban vitality. This includes predominantly observational qualitative studies (Sheng, 2013; X. Q. Zhu et al., 2013) and primarily survey-based quantitative methods (Banchiero et al., 2020; L. Chen & Ma, 2023; Mu et al., 2021). Additionally, most studies of spatial usage behaviour based on traditional methods involve intervention to purposefully collect data, which may be influenced by the researchers and the participants, making it difficult to assess the accuracy and reliability of the data. With the rise of urban big data analysis, it is now possible to analyze a wide range of instances non-invasively. This approach enables a more comprehensive and multi-scale analysis of urban problems, shifting from traditional research focused on "space" and "place" to a more nuanced analysis of the relationships between "people, activities, and space" (S. Liu et al., 2020). However, in current research on vitality evaluation based on big data analysis, most studies have only assessed the clustering of people in space, neglecting aspects such as the long-term and diverse nature of human activities in space and the psychological feedback that the space may provide to activity participants. As a result, it is necessary to explore more robust and context-sensitive methods for evaluating urban spaces' vitality, leveraging the potential of multi-source big data.

1.5 Research Questions

Concerning the research problem of this study, the Main Research Questions as follows:

> How can a multidimensional vitality evaluation framework be constructed to comprehensively identify the characteristics of leisure urban spaces through big data analysis?

There are some sub-Research Questions are as follows:

i: What are the characteristics and classifications of urban spaces from the leisure perspective?

ii. What are the primary dimensions and key indicators impacting the vitality of leisure urban spaces?

iii: How to construct a comprehensive evaluation framework for the vitality of leisure urban spaces in China using multi-source big data analysis methods?

iv: What commonalities, differences, and potential deficiencies exist in the vitality of various leisure urban spaces across Nanjing's Central Urban Areas?

1.6 Research Objectives

The Research Aim as follows:

> Develop a multidimensional vitality evaluation framework to comprehensively identify the characteristics of leisure urban spaces through big data analysis

To obtain this aim, the following sub-Research Objectives have been considered:

i: To understand the characteristics and types of urban spaces from the leisure perspective.

ii: To explore the primary dimensions and key indicators impacting the vitality of leisure urban spaces.

iii: To develop a comprehensive evaluation framework for the vitality of leisure urban spaces in China using multi-source data analysis methods

iv: To examine the commonalities, differences, and potential deficiencies in the vitality of various leisure urban spaces across Nanjing's Central Urban Areas.

1.7 Scope and limitation of the Study

This study focuses on public outdoor leisure urban spaces, which are designated areas provided by the government for residents' leisure activities. These spaces can be found within the built-up areas of a city or its metropolitan area and can be classified using various criteria. This study is restricted to four types of public LUS: parks, squares, waterfront spaces, and leisure blocks. The scope of this study includes both the interior of these spaces and the 500-meter buffer zone surrounding them.

However, this focus on public outdoor leisure spaces may limit the generalizability of the findings to other types of urban spaces, such as private or indoor leisure areas.

Additionally, the classification of spaces into these four types may not capture the full diversity of LUS.

The research area of this paper is limited to the CUA of Nanjing. According to the Territorial Spatial Master Planning of Nanjing (2021-2035), Nanjing is a multi-center city. The Nanjing urban area serves as the core of the metropolitan area and is one of the main areas carrying central city functions. It is also the region with the most abundant leisure urban space. Therefore, this area is highly suitable for the research content of this paper.

This geographical focus on Nanjing's CUA may limit the applicability of the study's findings to other urban settings, especially those with different urban layouts or leisure space distributions. Additionally, the study's reliance on the specific context of Nanjing may limit its applicability to other cities with different urban layouts, population densities, or leisure space distributions. However, the evaluation framework developed in this study can be adapted to other urban contexts in China by incorporating local conditions. For example, first-tier cities (e.g., Beijing, Shanghai) face challenges related to high population density and land scarcity, which may require different approaches to LUS planning and design. Similarly, small and medium-sized cities often lack well-developed LUS networks and may require targeted investments to improve public space quality and accessibility. By incorporating local data and adjusting evaluation indicators, the framework can be applied to diverse urban contexts, enhancing its broader relevance and practical impact.

1.8 Structure of Thesis

This study is structured into four distinct phases, as depicted in Figure 1.2, which maps the research process across four distinct phases.

Chapter 2: Literature Review

This phase will be divided into three parts. Firstly, it examines the definition and connotation of urban spaces in the context of leisure, systematizing the study of leisure activities, characteristics, and classifications in LUS. Secondly, it will identify research gaps and trends by conducting a literature review on research perspectives and evaluation methods of urban vitality. Finally, it explores the formation and composition of LUS vitality, drawing on related theories such as urban space system theory, spatiotemporal behavioural theory, and behaviour change theory.

Chapter 3: Metodology

This phase presents an in-depth exploration of the quantitative analysis methods used in this study. It begins by justifying the selection of Nanjing's CUA as the research area and the process for selecting sample spaces. It provides a detailed description of how multi-source data is collected and utilized, including the types and sources of the data and the collection techniques. Additionally, it delves into the use of Geographic Information System (GIS) technology for analyzing the spatial distribution of LUS. This section outlines the vitality evaluation framework for LUS, focusing on aspects of crowd activity and the built environment, and details the system's quantification methods for each indicator. Finally, it discusses the methods for correlation analysis and weight calculation among various indicators, providing a comprehensive approach to evaluating LUS vitality.

Chapter 4: Data Analysis and Findings

This phase aims to conduct a comprehensive analysis of the vitality of LUS in Nanjing's CUA, both at the systemic and individual levels. This includes an in-depth analysis of the performance of different indicators across various types of spaces, examining the impact of built environment factors on crowd activity, and determining the weight distribution of each indicator. each indicator. This forms a complete, multidimensional urban leisure vitality evaluation framework. Chapter 4 primarily involves using GIS technology to analyze and visualize the aggregation and distribution of existing LUS, selecting 11 spaces from a large dataset as samples for vitality evaluation. Chapter 4 conducts a comprehensive vitality evaluation of these 11 spaces, using numerical results for correlation analysis and weight calculation. This process derives final vitality values, categorizing spaces into high, medium, and low vitality types.

Chapter 5: Recommendations

This part of the study provides recommendations based on the findings from Phase 3, proposing improvement measures. At the system level, recommendations are provided for optimizing the spatial layout of areas with different geographical locations and space types. Moreover, specific suggestions are provided for enhancing the quality of spaces in different regions, of different types, and with varying levels of vitality from the individual level. These recommendations aim to improve the overall layout and quality of LUS, ultimately enhancing the vitality and attractiveness of urban areas for residents and visitors alike.

Chapter 6: Conclusion

The discussion synthesizes the research findings, highlights key recommendations, outlines the study's contributions, and draws broader inspirations for urban planning and policy. Additionally, the paper proposes practical guidelines for urban planners and policymakers and identifies potential directions for future research to further explore the dynamics of LUS vitality.

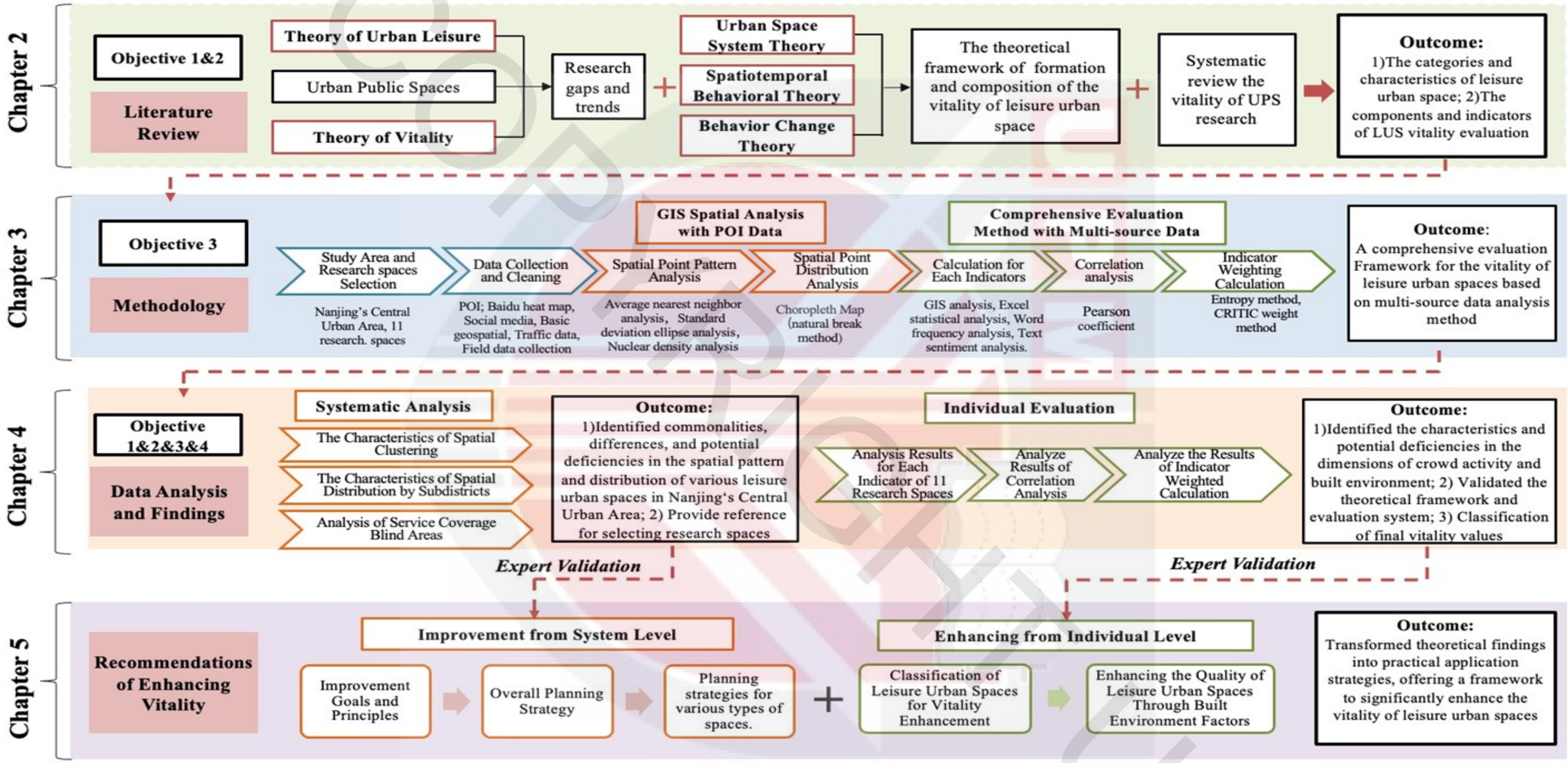


Figure 1.2 : Organization Structure of the Thesis
(Source: Author 2024)

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter aims to construct a multidimensional evaluation framework for the vitality of LUS based on crowd activity and the built environment. To achieve research objectives 1 and 2, it reviews relevant literature on LUS and urban vitality, identifies gaps in existing research, and explores future research directions. The formation mechanism and representation indicators of LUS' vitality are discussed and studied on this basis. The literature review is a crucial part of any research, as it allows researchers to connect their work to the current state of related knowledge and comprehend principles related to their study object. The literature review process is also essential in guiding the answers to research questions (Kraus et al., 2022). This study employs an integrated approach that combines Narrative Review and Systematic Review methods to ensure both theoretical depth and empirical rigour. This approach contributes to the theoretical depth and facilitates a systematic and comprehensive analysis of relevant empirical studies. Such a holistic literature review enhances the research's overall comprehensiveness, persuasive power, and academic value (Booth et al., 2021). This chapter is divided into three parts: the first part discusses the characteristics and classification of UPS from a leisure perspective. The second part delves into the fundamental theories and systematic review of UPS' vitality. The third part constructs the theoretical framework for the formation and composition of vitality in LUS, including its main dimensions, factors, and evaluation indicators.

2.2 Leisure Perspective in Urban Spaces: An Overview

2.2.1 Leisure and Leisure Activity

Currently, the concept of "leisure" has not been clearly defined. The earliest word for "leisure" evolved from the Greek word "schole," which refers to a type of "socially valuable" entertainment and personal self-development. According to the dictionary, 'leisure' is defined as free time, the use of free time for enjoyment, and the opportunity to engage in activities of one's choice. From the perspective of the laws of social development, leisure is a characteristic of social progress.

Leisure studies have a long history in Western countries. It is generally believed in academia that Thorstein B. Veblen's "The Theory of the Leisure Class," published in 1899, marked the birth of leisure studies. Veblen described the phenomenon of the emerging bourgeoisie at the time, who, having acquired wealth, were freed from labour and adopted a new lifestyle. He defined leisure as "non-productive time consumption." American leisure scholar Godbey (1985) believed that "leisure" is a relatively free lifestyle that liberates individuals from external pressures of cultural and material environments. It enables individuals to act instinctively and pursue activities they value, driven by personal passion, and provides a foundation for belief. French writer Roger Sue (1980) provided a more systematic interpretation of the leisure concept in his book "Leisure." He believed that "leisure" is, first and foremost, a concept of time that can be freely disposed of. Secondly, an activity concept is "freely chosen according to personal wishes and preferences."

Furthermore, leisure is a psychological state characterized by a sense of freedom and autonomy. Scholar Joffe Dumazedier (1967), in his groundbreaking work "Toward a

Society of Leisure," explored the relationship between leisure and family, work, and social policy from a critical realist perspective. Leisure is an individual's personal time freed from work, family, and social services and is a process of freely expressing creativity and shaping oneself. Pierce (1980) defined leisure as a voluntary, rather than compulsory, activity that aims to attain genuine happiness rather than maintain a livelihood.

Chinese scholars started to research leisure relatively late and have defined the concept of leisure from different research perspectives. Lin and Liu (2004) defined leisure as "an activity that includes rest, entertainment, and the improvement of self-cultivation skills." There are numerous interpretations of leisure, both in China and abroad, many of which align with the definitions mentioned above. Pang (2010) simplified it as follows: leisure is a relatively accessible way of life that involves being liberated from external pressure, engaging in activities one loves, and experiencing pleasure and value from them. Chinese scholars Hua and Lou (2009) explained leisure from multiple perspectives: as the rational use of free time and as a psychological state with conscious and cultural attributes.

Therefore, leisure can be understood from the following three aspects: 1) from the "time" perspective, leisure means disposable time, which is the free time outside of work hours; 2) from the "behaviour" perspective, leisure is defined as activities that individuals freely choose according to their own wishes and interests, without external pressures, after working and satisfying their physiological needs; 3) from the "psychological state" perspective, leisure means the inner experience of individuals when engaging in leisure activities, and leisure is a state of pleasure, relaxation, and development. Based on this, this paper believes that leisure can be an individual or group behaviour, and it is defined as activities that people freely choose to participate in according to their personal preferences during leisure time, with the primary purpose of relaxing and restoring physical and mental energy.

The ultimate goal of constructing LUS is to generate leisure activities, which serve as external expressions of vitality. Therefore, it is necessary to explore leisure activities. In the book "Life Between Buildings," author Gehl (2002) categorizes outdoor activities into three types: 1) necessary activities, which refer to activities that people must engage in, such as work or daily affairs; 2) spontaneous activities, which are organized based on a shared willingness to participate at random times and places; and 3) social activities, which are organized in specific social public places and often involve a large number of people. This type of activity can improve public space and promote social interaction. Based on this, this paper refers to the second type of urban leisure activity - spontaneous activity - because, as mentioned earlier, leisure is highly spontaneous. Spontaneous leisure activities include self-supplied and non-self-supplied activities. Self-supplied activities refer to leisure activities carried out by urban residents using their own facilities, equipment, or other resources, such as playing games, watching TV, listening to music, reading books, and chatting over tea. This activity is less dependent on facilities and services for people and society. Non-self-supplied activities refer to leisure activities carried out by urban residents using public or for-profit LUS and facilities. This type of activity depends more on facilities and services for others and sociality. This paper focuses on outdoor leisure activities of the non-self-supplied type. Many scholars have borrowed Jan Gehl's method of categorizing leisure activities for non-self-supplied leisure activities (Y. Liu et al., 2017; Jing et al., 2021; S. Liu, Long et al., 2021), including sightseeing leisure, cultural leisure, sports leisure, and consumption leisure. Leisure activities complement necessary activities, enhancing the vibrancy and attractiveness of social and public spaces. Together, they form the foundation of urban social and public life.

2.2.2 Public Spaces in Urban Leisure System

2.2.2.1 Public Spaces and Leisure Urban Spaces

Public spaces refer to the shared communal areas between urban structures, serving as venues for social interaction among citizens (Li, 2004). Over time, the concept of public spaces has continuously evolved, influenced by the varying degrees of emphasis placed on them by different cultures and societies. In China, the narrow definition of UPS pertains to outdoor areas designated for residents' daily life and social interactions, such as streets, squares, parks, and sports facilities (Li, 2006). The broader concept of UPS can be extended to include public facility lands, such as urban central districts, commercial areas, and urban green spaces. Public spaces are interconnected with the urban complex, forming urban public open spaces. These open spaces are collections of spaces with varying scales, functions, characteristics, and morphological structures, constituting an interconnected system that interweaves with other urban systems and natural spaces at the macro level, while being closely related to citizens' lives at the micro level (Gong et al., 2022).

Leisure urban spaces are defined in the "Classification and Requirements for Urban Public Leisure Spaces" (GB/T 31171-2014) as "public spaces within the urban built-up area that meet the leisure needs of the public," such as park green spaces, urban squares, and central business leisure districts (Zhu & Hu, 2014). Broadly, urban public leisure spaces refer to public spaces that accommodate all forms of leisure activities, while narrowly, they specifically denote public leisure venues, such as leisure squares and parks. Urban leisure spaces refer to areas within the city that allow people to freely choose and experience leisure activities (Guo, 2006). It is evident that leisure urban spaces are closely related to public spaces but offer more diverse functions, providing not only venues for social interaction but also rich spaces for leisure activities. Therefore, leisure urban spaces exhibit greater functional flexibility, focusing not only on meeting basic needs but also on providing comfortable leisure experiences. They are not merely a part of public spaces but an essential component of the urban public space system.

Based on the above discussion, this paper defines LUS broadly as ‘public spaces within the urban built-up area that provide individuals and groups with a relaxing, comfortable, and accessible environment for leisure activities. This can be understood as a regionalization of the concept of leisure. However, this paper recognizes the need for further classification of LUS. These aspects will be discussed in detail in Section 2.2.3.

2.2.2.2 Urban Leisure and Leisure Geography

A comprehensive analysis from multiple dimensions is essential to gain an in-depth understanding of LUS. With the increasing popularization and evolving development of the concept of leisure, research in this field has gradually extended into urban planning. In this context, urban leisure and leisure geography have emerged as complementary and significant branches.

Urban leisure primarily focuses on activities within the urban environment, encompassing various forms such as rest, entertainment, social interaction, and cultural participation (Gong et al., 2022). These activities enrich urban residents' lives and significantly impact individual well-being and social interaction (Kuper et al., 2023). Effective planning and management of urban leisure can substantially enhance residents' quality of life and foster harmony and vitality within communities. Particularly in a country like China, characterized by significant urban-rural differences and uneven regional development, studying leisure issues from the perspective of urban development holds special practical significance and profound impact. Although a unified definition of "urban leisure" has not yet been established in both domestic and international research, existing studies provide valuable insights. Chen (2006) defines urban leisure as the concepts and behaviours of leisure subjects within a specific geographical area; Zheng and Liu (2006) view it as leisure activities with the city as the carrier, aiming to improve the quality of life; Lv (2009) emphasizes the economic characteristics of urban leisure as a modern civilized lifestyle. Thus, urban leisure emerged as a multifaceted concept deeply intertwined with the socio-cultural fabric of the city, influencing and shaping the quality of urban life.

On the other hand, leisure geography concentrates on the distribution and dynamics of leisure activities in geographical space. This discipline analyzes the spatial distribution patterns of leisure activities and explores how these activities impact urban spatial structures and environments (Cosgrove & Jackson, 2015). The research content of leisure geography is rich, including the selection of locations, timing, and modes of leisure activities by residents, providing vital guidance for urban planners in understanding and meeting the leisure needs of residents (Crouch, 2006). These studies correspond to human social systems and their surrounding material environments, where spatial factors influence behavioural patterns. With the continuous development of the economy and urbanisation, people's feedback on and demands for the environment change dynamically. Consequently, the relationship between people, their behaviour, and the environment is dynamic, and the connection between leisure activities and UPS is inseparable.

In conclusion, while urban leisure and leisure geography focus on different aspects, they share a deep interconnection and complementarity. Leisure geography offers a valuable spatial perspective to understand urban leisure phenomena, aiding in analysing the distribution and dynamics of leisure activities in urban spaces. Simultaneously, the practice of urban leisure can draw theoretical support and spatial analysis tools from leisure geography research, especially in planning and designing more attractive and functional UPS. Both fields contribute to enhancing urban leisure experiences by improving spatial understanding and informing the effective planning and management of LUS. Effective urban leisure planning and management require not only spatial analysis and theoretical support from leisure geography but also in-depth studies of specific cases of LUS. In this way, we can better comprehend the complexity and dynamics of LUS, thereby creating more prosperous and meaningful leisure experiences for city residents. This interdisciplinary perspective is indispensable for urban planners, decision-makers, and designers in today's ever-changing urban environment. It not only aids them in better understanding the needs of urban residents but also provides a solid theoretical foundation and practical tools for creating more vibrant and inclusive urban spaces.

2.2.2.3 The Relationship between Urban Public Spaces and Residents' Lives

As carriers of human social civilization, cities exhibit their level of urban society by developing their public spaces. Consequently, one of a city's fundamental functions is to satisfy its people's leisure needs. Leisure, a complex and extensive social behaviour, is influenced by the external environment and individual subjective desires (Parker, 2021). UPS, such as parks, green spaces, and squares, are pivotal in achieving this objective (A. J. Johnson & Glover, 2013).

UPS are physical components of a city and serve as crucial venues for urban life. These spaces are primary venues for residents' leisure activities and serve as areas critical to everyday social interaction, cultural experiences, and relaxation (Peters, 2010). With the drive of urbanisation and economic development, the planning and design of UPS have become vital in meeting residents' leisure needs and enhancing their quality of life. The construction and improvement of urban public leisure spaces not only fulfil citizens' leisure needs but also improve the city's image, stimulate urban vitality, strengthen urban competitiveness, and uplift the city's quality (Carmona, 2021). The quality of these spaces directly affects the life experience and well-being of urban residents (Mansfield et al., 2020). Well-designed public spaces offer outdoor recreational facilities and also possess disaster prevention and landscape functions, adding beauty and greenery to the city (Botchwey et al., 2022).

The spatial environment quality of UPS significantly impacts residents' participation in leisure activities. Comfortable, safe, and accessible public spaces encourage outdoor activities, promoting healthy lifestyles. These spaces are not just places for leisure and entertainment but also platforms for community communication and cultural integration, aiding in strengthening neighbourhood relationships and community cohesion (Johnson & Glover, 2013; Lloyd & Auld, 2003).

From a socio-psychological perspective, leisure activities can substantially enhance personal quality of life. Such activities provide opportunities for social interaction, develop social cohesion, and promote mental and physical relaxation, thus improving life quality (Parker, 2021). UPS also play a crucial role in improving the quality of community life. The value orientation of leisure activities positively correlates with community life quality (A. Johnson & Backman, 2010).

UPS are intimately connected with residents' everyday lives. Insufficient or poorly designed leisure spaces can lead to a lack of vitality and vibrancy in residents' lives. Conversely, well-planned and pleasing leisure spaces can make life more comfortable and serene, fostering social stability and harmonious interpersonal relationships. In conclusion, the relationship between UPS and residents' lives is multidimensional and dynamic. With societal and economic changes, urban planners face the challenge of scientifically and rationally designing these spaces to adapt to the evolving leisure needs of residents. Effective planning and management of UPS are crucial for enhancing the quality of life of urban residents and promoting sustainable urban development.

2.2.2.4 Characteristics of Leisure Activities in Urban Public Spaces

The above analysis highlights the crucial role of public spaces in the urban leisure system. Therefore, discussing the characteristics of leisure activities in UPS is highly essential. Specifically, leisure activities in UPS exhibit the following three distinct characteristics:

Diverse Forms and Contents: Leisure activities are undertaken by individuals to attain physical and mental well-being, exhibiting unique personal characteristics. Differences in social and economic backgrounds, experiences, and personal values shape individuals' expectations and participation in leisure activities. Consequently, urban leisure activities take various forms.

Broad Participation: Urban leisure facilities and spaces cater to all residents and tourists visiting the city, encompassing people of different ages, genders, and professions, each with their own leisure needs. This necessitates that urban leisure facilities, activities, and services be varied in content and form, accommodating a wide range of participants.

Full Utilization of Urban Infrastructure: Leisure activities take place within urban spaces, utilizing existing infrastructure. These activities employ leisure spaces as carriers, and the various elements constituting these spaces significantly influence people's activities. These elements influence how efficiently the space is utilized and the comfort level of its users. Research into the relationship between people's activities and the elements composing the space is crucial in creating regional leisure spaces that are appropriate, enjoyable, and satisfying for visitors.

In summary, the leisure activities within UPS are diverse and colourful, reflecting the variety of urban culture, but they also serve as a critical source of vitality and attraction for urban communities. These activities foster social interaction, enrich urban life, and contribute to sustainable development. Therefore, a deep understanding and optimization of leisure activities in UPS are crucial for creating vibrant, livable, and friendly urban environments.

2.2.3 Classification and Characteristics of Leisure Urban Spaces in China

Based on the extensive definition of leisure city space discussed above, any public space within the urban area that can meet the leisure needs of city residents and allow leisure activities to take place can be considered part of the leisure city space. However, this article requires a detailed analysis and explanation of the categories and characteristics of spaces based on the context of China.

According to the differences in supply channels, LUS can be classified into three types: self-supply leisure spaces, public welfare supply leisure spaces, and profit-oriented supply leisure spaces. Moreover, based on the differences in the users of leisure spaces, urban public leisure spaces can be divided into two constituent parts: "recreational space" and "tourism space," both aimed at foreign visitors and residents. However, there are always overlapping areas between the two, and it is usually challenging to categorize them. Since this article previously discussed the importance of public spaces in urban leisure systems, the scope of this study remains limited to public leisure spaces. Concerning public leisure space, scholars initially focused on two types of LUS: "urban green spaces" and "public open spaces." According to the "Classification and Requirements of Chinese Urban Public Leisure Spaces" (GB/T31171-2014) issued on September 3, 2014, leisure spaces are divided into two categories: 1) specialized public leisure spaces - public leisure spaces that mainly feature one or a specific type of leisure function, including sports venues, cultural venues, leisure trails, bike lanes, and so on; and 2) comprehensive public leisure spaces - public leisure spaces that primarily feature multiple specialized leisure functions, including central leisure areas, parks, urban squares, leisure commercial districts, waterfront leisure areas, community leisure centre, and so on. In addition, specialized public spaces also include the spaces used for public facilities, such as the central and commercial areas of the city (L. Zhu & Hu, 2014).

Based on the above discussion, this article believes that spaces with characteristics of leisure complexes are more representative of the current status of leisure space and the diversity of leisure activities in China. Such spaces can, to some extent, support the production of tourism, culture, sports, entertainment, and leisure activities. Therefore, this article focuses on spaces with characteristics of leisure complexes, combined with the discussion of public spaces mentioned above, which include parks, squares, waterfront spaces, and leisure blocks. Each type of LUS in China offers unique characteristics and contributes differently to the urban fabric.

2.2.3.1 Parks

Parks refer to green spaces with a specific land area, an excellent ecological environment, and service facilities for public recreation (Mehhdi et al., 2017). Parks are not simply a combination of parks and green spaces but a general term for all green spaces with park functions. Therefore, parks refer to green spaces with park properties. According to China's "Urban Green Space Classification Standard" (CJJ/T85-2017), an urban park refers to a relatively concentrated and independent green space, open to the public in the city, with the primary function of recreation and some recreational facilities and service facilities.

2.2.3.2 Squares

Squares are large public activity spaces in urban built-up areas for recreation and leisure. "The Chinese Encyclopedia" mentions that "urban squares are open spaces surrounded by buildings, roads or green zones in cities, and are the Center of urban public social life. The square is a public space that reflects the urban historical culture and artistic appearance." An urban square's basic function is to provide a place for urban residents to relax, entertain, and gather (Salama et al., 2017; Zakariya et al., 2014).

2.2.3.3 Waterfront Spaces

Waterfront spaces refer to areas where leisure industries are concentrated, leisure services and product supplies are rich, and leisure environments are suitable, relying on water bodies (Shangi et al., 2020). Waterfront spaces are areas in the city that combine natural and artificial features. Urban waterfront spaces refer to a specific area formed by the city's connection of land and water. It is both the edge of the land and the edge of the water, including specific water space and the adjacent urban land space, with natural landscape and rich historical and cultural connotations. It is a city public open space where natural ecological systems and artificial construction systems are interwoven.

2.2.3.4 Leisure Blocks

Leisure Block in this study is defined as an UPS that integrates cultural, entertainment, retail, and dining activities, with an emphasis on creating pedestrian-friendly environments. In urban planning, a "block" refers to an area enclosed by streets or transit routes, typically containing multiple buildings and public spaces (Carmona, 2021). In the Chinese context, a Leisure Block is a specialized type of urban block designed to concentrate these activities, aiming not only to provide commercial opportunities but also to enhance pedestrian comfort and foster social interaction. The overarching goal is to create spaces that blend leisure with economic, social, and environmental benefits, forming a cohesive, pedestrian-friendly leisure system (Xi et al., 2024). Leisure Blocks are commonly found in retail shopping districts (RBDs), where shopping, dining, entertainment, and cultural experiences are seamlessly integrated. These types of blocks are especially prevalent in major cities, where urban planning strategies have increasingly embraced mixed-use developments(Zhang et al., 2021). In addition to their commercial functions, Leisure Blocks facilitate social interaction, contributing significantly to the creation of community-centered spaces.

2.2.4 Evolution and Development of Leisure Urban Spaces Research

2.2.4.1 The Evolution of Research on Leisure Urban Spaces in a Global Context

i. Pre-Industrial Era

Before the Industrial Revolution, the development of early cities was significantly influenced by military, political, and religious factors. In Western cities, public leisure spaces primarily served religious and political activities, mainly city squares, temples, churches, and public buildings (Xing & Siu, 2010). In contrast, public leisure spaces in Chinese cities were more engaged in the secular activities of the citizenry, predominantly located in market neighbourhoods, temples, Taoist temples, and streets and alleys (Kiang, 2007). Regarding spatial form, public leisure spaces in Western cities generally exhibited a "block-like" characteristic. In contrast, traditional Chinese urban public leisure spaces were more often "linear" in nature; especially post-Song Dynasty, the emergence of commercial streets - "hook rows" and "tile houses" - increased the recreational functions of road spaces in urban leisure (J. Su & Lun, 1978). Temples and Taoist temples, representing "point-like" urban public leisure spaces, usually utilized festivals as opportunities to hold temple fairs, thereby fulfilling their leisure functions, which fundamentally also represented a form of "linear" leisure space (Y. Li et al., 2024). Evidently, public leisure spaces in cities, both domestically and internationally, transitioned from block-like to linear configurations.

ii. Industrial Revolution period

From the late 19th century to the 1930s, Western countries experienced rapid industrialization. The urban landscape underwent significant changes due to advancements in transportation, leading to prominent urban issues such as deteriorating cityscapes, ecological degradation, and emerging health problems among urban residents. During this phase, the development of public leisure spaces in Western cities primarily focused on alleviating urban environmental and sanitary issues through ecological urban construction. Consequently, the establishment of these spaces often began with urban greening initiatives. The progression of urban greening led to vigorous urban park movements and city beautification campaigns, accelerating the development of public leisure spaces. The emergence of urban parks shifted the focus towards park design and functionality. Influential theories from this period include Howard’s "Garden City," Mata’s "Strip City," Corbusier’s "Radiant City," and Olmsted’s "Park City," all having a direct impact on urban planning in Western countries. Leisure research during this time predominantly concentrated on the theory and design of urban gardens and parks (Ren & Wu, 2010; Schreiner & Skinner, 1914).

The urban park and beautification movements somewhat alleviated the issues of overcrowded public spaces and the lack of leisure facilities. The approach to developing public leisure spaces in this period was based on urban spatial planning concepts, exploring construction models and developmental theories for these spaces. This involved planning UPS using subjective cognitive design forms and industrial symmetrical aesthetics (Akkerman, 2000). The urban spatial pattern influenced the evolution of public leisure spaces' form and development model during this stage. With the development of urban transportation, the organization of urban space expanded outward along major traffic routes, leading to the development of public leisure spaces towards a nodal-axis model (Falsetti & Ciotoli, 2017). In China, amidst a turbulent historical backdrop, the development of public leisure spaces was slow but began to be influenced by Western cities with the emergence of urban parks and sports facilities (Tianjie, 2022).

iii. Post-Industrial Era

This period marked a post-war era of rapid urban revitalization, during which Western nations began experimenting with planning to address urban issues through comprehensive city planning and construction. To curb infinite urban sprawl and meet citizens' leisure and recreation needs, "green belts" were employed by planners as an effective tool to control urban expansion and harmonize the relationship between natural environments and built-up areas. Notable planning examples include the "Greater London Plan" of 1944 and the "Ludwig Plan" of 1951. These initiatives interconnected green belts with urban park systems and open space networks, forming a public space leisure system to address the need for recreational spaces. As ecological values became integrated into urban design, green spaces emerged as primary venues for citizen relaxation and recreation (H. Zhang & Cen, 2007).

As times changed, economic shifts and evolving citizen demands made traditional material-based planning ideologies insufficient to meet leisure needs. This led to a gradual emphasis on human-centric urban planning. The development of urban public leisure spaces progressively embraced a humanistic approach, focusing on creating environments that catered to perceptual intentions and aesthetic experiences. In urban form design and planning, Kevin Lynch's "The Image of the City" in 1977 is a seminal work. The theory of this era accentuated the creation of a harmonious city-wide environment. It necessitated urban planning and design professionals to offer varied environments for residents of diverse backgrounds, classes, and professions.

With the increasing variety of urban public leisure space types and a growing emphasis on human-centric experiential perspectives, the connectivity of these spaces gained significant attention. Furthermore, expanding urban scale and forming urban spatial networks led to a trend towards networked development in urban public leisure spaces. The development of commercial leisure spaces during this period also saw rapid growth, with commercial buildings merging with public leisure spaces to form integrated commercial leisure spaces that combined entertainment and shopping functions. Notable examples include the integration of commercial pedestrian streets in Coventry and Stevenage city centres with urban squares and libraries, marking significant milestones in urban commercial leisure space development (Alexander, 2009). During this period, the development of public leisure spaces in Chinese cities remained relatively slow, heavily influenced by the Soviet model, with city squares and parks serving as primary leisure spaces (M. Li, 2004).

iv. Modern Developments

The post-industrial era has heralded significant technological advancements, reshaping societal dynamics and lifestyle patterns. This transformative period has notably increased leisure time and recreational demands, necessitating a reevaluation of LUS. In response to these evolving needs, urban areas have experienced a proliferation of diverse leisure spaces and facilities, marking a maturity phase in their development. Cities in this era have transformed into complex, expansive systems, with the development of urban public leisure spaces adapting to more integrated, composite models.

In 1961, renowned scholar Mumford highlighted the dual role of urban green spaces: satisfying city residents' leisure needs and fostering environmental development, thereby promoting harmony between humans and their environment. Similarly, in the same year, Jacobs introduced the concept of "vitality," advocating for vibrant parks seamlessly integrated into mic-urban life, countering the notion of isolated parks or squares (Jacobs, 1961). Since the 1990s, leisure research has expanded to include new areas such as 'ecosystem services,' 'social justice,' and 'urban vitality'. These emerging themes have steered LUS studies towards a multidimensional approach, reflecting the evolving complexities of urban life. As we entered the 21st century, integrating technological advancements and big data has revolutionized research on LUS. This era is characterized by a data-driven and interdisciplinary approach, blending urban planning, design, sociology, and psychology (Jing et al., 2021; S. Liu, Long, et al., 2021). This current state of research points towards a future where LUS are understood and developed through a more nuanced, holistic lens.

2.2.4.2 Comparative Empirical Research on Leisure Urban Spaces: International and Chinese Perspectives

i. International Research

Early research on leisure spaces was somewhat fragmented. It was not until the 1933 Athens Charter, which identified recreation as one of the fundamental functions of a city, that more systematic studies began in the fields of architecture and urban and rural planning. These studies focused on urban public leisure spaces in three dimensions: physical space, spatial behaviour, and spatial benefits. Research on the physical space dimension mainly involves the environmental design and spatial layout of urban public leisure spaces (Dahmann et al., 2010; Freestone & Nichols, 2004; Gospodini, 2001; Jensen & Ouis, 2008; Stansfield Jr & Rickert, 1970; van Weerdenburg et al., 2019). Studies on the spatial behaviour dimension primarily examine psychological cognition and behavioural influencing factors (Azlina & Zulkiflee, 2012; Wen et al., 2018). Research on the spatial benefits dimension focuses on the individual health benefits and social benefits generated by leisure activities (Coutts & Miles, 2011; Drake & Lawson, 2014; Grahn & Stigsdotter, 2010; Paquet et al., 2013; Wolch et al., 2005).

ii. Chinese Research

Compared to international scholars, Chinese researchers started later in the field of leisure space characteristics. Around the turn of the 21st century, Chinese scholars began to intensify their research in this area. Early studies on urban public leisure spaces, also called urban public recreational spaces under specific conditions, mainly focused on the physical layout and spatial behaviour.

In terms of the physical spatial layout, at the macro level, researchers have analyzed the characteristics and influencing factors of the overall layout of leisure spaces in cities like Shanghai, Chongqing, and Wuhan, proposing innovative layout adjustment ideas to address existing issues in LUS (Fang, 2004; Wang, 2012; Yin, 2010). At the micro level, in-depth studies have been conducted on the layout of specific types of leisure spaces, such as urban green leisure spaces (Zhou, 2008), urban waterfront spaces (Fang, 2006), and leisure business (LBD) spaces (T. Fang, 2006).

In terms of spatial behaviour, the research primarily falls into categories including the study of activity satisfaction and engagement (Bai, 2010; Y. Fang & Zhu, 2007), patterns of crowd movement in activities (W. Su et al., 1996; Wu, 2001), preferences in activity spaces (X. Yang & Wang, 2005), and the characteristics of activities in relation concerning space (Chai & Tan, 2017; Sun et al., 2001; Zhao & Chai, 2016).

2.2.4.3 Identifying Research Gaps and Emerging Trends in China

Regarding research subjects, existing studies on LUS often focus narrowly on specific types of spaces, overlooking the leisure characteristics of the entire urban space. To comprehensively reveal the characteristics and patterns of LUS, a systematic comparative analysis of various leisure places, such as parks, squares, and waterfront spaces, is necessary.

Regarding the content of research, despite the significant attention given to spatial layout, planning, and design by urban managers and researchers amidst the massive renewal of urban spaces in China, research on LUS is mainly limited to specific case studies and lacks a comprehensive theoretical framework. Most of these studies are conducted from managers' perspective, neglecting the importance of exploring leisure spaces from the viewpoint of urban residents. Current research often focuses on the physical attributes of leisure spaces while ignoring the overall aspects of leisure activities and user experiences and the impact of urban planning on leisure behaviour. Therefore, thoroughly exploring the intrinsic mechanisms of LUS and their interaction with urban spaces is crucial for understanding and explaining the emergence and evolution of leisure behaviours in urban spaces.

Regarding research methodology, current studies typically lack comprehensive data support and standardized evaluation criteria, leading to inconsistencies in research findings. There is a need to strengthen interdisciplinary research approaches, utilizing advanced data analysis techniques and placing particular emphasis on the role of empirical research. Collecting data through empirical surveys and using statistical analysis to investigate key factors affecting leisure activities will provide a solid foundation for identifying, analyzing, and addressing issues. Consequently, a more comprehensive and multidimensional research approach is required to deepen our understanding of LUS in China, enhance their quality, and ensure they meet diverse needs and preferences.

2.3 Fundamental Theories and Systematic Review of the Vitality of Urban Public Spaces

2.3.1 Concept and Elements of Vitality of Urban Public Spaces

The term "vitality," originally from biology and ecology, refers to the ability of living organisms to sustain life and development. In urban studies, since the 1960s, "vitality" in these spaces has taken on various abstract meanings, mainly focusing on how public spaces represent urban environments. Despite a lack of a singular definition in academia, many scholars have offered diverse perspectives on the vitality of UPS. Kevin Lynch (1984) outlines five key indicators of urban spatial quality - vitality being the primary one, including elements of life support and diversity. Louis Wirth (1991), in "Urbanism as a Way of Life", points out that urban scale, density, and heterogeneity are vital factors. Jane Jacobs (1961) argues in "The Death and Life of Great American Cities" that urban vitality arises from the interplay of people, activities, and places, creating urban diversity. Jan Gehl (2002) emphasizes social interactions in urban spaces, with vitality stemming from the relationship between places, crowds, and activities. Ian Bentley (2001), in "Responsive Environments: A Manual for Designers", describes vitality as a place's ability to support various functions and choices. Montgomery (1998) focuses on the neighbourhood population, highlighting the importance of density and mixed-use. Maas (1984) defines urban vitality as combining diverse commercial and entertainment opportunities and a varied pedestrian population. Chinese scholar Jiang (2007), in "Vitality Theory of Urban Form", sees it as public spaces' ability to provide a humane living environment, encompassing economic, social, and cultural vitality. Wang Hai (2012) views public vitality as reflecting the comfort and satisfaction of users with spatial environments, with human behaviour in these spaces indicating urban vitality. Wang (2018) considers the material space's capacity to attract people for social activities and their perception and identification of these spaces. While definitions vary, they converge around three key elements: people, activities, and locations, with people's needs, activity density, and frequency being vital indicators.

Despite the absence of a unified definition, there is consensus among scholars that vitality in urban and public spaces centres around three essential elements: people, their activities, and the places where these activities occur. Human needs are the root of activity, with the density and frequency of crowd activity serving as external signs of vitality. Space is the tangible medium for activities and the underlying mechanism of vitality (Pan et al., 2021). Without active spaces, a place is just a physical environment lacking organic vitality. Without spatial support, social activities cannot be diverse or sustained. Conversely, spaces that don't meet user needs or stimulate activities cannot create a vibrant atmosphere.

2.3.2 Systematic Review of Evaluation of the Vitality of Urban Public Spaces

As discussed in Sections 2.2.2 and 2.2.3, LUS constitute an essential subset of UPS, primarily including parks, squares, waterfront spaces, and leisure blocks. Despite the current absence of comprehensive literature specifically addressing the vitality of LUS in China, this study aims to conduct a systematic literature review focusing on these UPS to identify commonly used evaluation indicators for vitality evaluation. The purpose of this review is to reveal the current state of research, gaps, and trends, analyzing from three perspectives: the research subjects, representations of vitality, built environment factors influencing vitality, and research methodologies, all based on the dual research dimensions of crowd activity and physical space. The findings of this systematic review are primarily based on the author's published journal article (X. Li et al., 2024). Utilizing PRISMA guidelines, this systematic review on urban public space (UPS) vitality focused on English articles from 2008 to 2023, using key terms ("park" OR "square" OR "waterfront" OR "street" OR "block" OR "public space" OR "green space" OR "open space" OR "urban space") AND ("vitality" OR "vigor").

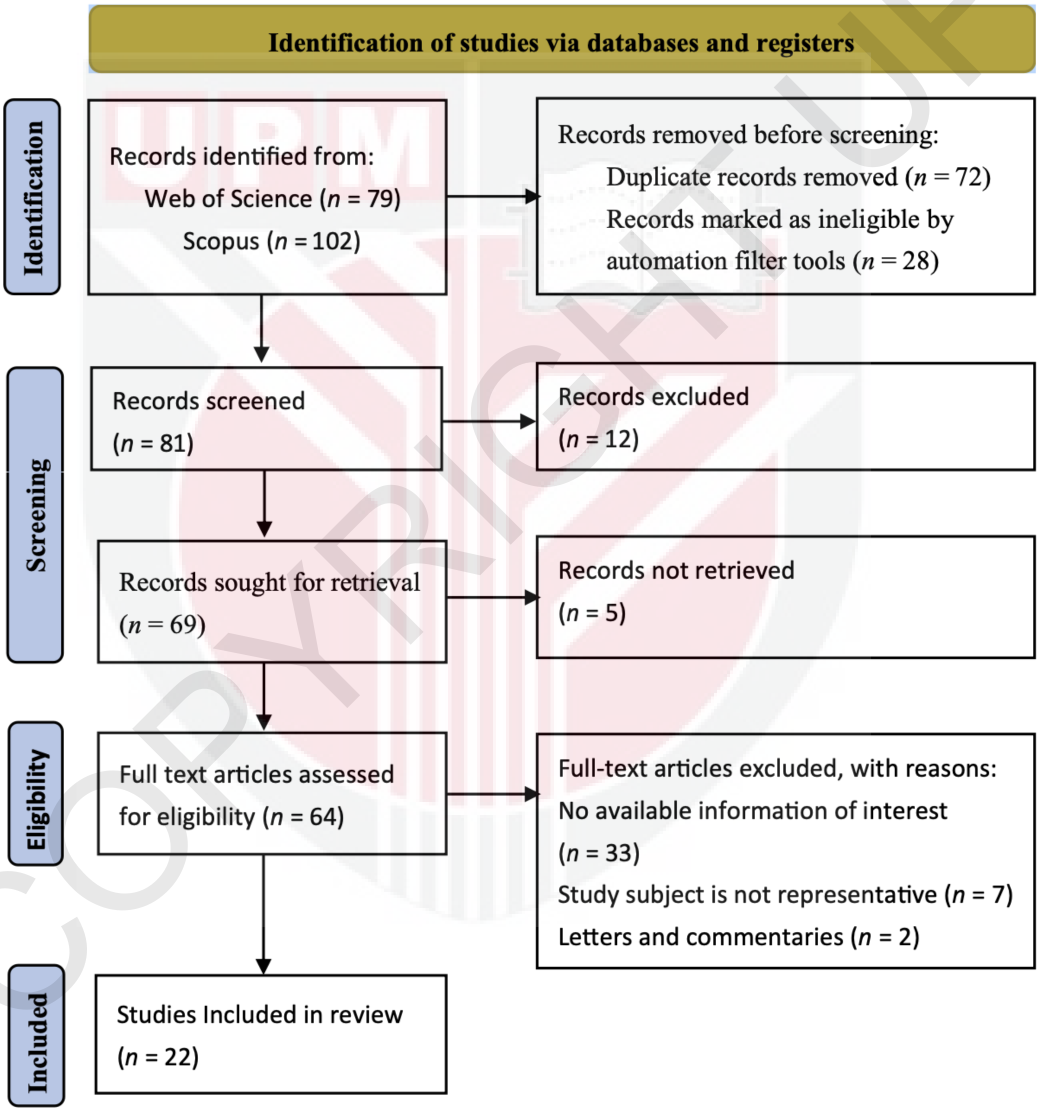


Figure 2.1 : The Systematic Literature Review Process as Captured Via a PRISMA Flowchart
(Source: Author 2024)

It aimed to identify primary research themes, factors contributing to UPS vitality, and common evaluation methods. Inclusion criteria targeted recent English studies, with an initial pool of 167 articles reduced to 22 through meticulous screening. Figure 2.1 illustrates the process of selecting eligible items using the PRISMA method. The information and results of the final 22 selected review articles are summarised in Appendix A, which presents the source, research objects, components of vitality, and research methods for each article.

2.3.2.1 Research Objects

Urban Public Spaces (UPS) with distinct functionalities can be categorized into three types: 1) Point spaces, referring to isolated and critical nodes within the city, including city squares, parks, and waterfront spaces; 2) Linear spaces, which refers to linear distributions along a specific axis, including streets and waterfronts; and 3) Planar spaces, which are expenses that extend horizontally, forming open areas, including historic districts and residential public spaces. This study selected representative literature from various research achievements and classified them based on different objects of vitality evaluation.

Based on the 22 representative literatures selected in this study, it is evident that many researchers are primarily focusing on Linear and planar space, such as waterfront areas and street blocks. This is likely because planar public spaces occupy a significant proportion of cities and have a significant impact on urban functionality and attractiveness. However, the evaluation of vitality in point-like spaces, especially squares and waterfront spaces, is relatively insufficient. Only four articles specifically analyze point-like spaces (Banchiero et al., 2020; Chen & Ma, 2023; Mu et al., 2021;

J. Zhu et al., 2020), and these four articles selected specific samples from a large number of spaces for analysis. This discrepancy is noteworthy because these point-like spaces serve as important locations for residents' basic recreational activities and contribute to economic and cultural exchanges within the city. Moreover, the evaluation of the vitality of UPS is currently fragmented, with research predominantly concentrated on specific types of spaces, lacking systematic evaluation of different types of spaces. This limits our comprehensive understanding of the overall vitality levels of UPS. Additionally, there is limited research on the commonalities and differences among different types of spaces, which hinders a deeper understanding of public space planning and design.

In essence, while there is some accumulation of research on the vitality of UPS, there are still deficiencies in studying point-like spaces, conducting comprehensive evaluations, and exploring the commonalities and differences among different types of spaces.

2.3.2.2 Different Research Perspectives on Vitality

This study concludes that assessment and research of UPS's vitality are primarily associated with two dimensions: crowd behavior and activities, and the built environment. Some scholars, like Sheng (2013), F. Zhang et al. (2022), and X. Q. Zhu et al. (2013), solely evaluate vitality based on built environment factors. Only two articles, Molavi et al. (2017) and T. Wang et al. (2022), fall into this category when assessing square vitality. While this approach reveals built environment characteristics, it may yield partial outcomes by neglecting crowd behavior and activities. UPS's vitality is closely tied to people's interactions, behaviors, and perceptions, reflecting space attractiveness, social interaction, and public acceptance. Studies relying solely on built environment factors may not fully capture space dynamics. Another approach constructs an evaluation framework using built environment factors, aligning with crowd activity characteristics to confirm effectiveness (Niu et al., 2021). Remaining studies primarily analyze built environment factors influencing vitality, treating crowd activity as an external representation and the built environment as an internal mechanism. However, scholars often have limitations in evaluating crowd activity, relying on spatial and temporal clustering, neglecting factors like crowd satisfaction and feedback. To provide a detailed understanding of factors and indicators in current vitality studies, this article will elaborate from the perspectives of crowd activity and the built environment.

2.3.2.3 Research on Crowd Activity as the Representation of Vitality

Crowd activity refer to various activities conducted by people within the spatial environment and serve as the main subject and external representation of the vitality of UPS. Currently, the evaluation and description of crowd activity characteristics in vitality research mainly focus on the spatiotemporal features of crowd aggregation. Indicators such as crowd density, scale, and intensity variations are often used as evaluation criteria for vitality However, only a small portion of studies consider the diversity of crowd activity and the satisfaction of participants as factors of vitality evaluation.

Research on crowd activity as a representation of vitality can be broadly classified into five categories: The first category does not consider the temporal dimension and simply represents vitality through the statistical visitor density (J. Zhu et al., 2020) or the number of visitors (Yuan & Chen, 2021). However, this approach is too simplistic as it cannot capture the average value over a period or objectively reflect the long-term activity patterns in the space. The second category combines both spatial and temporal dimensions by calculating the average activity density (Dong et al., 2022; Fan et al., 2021; M. Liu, Jiang, et al., 2021), average number of visitors (Xu et al., 2018), or average activity intensity (Y. Niu et al., 2021; F. Wang et al., 2020) at different time points. Although these studies consider the temporal dimension, most of them do not analyze or compare temporal variations. Only a few studies, such as Mu et al.(2021) compared the average activity density between weekdays and weekends, while Xu et al.(2018) compared visitor numbers in three different periods on weekends, morning, afternoon and evening, without taking into account weekdays. The third category aims to observe and compare the crowd density and intensity at different time points, as well as their correlation with built environment factors (Banchiero et al., 2020; Wangbao, 2022), to delve into the temporal variations in how the physical space influences activities. The fourth category of research involves evaluating the distribution of crowd activity density (Ding et al., 2023; M. Liu, Jiang, et al., 2021; Y. Yang et al., 2021) or the distribution of spatial aggregation (Huang et al., 2023; F. Wang et al., 2020; Y. Zhang et al., 2021) at different time points to represent vitality. Activity density stability refers to whether the trend of crowd activity density remains relatively stable across different time points or periods. This analysis method can provide a better understanding of the patterns and trends of crowd activity in space through aspects such as temporal variations and average activity values. In addition to the aforementioned indicators of temporal and spatial characteristics of crowd activity, some researchers have also considered measurements from the user perspective, including visitor diversity (Banchiero et al., 2020; Mu et al., 2021), satisfaction with activity experiences(J. Zhu et al., 2020), and diversity of activity types (L. Chen & Ma, 2023; Mu et al., 2021).

Current research on UPS's vitality primarily focuses on describing the spatial and temporal distribution of crowd activity. However, this approach has limitations and may not capture the true vitality of the spaces. For example, while busy streets during peak hours or round-the-clock office workers may exhibit high-density crowd activity, this alone does not characterize a vibrant space. According to place-making theory, community involvement in any planning and design process is influenced to some extent by the goals and purposes of the activities to be realized in that space. A vibrant space requires consideration of individuals' community attachment and local sentiment (Ellery & Ellery, 2019). Therefore, assessing the satisfaction and sentimental feedback of different groups in UPS activities is crucial, as it is a key factor in ensuring the sustainability of UPS crowd activity.

2.3.2.4 Factors of Built Environment Influencing Vitality

The physical space shapes crowd activity and is crucial for the vitality of UPS. Research links the quality of built quality to UPS's vitality, exploring factors like density, accessibility, amenities, and green spaces. Scholars use crowd activity levels as vitality indicators, analyzing their relationship with the built environment and studying environmental factors' impact. Figure 2.2 categorizes key indicators impacting vitality based on literature analysis. Studies solely assessing vitality through built environment factors are excluded due to unverified evaluation indicators regarding dependent variables.

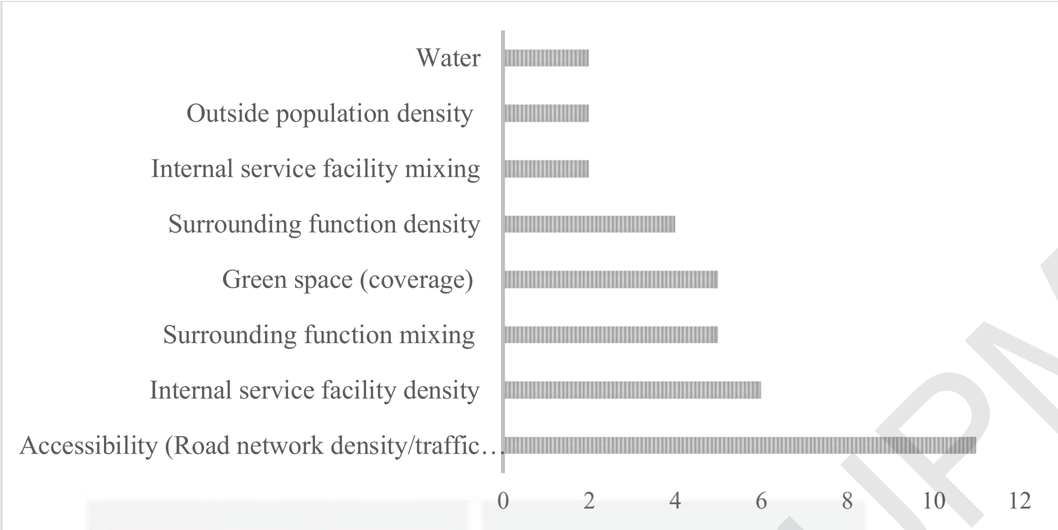


Figure 2.2 : The Frequency Statistics of Significant Impact Factors and Indicators
(Source: Author 2024)

According to the results, it is evident that accessibility is the most crucial factor influencing visitors' access and use of UPS among all the physical environmental factors. Half of the 22 articles have demonstrated the significant impact of accessibility on vitality. Key evaluation indicators of accessibility include external road network density (Dong et al., 2022; Y. Niu et al., 2021; F. Wang et al., 2020; T. Wang et al., 2022; Y. Yang et al., 2021) non-motorized vehicle lane accessibility(S. Liu, Lai, et al., 2021; Y. Niu et al., 2021), connectivity to public transportation stops (Dong et al., 2022; Y. Niu et al., 2021), and openness of entrances to public spaces (Yuan & Chen, 2021). Internal service facilities and external urban function are also two important factors for vitality. The importance of internal facility density is significantly greater than that of mixing, and this indicator has been proven to have a significant impact on vitality in six relevant articles. Park service facilities typically include recreational amenities such as footpaths, fitness areas, kiosks, picnic areas, food services, stores, and some basic facilities like toilets and dustbins, as well as road lamps (Mu et al., 2021; J. Zhu et al., 2020). Waterfront areas have facilities such as public recreation visitor centers, bicycle parking spots, drinking water points, vending machines, fitness facilities, and service stations, and may also include commercial facilities such as shopping and catering (L. Chen & Ma, 2023; S. Liu, Lai, et al., 2021). Residential neighborhoods' facilities are usually analyzed using POI data, which typically include education, health, public services, administration, and sports facilities (Huang et al., 2023). Leisure-oriented historical neighborhoods often include dining facilities, entertainment facilities, shopping facilities, transportation facilities, tourist attractions, housing facilities, and business density (F. Zhang et al., 2022). Some scholars have also confirmed the significance of external urban function density (Huang et al., 2023; M. Liu et al., 2021; Y. Yang et al., 2021; F. Zhang et al., 2022), and mixing (Ding et al., 2023; M. Liu, Jiang, et al., 2021; Y. Niu et al., 2021; T. Wang et al., 2022) for vitality. Scholars often categorize external urban functions through land use (Ding et al., 2023; Wangbao, 2022) or POI data (M. Liu, Jiang, et al., 2021; Y. Niu et al., 2021; Y. Yang et al., 2021) which generally include seven categories, Residential communities; Public administration and service; Education; Commercial service; Office building/space; Transport facilities; Parks and scenic spots. Some studies have found that the quality and proportion of green spaces and vegetation within the space also have a significant impact on vitality (Ding et al., 2023; Dong et al., 2022; Mu et al., 2021; Y. Zhang et al., 2021; X. Zhong et al., 2021). Some researchers have also found that the external residential density can affect the activity levels within the space (F. Wang et al., 2020; J. Zhu et al., 2020), possibly because people tend to prefer leisure and recreational activities in public spaces near their homes. Additionally, the quality and provision of water features within the space can influence the number of visitors and the duration of their stay in UPS (Mu et al., 2021; J. Zhu et al., 2020).

The vitality of UPS exhibits a positive correlation with their physical environmental quality within a certain range, indicating a close nexus with human activities. While some scholars acknowledge both crowd activity and the physical environment in evaluating vitality, the majority of researchers prioritize crowd activity as the primary representation. However, there is a limited body of literature comprehensively evaluating both aspects through integrated evaluation frameworks. The emergence of smart city, theories, and methodologies from disciplines such as sociology, environmental psychology, and geography offer deeper insights into human behavior and activities, all of which are closely intertwined with the built environment. For instance, how the physical design of spaces influences individuals' perceptions and emotional responses; and how spaces impact social interactions and collective behavior. Integrating these interdisciplinary perspectives into studies of the built environment not only facilitates a more comprehensive understanding but also enhances the depth of evaluation and design of public vitality.

2.3.2.5 Data sources and Types of Vitality Studies

In the exploration of UPS's vitality, methodological approaches have gradually shifted from early mixed methods to primarily utilizing quantitative data. This transition is partly attributed to the limitations of early methods, often constrained by small-scale samples and data collection. With the rapid development of emerging theories such as smart cities and information technologies, big data techniques have brought about broader perspectives and more efficient tools for analyzing behavioral activities and built environments. This paper will delve into the specific roles and significance of these methods in understanding and evaluating UPS's vitality.

i. Mixed Method

Early studies utilized mixed research methods, with a focus on representing vitality through the built environment. For instance, Sheng (2013) employed spatial syntax to quantitatively analyze the topological patterns of urban block networks in Beijing and Tianjin, arguing that the quantity and location of shops can indicate the vitality of urban blocks, and qualitatively analyzed and compared the impact of block morphology on the quantity and location of markets, grocery stores, clubs, and street vendors in the two cities. X. Q. Zhu et al. (2013) proposed that vitality consists of three aspects: location features, functional composition, and spatial patterns. They qualitatively analyzed the vitality of two representative historical neighbourhoods in Hangzhou through observation and further explored factors for optimizing vitality by surveying users' needs and satisfaction levels. However, since vitality research primarily relies on exploring crowd activity, results often suffer from significant errors if the sample size is insufficient. Thus, this paper will primarily discuss literature on quantitative research, categorizing it into data types and data analysis for further discussion.

Existing research methods on the vitality characteristics of UPS can be divided into two categories: vitality studies based on traditional data collection methods such as field research and questionnaire interviews, and vitality evaluation research based on big data analysis.

ii. Traditional Data

Firstly, in quantitative studies on the vitality of urban parks, researchers often employ methods such as statistical data analysis, questionnaire surveys, and on-site observations to observe the behaviors and perceptions of space users through questionnaire interviews. For example, Banchiero et al. (2020) conducted a systematic photographic documentation, where three experts directly observed three different parks during morning, noon, and evening periods to capture the number of active individuals, visitors' background information (age, gender, nationality), and activity types. Mu et al.(2021) collected data in three parks on both weekdays and weekends, utilizing timers, park maps, laptops, and smartphone cameras to record the quantity of people, their backgrounds, and activities; Additionally, they distributed 150 questionnaires to the park visitors, focusing on 14 factors related to the park environment, and asked them to identify the top five factors influencing their decision to visit the park. Molavi et al. (2017) used observation and questionnaire surveys to obtain information on functional and physical aspects of the creation of vitality in the square. Chen and Ma (2023) conducted on-site investigations using behavior counting methods, observing and counting the occurrence frequency and duration of different activities by the waterfront space in the morning and afternoon periods.

iii. Big Data

To better understand the application of big data in the study of vitality, this paper refers to the basis of big data classification in the relevant literature (Y. Long & Mao, 2019; J. Yang & Cao, 2017).

Table 2.1 : Types and Sources of Multi-Source Big Data

Crowd Activity	Built Environment
Dynamic Big Data: Data with fine-grained time information Mobile Location Service Data (Baidu Heat Map, Mobile Phone Signals, Social Media Check-in Data)： Transport Sensing Data (Real-time Traffic Data, Bus Card Swipes, Taxi Data, GPS-enabled Shared Bikes)	**Static Big Data:** Data with physical spatial information Geospatial data (traffic network, transportation facilities, building outlines, water, and space boundaries); Remote sensing image data
Explicit Big Data: Data on the subjective perception of the city by individuals Social media data (rating, reviews, photo sharing)	**Implicit Big Data:** Data that is objective `but not visible POI data (Point of Interest)

From the perspective of the two important aspects of vitality evaluation, big data types can be mainly divided into two categories: behavioral activity big data and built environment big data, of which Dynamic Big Data and Explicit Big Data analyze people and their activities and belong to behavioral activity big data; Static Big Data and Implicit Big Data are statistics on urban spatial information, and therefore belong to built environment big data. See Table 2.1 for details.

(a) Crowd activity: Researchers analyzing spatiotemporal characteristics of crowd activity predominantly rely on dynamic big data. Baidu Heat Map Data (BHMD) is a common source visualizing user location data, crucial for assessing population density and activity stability (J. Ding et al., 2023; Dong et al., 2022; Fan et al., 2021; Huang et al., 2023; M. Liu et al., 2021; Y. Zhang et al., 2021). Mobile Signaling Data (MSD) is significant, recording user location and communication duration. F. Wang et al. (2020) and Y. Yang et al. (2021) used MSD to explore human mobility patterns. Tencent Real-Time User Location Data (RTUD) offers real-time insights into user behavior, population distribution, and activity hotspots with a spatial resolution of 25 meters. Scholars like M. Liu et al. (2021) utilized RTUD for insights into user behavior patterns in Shanghai's waterfront area. Some researchers integrate dynamic and explicit big data, as seen in studies by J. Zhu et al. (2020) and J. Ding et al. (2023), combining Meituan-Dianping (MD) check-ins and user satisfaction ratings. In summary, analyzing crowd activity characteristics involves methods with strengths and weaknesses. BHMD provides visual representation but lacks detailed insights. MSD reveals communication behavior but faces challenges due to data volume. RTUD focuses on location information but raises privacy concerns. Social media data reflects preferences but has limited coverage. Traffic sensing data provides detailed traffic flow but has limitations for non-motorized vehicles. Combining sources enhances diversity and reliability but exploring traffic sensing data and explicit big data further is essential.

In summary, analyzing crowd activity characteristics involves methods with strengths and weaknesses. BHMD provides visual representation but lacks detailed insights. MSD reveals communication behavior but faces challenges due to data volume. RTUD focuses on location information but raises privacy concerns. Social media data reflects preferences but has limited coverage. Traffic sensing data provides detailed traffic flow but has limitations for non-motorized vehicles. Combining sources enhances diversity and reliability but exploring traffic sensing data and explicit big data further is essential.

(b) Built environment: The main sources of big data used to analyze urban spatial structure characteristics are static big data and implicit big data. Almost every study requires the use of geographic information data from static big data. These data are relatively stable and provide tangible spatial information. Basic geographic information mostly comes from map service providers (such as Baidu Maps and Amap) or data provided by official authorities in the research area. The source of Road network data and Building data is mainly OpenStreetMap (OSM). Furthermore, Xu et al. (Xu et al., 2018) utilized the official traffic application "My Nanjing" in Nanjing to gather public transportation information about locations, including the number of subway stations, bus stops, and street entrances/exits. T. Wang et al. (T. Wang et al., 2022) used WorldPop to obtain population data. Some scholars obtained actual information about locations using Baidu Street View(M. Liu, Jiang, et al., 2021; Xu et al., 2018; Y. Yang et al., 2021). Chen and Ma (2023) and Y. Zhang et al. (2021) obtained geographic information about locations by analyzing remote sensing images from BIGEMAP and utilizing ENVI software for processing. Implicit Big Data refers to the spatial location, industry category, and institutional attributes of social, production, life, and various service functions that support the orderly operation of the city. Based on this, scholars have used various comprehensive data analysis methods to analyze the factors affecting vitality in cities. In nearly half of the 22 studies, POI (point of interest) data was utilized. These scholars linked the degree of aggregation of urban functional facilities and other information with human activity intensity using POI data.

Despite using various static and implicit big data sources, there are limitations. Static big data, primarily from map providers and official sources, may lack timely updates. Tools like Baidu Street View, while useful, might have limited coverage, not fully representing the entire study area. Acquiring implicit big data is challenging, requiring a comprehensive analysis of spatial locations, industry categories, and institutional attributes. To enhance reliability and comprehensiveness, future studies can explore updated data sources and adopt comprehensive analysis methods for more accurate and timely outcomes.

2.3.2.6 Data Analysis of Vitality Studies

i. Correlation Analysis

Correlation analysis involves examining relationships between numerical data and spatial factors. Scholars use various regression methods, such as multiple regression analysis, to understand the impact of environmental factors on vitality indicators. For instance, J. Zhu et al. (2020) used multiple regression to explore the influence of environmental factors on park vitality. Pearson's coefficient is frequently employed for correlation analysis between built environmental factors and crowd activity characteristics, as seen in Chen and Ma's (2023) study on waterfront spaces. Spatial correlation analysis, focusing on geographic space, often employs the geographically Weighted Regression model. Studies show significant spatiotemporal heterogeneity in vitality, with cores often in urban centers. J. Ding et al. (2023) utilized the Multiscale Geographically Weighted Regression model, arguing its higher precision in capturing spatial differentiation structures. Sheng (2013) analyzed street network topological patterns using the Layered Movement Network Model in spatial syntax, emphasizing the importance of choosing the right method based on research accuracy and study areas.

ii. Comprehensive Evaluation Method

Scholars employ comprehensive evaluation methods to assess numerous indicators. Techniques like weighting algorithms are crucial, with the average weighting method, used by Banchiero et al. (2020) for three crowd activity indicators, being simple but not accounting for varying importance. The expert scoring method is commonly used, offering more objectivity. For example, Mu et al. (2021) determined weights for four crowd activity indicators based on 13 expert scores, while T. Wang et al. (2022) used 20 expert scores to weigh four built environmental vitality indicators. Molavi et al. (2017) employed the Analytic Network Process software, integrating expert scores to calculate weights through the feature weight vector method. Some scholars combine the expert scoring method with the Analytic Hierarchy Process. Niu et al. (2021) used Analytic Hierarchy Process for a vitality evaluation model based on built environmental factors, determining element importance through expert scores. Y. Zhang et al. (2021) used Analytic Hierarchy Process for an evaluation framework, conducting an exploratory factor analysis to analyze the influence levels of 17 indicators on vitality and calculate weights based on the analysis results.

2.3.3 Research Gap and Future Research

The analysis in the preceding sections, considering research objects, perspectives, and methods, leads to the following three suggestions and prospects:

In the future, there should be a stronger emphasis on comprehensive studies of point-based UPS, especially square and waterfront spaces, to explore their characteristics and vitality evaluation methods. Additionally, cross-type studies should be conducted to compare and comprehensively evaluate different types of public spaces, aiming for a more comprehensive understanding. It is important to enhance research on the commonalities and differences of UPS, providing a scientific basis for personalized spatial improvements.

The evaluation of UPS's vitality is shifting from a singular dimension to a comprehensive multidimensional analysis, reflecting current and future developmental trends. This paper aims to understand the multifaceted significance and foundational aspects of UPS's vitality through an integrated study of the interplay between crowd activity and the built environment. Consequently, the construction of a comprehensive evaluation framework with multiple indicators becomes essential. Future research should adopt an interdisciplinary approach, thoroughly analyzing the components of UPS. This includes not only the spatiotemporal behavior characteristics of individuals but also their intrinsic influencing factors, such as satisfaction with activities, emotional feedback post-activity, social interactions, and more. Additionally, exploring the transition from fragmented to integrated behavioral influence factors within a comprehensive framework is essential. This also involves delving deeper into the extent to which the built environment impacts various dimensions of crowd activity. The goal is to develop a multidimensional and comprehensive evaluation framework of the vitality of UPS.

The emerging data environment offers opportunities for leveraging urban big data and technology in studying the vitality of UPS. This shift enables a more comprehensive exploration of how the physical environment multidimensionally impacts human activities. However, evaluating the vitality of UPS in the context of big data necessitates further research into its universality, applicability, and information-mining capabilities. Future studies should consider utilizing diverse and updated data sources and employing comprehensive data analysis methods to ensure accurate and timely results. To ascertain the significance and interrelationships of these factors, there is a need for more empirical quantitative research. Additionally, new technologies can be harnessed to extract visitors sentimental feedback and activity information from online reviews. It's crucial to acknowledge that big data analysis may contain inherent biases; thus, integrating traditional surveys with big data analysis can offer a more balanced and realistic view of research findings. Furthermore, the use of qualitative methods in assessing UPS's vitality, though currently underutilized, is essential. Qualitative research can deeply explore individual subjective perceptions and experiences of UPS, offering rich insights that complement quantitative data. Therefore, an integrative approach that combines both qualitative and quantitative research methods is essential for a more holistic understanding of UPS's vitality in future studies.

2.4 Theoretical Framework for the Formation and Composition of Vitality in Leisure Urban Spaces

Research on urban space vitality has evolved into an interdisciplinary field, building on a comprehensive summary of the basic concepts and empirical studies of UPS vitality. Numerous scholars have delved into the meaning of urban space vitality from various perspectives, such as urban spatial design, environmental behaviour, and user psychology. This paper employs the spatiotemporal behavioural theory from leisure geography and the interdisciplinary Behavior Change Theory to construct the formation process of urban space vitality. It also introduces the concept of "leisure urban space vitality" and analyzes the components of spatial vitality based on this concept. Finally, by integrating the analysis of vitality-influencing indicators from a systematic literature review, the paper establishes a comprehensive evaluation framework for the vitality of leisure urban spaces.

2.4.1 Theoretical Basis

2.4.1.1 Urban Space System Theory

The theory of the urban space system, based on L·V·Beralanfy's general systems theory, emphasizes the holistic nature and interactive relationships among its constituent parts (Bertalanffy, 1968). System theory focuses on the entirety of systems, encompassing interactions between internal components and the external environment, as well as their dynamic changes. Bertalanffy defines a system as a structured whole composed of elements whose functionality is sustained through their interactions with the environment. In the context of urban space, this implies that cities are not only constituent parts of larger urban systems but also constitute orderly systems themselves, reflecting the systemic characteristics of urban space (Yakovenko & Komov, 2021).

Building on this perspective, the theory of urban space system identifies leisure urban space as a subsystem of the urban system, characterized by a balanced layout of public spaces, continuity of spatial systems, and openness of internal and external interfaces. Moreover, critical attributes of this theoretical framework include transportation accessibility and the complexity of UPS - that is, the interconnection of various spatial elements with other urban subsystems. Consequently, LUS is analyzed at two scales within the systemic approach: the system level, focusing on overall urban structure, and the individual level, focusing on specific public spaces.

At the system level, the core of LUS lies in the interaction between its overall structure and the spatial layouts of adjacent areas, forming coordinated configurations of its constituent parts. Analysis of the LUS structure focuses on the distribution of different spaces within the city and their interactive relationships, establishing an overall framework composed of distinct hallmark factors.

The individual level involves specific functional urban public places with an overall environment, particularly parks, squares, waterfront spaces, and leisure blocks. These spaces are closely tied to the morphology of urban space, exhibiting clarity and integrity in their design and function. They provide rich social leisure activities for urban residents and emphasize openness to the public due to their characteristics of crowd gathering and sustained activities. When analyzing these spaces, the focus is on the constituent elements of leisure environments and their impact on residents' behaviours and experiences.

Based on system theory, this study investigates LUS vitality at both the system and individual levels, aiming to understand how LUS supports leisure activities and promotes sustainability.

2.4.1.2 Spatiotemporal Behavioural Theory

Spatiotemporal behavior, anchored in Time Geography and Behavioral Geography, explores the ontological understanding of material reality and emphasizes the role of individuals in regional and urban settings (Caldeira & Kastenholz, 2019). This approach highlights the interplay of constraints and decision-making within the spatiotemporal framework, enhancing our understanding of the relationships among people, time, and space (Raubal & Winter, 2010). It lays the foundation for a spatiotemporal philosophy and methodology rooted in geographical principles for urban research and planning applications. Investigating human behaviour and its spatial context in environmental psychology is considered a dynamic, mutually constraining process. Human behaviour not only shapes the physical attributes of space but is also influenced by the spatial environment. This reciprocal interaction suggests that in designing and optimizing spatial environments, human behaviour should be the primary consideration (Cassidy, 2013).

Within this context, leisure spatiotemporal behaviour is a key perspective in leisure studies, connecting the inherent needs for leisure with the practical use of leisure spaces. The notion of residents' spatiotemporal behaviour in this research pertains to their distribution characteristics within LUS. By analyzing activity paths, occurrence spaces, and durations, it is possible to discern the spatiotemporal distribution patterns of daily leisure activities among various user groups. This provides a crucial basis for refurbishing and constructing leisure activity spaces in existing residential areas (S. Liu, Long, et al., 2021).

Furthermore, the recent advancements in communication and network technologies have catalyzed the emergence of a significant volume of spatiotemporal big data. This data provides new channels for acquiring extensive information on spatiotemporal activities, offering novel insights into urban leisure behaviour and the optimization of urban spatial structures. It illuminates the spatiotemporal behavioural patterns of crowds, the impact of time and space constraints on these patterns, and the decision-making mechanisms underpinning residents' spatiotemporal behaviours. This comprehensive perspective on crowd activity behaviour integrates both time and space dimensions, facilitating a nuanced analysis of activity characteristics and spatiotemporal patterns of crowd behaviour (Dong et al., 2022; Jacobs-Crisioni et al., 2014; Shiwen et al., 2021).

2.4.1.3 Behaviour Change Theory

In the behaviour change theory, a key concept is that external factors exert a far greater influence on human motivation than internal factors (Bandura, 2014). Hence, LUS, as an external environmental element, represents influential factors in the context and environment in which behaviour occurs, playing a significant role in the process of behavioural change (Bandura, 2014).

Lawrence Green and Marshall Kreuter synthesized various behaviour change models and theories for practical applications. They comprehensively and systematically studied the interactions between people, environment, and behaviour change and proposed the PRECEDE-PROCEED model. This model is a highly adaptable framework that can guide people to identify behavioural problems and provide guidance for analyzing problems, developing plans, implementing strategies, and evaluating outcomes. They believed that "any behaviour is influenced by three factors: Predisposing, Enabling, and Reinforcing." The three factors form a complete system. Predisposing factors are the motivations that drive individuals to engage in a behaviour. Enabling factors supply the material resources needed to carry out the behaviour, and reinforcing factors create an environment that promotes the persistence of the behaviour. These three factors coexist and interact (Gielen et al., 2008).

Furthermore, reinforcing factors can promote the upgrade of enabling factors, and enabling factors can stimulate the generation of predisposing factors. Therefore, the three factors should be developed to promote behaviour change fully. From the concept of the three factors of behaviour change mentioned above, it can be understood that the allocation of LUS exists as an enabling factor, and to understand the process of how the environment promotes leisure behaviour, it is necessary to study and discuss the three factors.

2.4.2 The Constituent Factors and Evaluation Indicators of Crowd Activity

Through a comparative analysis of pertinent literature, this paper identifies several shortcomings in the current approach to evaluating urban vitality using big data. Firstly, there is an oversimplification in the vitality evaluation dimensions. Most big data-driven studies on urban park vitality rely predominantly on the spatiotemporal aspects of crowd gatherings as metrics for vitality's external representation, often neglecting the emotional feedback from space users—a contrast to traditional survey-based research. Secondly, aligning with the 'psychological state' perspective of leisure as defined in section 2.2.1, leisure is fundamentally about individuals' internal experiences characterized by pleasure, relaxation, and personal growth. Hence, attaining positive emotions during activities is the essence of leisure. Lastly, while big data studies on vitality's external representation tend to concentrate on crowd density and activity diversity, the emotional responses of participants are frequently overlooked. However, traditional research methods emphasize activity intensity, duration, type, and user satisfaction as critical vitality indicators. The preceding analysis underscores the need for a more nuanced approach to its vitality evaluation, incorporating both quantitative and qualitative aspects.

2.4.2.1 Spatial Factor

In research on urban space vitality, crowds are the primary activity agents, while the physical space serves as the medium. As discussed in Section 2.3.4, these studies typically include the number or density of users in a space as a fundamental indicator of vitality assessment. The overall scale refers to the total number of people's activities in a specific space throughout a day, which directly reflects the attractiveness of that space (Yuan & Chen, 2021; J. Zhu et al., 2020). Secondly, user density is measured based on the ratio of the number of visitors to the area of the space; higher population density indicates greater vitality in public spaces. Based on this, the paper suggests that 'Spatial Clustering' could serve as an indicator of crowd activity within spatial factors characterized by user density over a period. However, relying solely on spatial clustering to measure the vitality of LUS has certain limitations

2.4.2.2 Temporal Factor

According to the spatiotemporal behaviour theory, the study of behaviour encompasses not only spatial factors but also changes in the temporal dimension. As outlined in Section 2.3.4, numerous studies have also considered the temporal variations of crowd activity. The vitality of LUS is reflected in both short-term crowd surges and long-term fluctuations in activity levels. The aim is to have many people engaging in activities across various periods, with high activity frequency during peak hours, minimal fluctuation coefficient, and extended durations (Ding et al., 2023; S. Liu et al., 2021; F. Wang et al., 2020). Key metrics include moment intensity, fluctuation variation, and duration. Moment intensity refers to the number of activities in a public space during peak hours, reflecting the ongoing fluctuation of activity numbers in space. Fluctuation variation is the standard deviation of activity intensity at a given time in a public space and is used to describe activity levels. Duration indicates the sustainability of leisure space vitality, representing the cumulative daily activity time in a space. Maintaining constant vitality in every node of LUS is challenging. However, if a space is active for a certain duration, it can possess some attractiveness to users. Therefore, this paper suggests that "Temporal Persistence" is a key indicator of crowd activity in temporal factors, encompassing both the fluctuation coefficient of activities and the persistence of high-intensity activities.

2.4.2.3 User Factor

In addition to the previously mentioned factors, analyzing the users and primary agents of activity in space — the crowd — is very important. A vibrant space requires both sustained crowd presence and diverse user engagement. Past studies have often focused on the age diversity of visitors as a vitality assessment metric (Banchiero et al., 2020; Mu et al., 2021). However, this study posits that the diversity of leisure activities extends beyond just the age of users to include individual behaviours and interpersonal relationships (Wang, 2016; Zhou & Wang, 2010; Zhu et al., 2020). Drawing from relevant domestic and international literature, this study categorizes leisure companionship into five types: family, couple, friends, group, and individual (Chen, 2019; Peters, 2010; J. Wang, 2021). Family leisure activities are instrumental in strengthening familial ties, especially in the context of urban leisure in China, where they often involve the entire family's participation. Leisure activities with friends are significant in Chinese urban leisure habits, expanding social networks and fostering friendship development and a sense of belonging. Group leisure activities, including organized tours, school excursions, club gatherings, and religious events, are also prevalent, promoting collective identity and cooperation. Individual leisure activities, pursued alone, emphasize personal autonomy and self-growth, seeking unique experiences and personal development to satisfy intrinsic needs and personal interests. Consequently, utilizing various types of leisure companionship to reflect the diversity of people in leisure activities offers a more comprehensive approach. Considering social relationships and leisure experiences, this perspective contributes to a deeper understanding of the social dynamics and varied experiences within urban leisure contexts. Therefore, this paper identifies "Group Diversity," encompassing family, couples, friends, groups, and individuals, as a key indicator of crowd activity in user factors.

2.4.2.4 Feedback Factor

The vitality of leisure activities for individuals is manifested in external expressions and sentimental feedback. According to this article's definition of leisure, the goal of leisure is to achieve inner satisfaction for individuals. Therefore, positive sentimental feedback is a crucial source for leisure evaluation, a factor that has been relatively overlooked in previous research. Regarding activity feedback factors, only J. Zhu et al (2020) evaluated vitality from the perspective of tourists' overall satisfaction, using the rating attribute of scenic spots on MD, a Chinese user-generated review platform. However, the rating function of MD is limited to five options (1-5), providing a narrow scoring range that can only approximately reflect user evaluations, making it challenging to finely describe visitors' psychological feelings. Thus, this article aims to explore how to utilize more information displayed by visitors on social media, such as online reviews, to ascertain their sentimental feedback in participating in activities, as such data encompasses richer sentimental feedback information. Therefore, this factor is primarily evaluated through the psychological feelings of activity participants in urban spaces and their satisfaction with leisure services. Based on this, the paper suggests that "Feedback Positivity" could be a key indicator of crowd activity in the feedback factor, encompassing overall satisfaction and sentimental feedback of the activities.

2.4.3 The Constituent Factors and Evaluation Indicators of Built Environment

As discussed in Section 2.4.2.2, the built environment's vitality mechanism consists of two key aspects: spatial supportiveness as an enabling factor for activity formation and functional diversity as a reinforcing factor for crowd activity.

2.4.3.1 Spatial Supportiveness

As mentioned earlier, spatial supportiveness is fundamental for generating leisure activity. In the context of LUS, it pertains to the ability to effectively enable people to access the space and engage in leisure activities. Thus, the entire process of leisure activities is divided into two parts: transportation activities from residence to leisure space, which are urban-scale scale activities focusing on the traffic accessibility of LUS, and the actual service capacity of the space, which are place-scale activities concerning the residents covered by the actual service range. Consequently, spatial supportiveness is divided into the following two factors:

i. Residential Density

Research indicates that the higher the population density within a service range, the more frequently activities occur in public spaces, particularly leisure spaces (Shiwen et al., 2021; F. Wang et al., 2020; J. Zhu et al., 2020). It is an essential indicator for urban planning and public policy, determining whether the main source of activity within the space comes from surrounding residents and identifying underserved areas or requiring additional services. This provides information for decision-making on where to establish new services or facilities to improve access for underserved populations. Therefore, this study considers the "Service Coverage Rate" as a crucial assessment indicator, which refers to a comprehensive measure of residents' convenience in accessing recreational resources. This factor should involve the spatial service coverage and the demand of the surrounding population, thus represented by the service population density.

ii. Traffic Accessibility

As noted in Section 2.3.5, accessibility is the most critical physical environmental factor influencing visitors' access to and use of UPS. Accessibility mainly includes autonomous modes of travel, such as driving, cycling, and walking, as well as public transportation modes like metro and bus. The following two indicators can represent this:

(a) Road Network Density examines the accessibility of driving, cycling, and walking to the space. Scholars have demonstrated that road network density is a key indicator of accessibility (Dong et al., 2022; F. Wang et al., 2020). It refers to the number of roads within a given area, usually measured in terms of road kilometres per square kilometre. It is crucial for assessing the transportation infrastructure of a region or city, reflecting the connectivity and accessibility of different areas. A well-connected transportation network and diverse travel options improve accessibility.

(b) Public Traffic Convenience is the accessibility of taking the subway and bus to the space. Scholars have shown that the number of public transport options outside the space is an essential indicator for accessibility measurement (Y. Niu et al., 2021; Xu et al., 2018). It refers to the convenience of people reaching a certain location through the subway or bus.

2.4.3.2 Functional Diversity

As noted in Section 2.3.5, external functions and internal facilities significantly influence visitors' access to and use of UPS. The diversity of spatial functions is characterized by the neighbourhood environment and the internal environment. Leisure spaces within cities are not isolated entities; their vitality is shaped by both internal spatial environments and surrounding characteristics. When residents visit urban spaces for leisure activities, some are attracted by the environment around the space (Huang et al., 2023; M. Liu, Jiang, et al., 2021; Y. Niu et al., 2021; T. Wang et al., 2022), while others are drawn to the leisure space as their destination (Mu et al., 2021; Shiwen et al., 2021; F. Wang et al., 2020; J. Zhu et al., 2020).

i. Surrounding Functions

These indicators primarily measure the functional and commercial patterns surrounding urban spaces.

(a) Surrounding Function Density: The total number of functional facilities within a certain radius of the space. A higher surrounding function density indicates more services and convenient facilities in the area.

(b) Surrounding Function Mixedness: The variety of different types of functional. facilities within a certain radius of the space. An area with a wide variety of surrounding facilities has higher mixedness, while the opposite holds for areas with low mixedness. Higher mixedness indicates a greater diversity of services and facilities in the area.

ii. Internal Facilities

Internal facilities include physical structures, equipment, and resources within urban recreational spaces designed to enhance leisure opportunities and residents' quality of life.

(a) Internal Facility Density: The number of facilities per unit area within the space, meaning a higher number of facilities equates to higher density. This indicator reflects the richness and intensity of facilities within the space and is one of the important metrics for evaluating internal diversity.

(b) Internal Facility Mixedness: The degree of mixture of facilities within the space providing various leisure activities. This indicator reflects the diversity and combination of different leisure facilities within the space.

2.4.4 Formation and Definition of Vitality of Leisure Urban Spaces

2.4.4.1 Formation

Based on the above analysis, analysing the distribution of LUS at the system level is crucial to ensuring their supply is sufficient and effective. Considering vitality, discussing inadequate leisure spaces or uneven distribution fails to meet residents' basic leisure needs and hinders the stimulation and sustenance of leisure activities, directly impacting vitality. Therefore, urban planning and policies should strive to optimize the distribution of leisure spaces, ensuring that people can easily access and utilize these spaces, thereby achieving a balanced distribution of vitality throughout the entire urban system, which is also a basic condition. Additionally, the introduction of spatiotemporal behavioural theory provides deeper insights and can help understand residents' utilization of leisure spaces and the characteristics of activities generated under different spatiotemporal conditions.

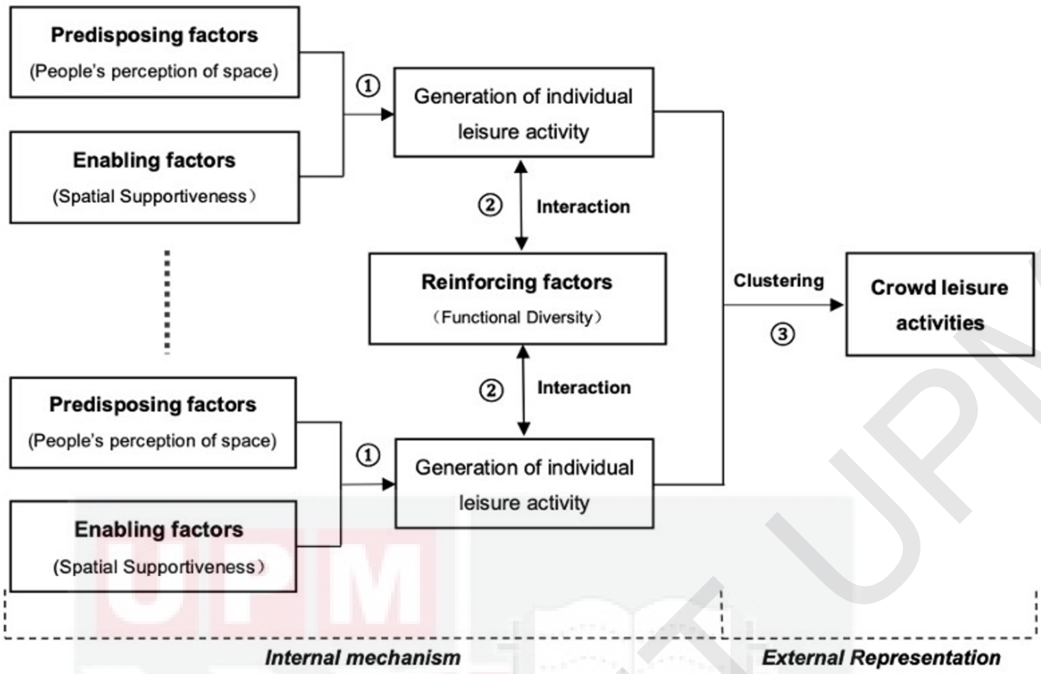


Figure 2.3 : The Formation and Composition of the Vitality of LUS
(Source: Author 2024)

Besides, this study focuses on analyzing the relationship between space environment and leisure activities from the individual level. The two principal elements constituting the vitality of LUS are crowd activity and the built environment. People are the main body of vitality in public spaces, while public spaces are the object. These two elements are essential. If public spaces lack human activities, they are merely a pure material environment, lacking organic vitality. Therefore, crowd activity is the external representation of vitality, and the characteristics of human activities directly reflect the situation of vitality. As a carrier of crowd activity, space is the internal mechanism of vitality formation. Its own spatial features are the internal support of vitality, specifically reflected in the capacity and attraction of space for people and their activities and can promote the gathering, sustainability, diversity, and inner satisfaction of crowd activity.

This article elaborates in detail on the formation and composition of the vitality of LUS based on the three factors of behaviour change theory. The article believes that the formation of the vitality of LUS undergoes three stages: ① the generation of individual activities (Predisposing factors and Enabling factors), ② the clustering of individual leisure activities (Reinforcing factors), and ③ the generation of crowd leisure activities. The specific process is shown in Figure 2.3.

2.4.4.2 Definition

Based on the preceding analysis, this paper defines the vitality of leisure urban spaces as follows: The extent to which urban space supports the basic needs of urban leisure drives diverse leisure activities and generates sustained crowd clustering, crowd activity and built environment serve as its external representation and internal mechanism, respectively.

2.4.4.3 Crowd Activity as the External Representation of Vitality

The external representation of vitality in LUS is its most tangible expression. This article posits that the external representation of vitality in LUS encompasses individual and crowd activities, integrating the theoretical implications of leisure, vitality evaluation, and the spatiotemporal behaviour theory. Firstly, tracing the origins of vitality research, people's activities and psychological responses have always been central to vitality studies. Jan Gehl (2002) asserted that "humanized public space can engender vitality," emphasizing that human activities are at the heart of urban public vitality. Chinese scholar Wang (2018), in his discourse on vitality, remarked, "People are the users of public space and its core. Therefore, the ultimate measure of public space quality is invariably the personal experience of individuals within it." Li and Fu

(2010) highlighted people's activities and psychological responses, stating that public vitality refers to the capacity of public spaces to fulfil the physiological and psychological needs of users and augment their sense of place belonging.

2.4.4.4 Built Environment as the Internal Mechanism of Vitality

Drawing on the previously mentioned behaviour change theory, this article posits that the formation of leisure urban spatial activities unfolds through three stages: ① the initiation of individual activities (Predisposing and Enabling factors), ② The clustering of individual leisure activities (Reinforcing factors), and ③ the emergence of crowd leisure activities. This process is examined through three factors: predisposing factors as internal drivers, while enabling and reinforcing factors shape spatial characteristics, forming the core of this study's investigation into vitality mechanisms.

Predisposing factors refer to individuals' inclinations to participate in leisure activities, representing the first phase in vitality development. Participation in leisure activities originates from personal interests or preferences and is a psychological process fulfilling internal needs. As there is an interactive relationship between people and space, the motivation for activities arises from internal and external factors. The internal drivers are the individual's needs to achieve or maintain certain states or feelings, such as physical health or comfort, pleasure, etc. External drivers include influences from activity venues and transportation. Hence, this stage's genesis lies in the demand for leisure activity space by individuals or the allure of leisure spaces. In motivation theory, Maslow's "Hierarchy of Needs" theory is notably influential. Reflecting this, Alfonzo (2005) proposed a hierarchical model for pedestrian activity behaviour needs in urban spaces, identifying the bottom-most constrained demand as feasibility demand. If unmet, walking leisure activities do not occur. Upon satisfying these base-level needs, individuals gradually develop the willingness to engage in walking leisure activities, thereby facilitating such activities.

Enabling factors refer to the built environment's capacity to accommodate public leisure demands, encouraging participation and forming the second link in vitality generation—'the formation of individual leisure activities.' This article argues that spatial supportiveness is the fundamental prerequisite for leisure activities; without it, such activities do not occur. Spatial supportability is the basic condition for active individual formation and the catalyst for activity genesis. Kevin Lynch (1984) underscored in his definition of vitality the importance of urban spatial forms in supporting basic human needs. Similarly, Chinese scholar Wang (2018) defined urban vitality as the capacity of material space to accommodate people and their activities. Therefore, in the context of vitality, the built environment's capacity to support public activities is crucial. Behaviour is a fundamental human activity and an essential component of individual life. An environment that facilitates leisure refers specifically to the capacity of a built environment to support and sustain public engagement in specific activities. Consequently, as the foundational condition for the emergence of leisure activities in urban spaces, spatial supportability denotes the ability to enable public access and participation in leisure activities within these spaces.

Reinforcing factors relate to the group resonance manifested in space. When numerous "active individuals" congregate and interact in a space, it imbues the space with vitality and dynamic energy, representing the third stage in vitality generation - "the aggregation of active individuals" and marking the onset of high vitality. This article considers the reinforcement factor of leisure urban vitality to be the functional diversity of space. Jane Jacobs initiated her research focusing on urban streets, positing that the vitality of these streets stems from the interplay of activities and living spaces among people. Streets and residential areas rich in diversity are vibrant. She asserted that urban vitality is achievable only through diversified activities, facilitating activity integration. Diverse activities attract more people, thus promoting vitality. Furthermore, Maas (1984) suggested providing residents with diverse entertainment options is critical to enhancing vitality. Ian Bentley (2001) also believed that spaces adaptable to various uses and offering users more choices are more likely to boost vitality than those limited to single, fixed functions. The characteristics of lively spaces provide people with activity spaces of varying functions, purposes, and choices. The essence of urban vitality lies in diversity, which is an essential factor in promoting it. More mixed urban functions are believed to encourage people to frequent streets and public spaces, offering various social activities and cultural exchanges. This improves the perceived access subjective measure of accessibility of nearby urban spaces and people's willingness to visit these spaces (J. Zhu et al., 2020). Hence, as a driving force for leisure activity generation, functional diversity can produce a group resonance effect, attracting more diverse groups to engage in space utilization and enhancing vitality.

2.5 Summary

This chapter elucidates the fundamental theoretical framework underpinning the vitality of LUS. It unfolds over three pivotal sections: First, understanding Urban Spaces from a Leisure Perspective: Incorporating insights from interdisciplinary fields such as urban leisure, leisure geography, and environmental psychology, this section defines and classifies LUS within Chinese policies and realities. It articulates the features of various space types, including parks, squares, waterfront spaces, and leisure blocks. This part accomplishes the study's first research objective by scrutinizing the evolution and development of global and Chinese research on LUS, thereby identifying prevailing research gaps and emerging trends in China. Secondly, In-Depth Interpretation of Vitality Theories in Urban Spaces: The chapter thoroughly examines the foundational theories of vitality within urban spaces, focusing on three essential elements: people, their activities, and the venues of these activities. It also conducts a comprehensive review of research over the past 15 years on the vitality of UPS, encompassing aspects like research subjects, composition of vitality, influencing factors, and methodologies. This review identifies gaps in research related to urban space vitality and potential future research directions. Finally, developing a Framework for Vitality in LUS: Building on previous analyses and relevant theories such as urban space system theory, spatiotemporal behaviour and behaviour change theories, this section formulates a framework for vitality in LUS. The specific theoretical framework can be seen in Figure 2.4.

This study directly addresses several research gaps identified in the literature. As illustrated in Figure 2.4, the research gaps are addressed through the integration of key theoretical frameworks. First, the gap in multidimensional analysis of urban spaces from a leisure perspective is addressed using Urban Space System Theory. This theory evaluates vitality at both the system level and individual level, answering key questions of "where" and "what". The system level analysis examines the variations in supply across different regions within LUS. In contrast, the individual level focuses on identifying differences in supply and usage within existing spaces. The individual level includes two dimensions: crowd activity and the built environment, representing the external representation and internal mechanism of vitality. Second, the study explores the mechanisms of vitality formation by focusing on the dynamic relationship between the built environment and crowd activities. The built environment, which encompasses both spatial supportiveness and functional diversity, influences vitality through predisposing, enabling, and reinforcing factors, as outlined in Behaviour Change Theory. These factors shape how individuals interact with space, thereby generating vitality by fostering diverse leisure activities and social interactions. This study provides a deeper understanding of how the built environment—shaped by spatial supportiveness and functional diversity—drives the vitality of LUS, contributing to sustained crowd engagement and active use of urban spaces. Third, the study expands the assessment of crowd activity by building on Spatiotemporal Behavioural Theory, incorporating four key factors: spatial, temporal, user, and feedback factors. This framework enables a comprehensive evaluation of vitality, emphasizing how spatial characteristics, timing of activities, user dynamics, and environmental feedback interact to shape the liveliness of urban spaces.

Integrating interdisciplinary theories and systematic literature review findings, the chapter identifies critical factors and evaluation indicators for these dimensions, where crowd activity is treated as the dependent variable (DV), and the built environment as the independent variable (IV). This relationship helps in understanding how the built environment influences the vitality of LUS. Ultimately, the chapter establishes a comprehensive indicator framework for evaluating the vitality of LUS in China, as delineated in Table 2.2.

Table 2.2 : Framework of Evaluation Indicators for LUS Vitality

System Level -The basic conditions of vitality Analysis of the spatial distribution characteristics, the variances between supply and demand, and their interrelation with the distribution of crowd activities			
Individual Level -The main sources of vitality			
Dimension	**Factor**		**Indicator**
Crowd Activity (DV)	Spatial		Spatial clustering
	Temporal		Temporal persistence
	User		Group diversity
	Feedback		Feedback positivity
Built Environment (IV)	Spatial Supportiveness	Population density	Service coverage rate
		Traffic accessibility	Road network density
			Public traffic convenience
	Functional Diversity	Surrounding functions	Surrounding function density
			Surrounding function mixedness
		Internal facilities	Internal facility density
			Internal facility mixedness

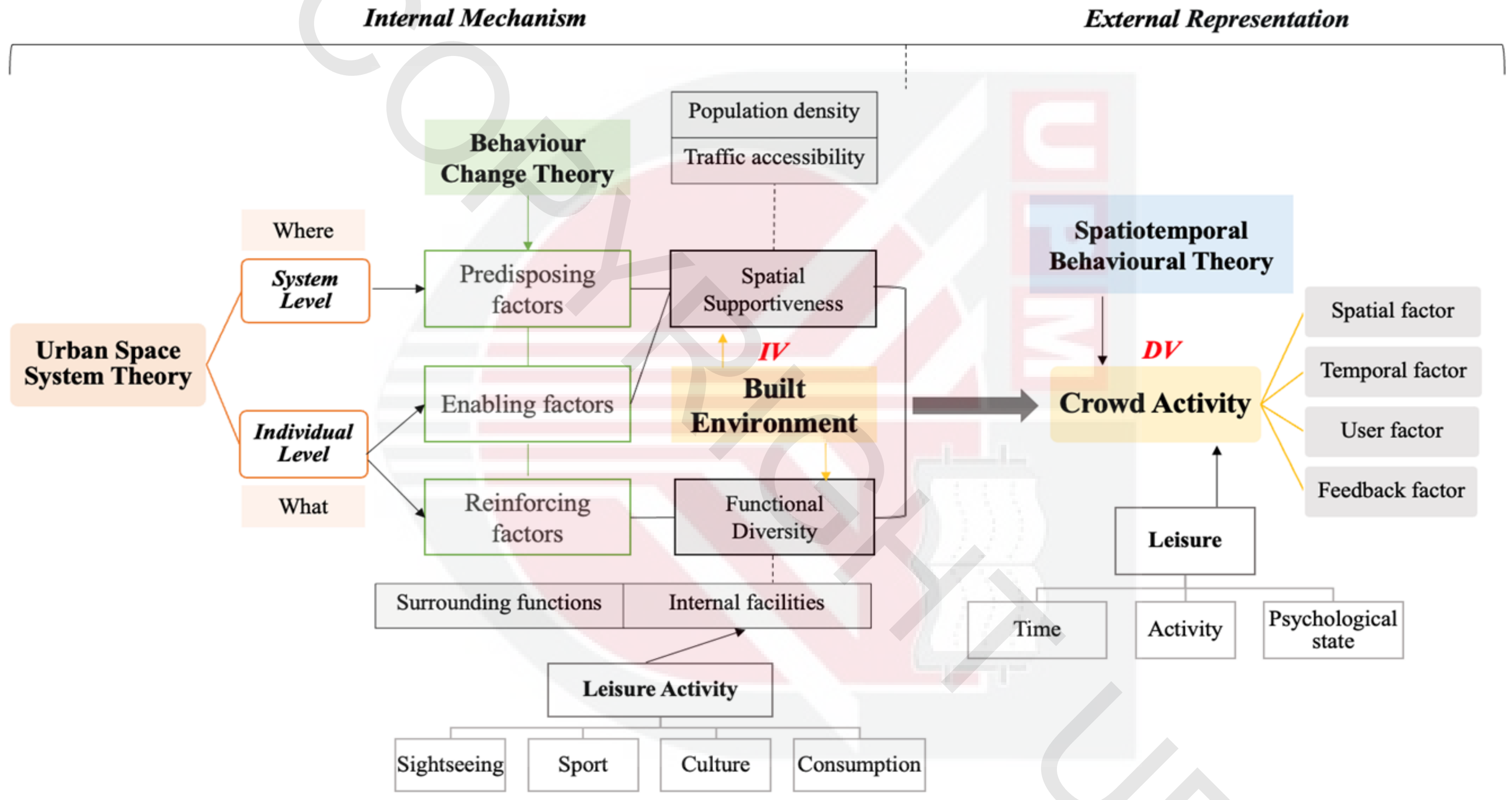


Figure 2.4 : Theoretical Framework of the Composition of LUS Vitality
(Source: Author 2024)

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This study employs a quantitative case study approach integrating multi-source big data analysis and field surveys to systematically assess the vitality of LUS in Nanjing. The research design follows a multi-level analytical framework, incorporating exploratory, descriptive, and explanatory methods to uncover spatial patterns, evaluate LUS characteristics, and analyze relationships between the built environment and crowd activity. Research methodology is a systematic approach to problem-solving, encompassing methods and theories for developing systematic models. Essentially, research methodology explains how research can be conducted and how researchers describe, explain, and predict phenomena known as research methods (Goundar, 2012). Given the research objectives and questions of this study, the primary aim of this chapter is to fulfil Research Objective 3: to construct a comprehensive evaluation framework for the vitality of LUS using multi-source big data analysis methods and to find ways to validate the theoretical framework mentioned in Chapter 2 about the impact of the built environment on crowd activity. Therefore, this chapter is divided into five main parts: (a) explaining the methodological approach of the research; (b) introducing the study area and the selection of research spaces (samples); (c) describing the data collection techniques and procedures used; (d) exploring the analytical methods that can be used with multi-source data in establishing a comprehensive evaluation framework; (e) investigating the potential relationships between indicators.

3.2 The Methodological Approach

Research methodology is recognized as a scientific approach to investigating research questions. Methodology refers to the overarching research approach related to a paradigm or theoretical framework. In contrast, methods refer to the systematic patterns, procedures, or tools for collecting and analyzing data to address research questions (Mackenzie & Knipe, 2006). Research methods are categorized into quantitative, qualitative, and mixed (Creswell & Creswell, 2017). In line with the research objective, which is to develop a comprehensive framework for the vitality of LUS using multi-source data analysis, this paper employs a quantitative case study approach using big data.

The case study is a strategy for in-depth investigation of complex phenomena within specific contexts. It allows researchers better to understand the real-world contexts and dynamics behind the data. Evidence in case study research comes from multiple sources, each linked to a set of data or evidence (Yin, 2009). Although case studies are typically qualitative, large-sample exploratory studies can also be quantitative (Baskarada, 2014). Overall, a quantitative approach with multi-source big data is a robust methodology for case study research, particularly suited for understanding broad data patterns within detailed contexts. This method enables researchers not only to describe and measure phenomena but also to understand the contexts and complexities involved deeply.

As highlighted in Chapter 2, the future trend in vitality research in urban areas is to deepen evaluation using the digital environment of big data. While big data is crucial for evaluating urban space vitality, it is insufficient for analyzing specific data, such as the quantity and types of facilities in small-scale spaces. Therefore, this study combines big data analysis with field surveys to effectively utilize multi-source data and establish a comprehensive evaluation framework for LUS vitality.

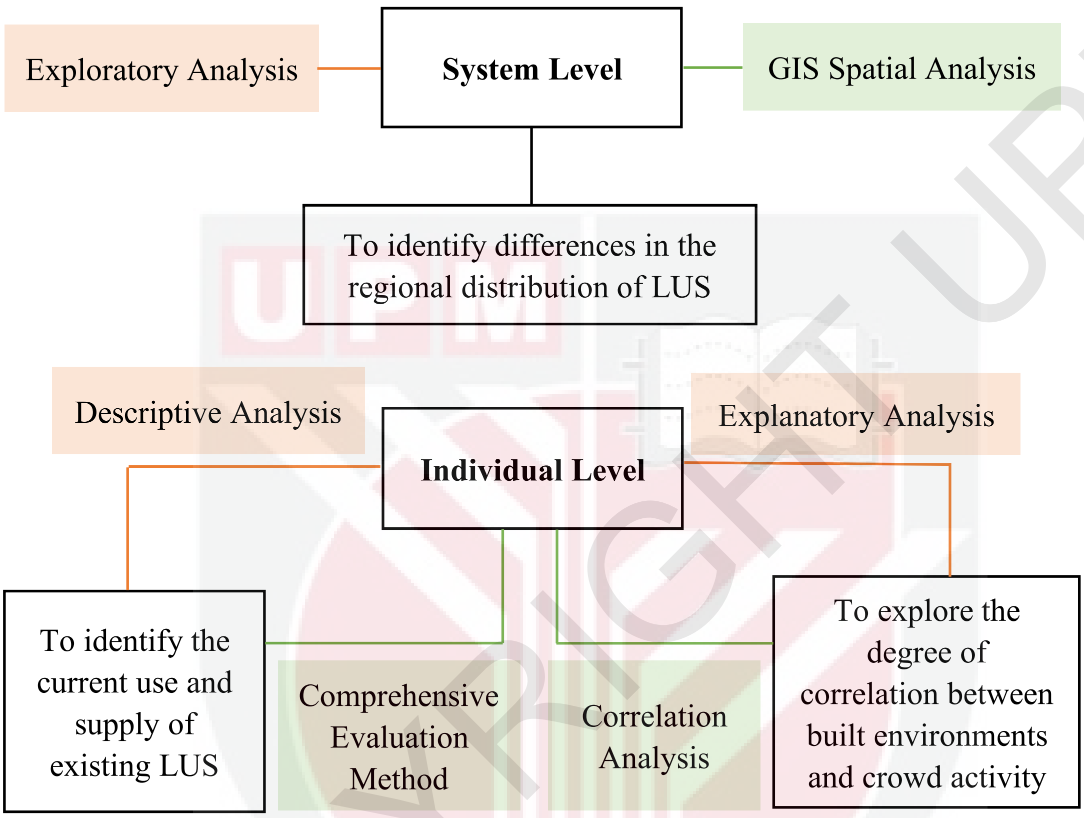


Figure 3.1 : Methodological Framework for Evaluating the Vitality of LUS at System and Individual Levels
(Source: Author 2024)

This study aims to comprehensively describe the vitality characteristics of LUS in Nanjing, covering multiple levels and dimensions. A combination of exploratory, descriptive, and explanatory analyses has been employed to investigate the study area in depth. Figure 3.1 illustrates the analytical logic of this research. Firstly, at the system level, GIS spatial analysis is utilized to examine the distribution characteristics of LUS. This exploratory analysis identifies new patterns, trends, or issues, providing insights that guide subsequent research directions (Jebb et al., 2017; Tukey, 1977). Such exploration of spatial distribution patterns lays the foundation for understanding the broader dynamics of urban space utilization. Subsequently, at the individual level, a comprehensive evaluation method is employed to analyze the performance of each indicator and assess the current usage and supply of LUS. This descriptive analysis plays a crucial role in accurately recording and summarizing data, offering detailed background information that helps researchers understand the phenomena under investigation (Dulock, 1993; Siedlecki, 2020). By capturing key characteristics and trends of LUS utilization, it enhances the understanding of spatial and temporal variations in vitality. Furthermore, through correlational analysis, the relationship between the built environment and crowd activity is examined. This helps to validate the theoretical framework of vitality formation, as proposed in Chapter 2, and identifies the critical environmental factors that enhance the vitality of LUS. The explanatory analysis explores causal relationships, providing theoretical support that can guide practical applications, such as urban planning and policy-making (Grace & Irvine, 2020; Næss, 2016). Together, these analytical approaches provide a comprehensive understanding of LUS vitality, addressing both theoretical and practical aspects for effective urban development.

By employing these three research approaches, the study collects and analyzes data, enabling a deeper understanding and explanation of the observed phenomena. The methodological design of this research, characterized by its rigour and depth, is highly suitable for complex and multivariate social science research. By examining LUS vitality from multiple perspectives, this research enhances our understanding of urban leisure spaces and explores ways to improve the city's overall vitality and attractiveness.

3.3 Study Area and Spaces Selection

3.3.1 Study Area Introduction

Nanjing, the capital of Jiangsu Province in Eastern China, provides a compelling backdrop for this study with its rich historical, cultural, and environmental attributes. The city is a crucial hub in the Yangtze River Delta Economic Zone, spanning 6,598 square kilometres and offering a diverse urban landscape across its 11 districts. As of 2022, Nanjing's total population reached 9.49 million, showcasing a high urbanisation rate of 86.9% (Nanjing GOV, 2021). This population density and urban growth have led to a heightened demand for LUS, setting the stage for this research.

Nanjing's rich historical, cultural, and environmental attributes, supported by modern infrastructure and amenities, make it an ideal case study for assessing the vitality of LUS. The city attracted over 10 million visitors in 2019 (Liu et al., 2021), reflecting its appeal as a tourist destination and leisure hub. Territorial Spatial Master Planning of Nanjing (2021-2035) aims to develop the city into a vibrant, international metropolis with unique cultural features and an appealing living environment, underscoring the relevance of studying its LUS (NMPG, 2022). Nanjing is located in the lower reaches of the Yangtze River, which traverses the city from southwest to northeast, covering a distance of about 93 kilometres, and is more than 300 kilometres from the estuary to the east. The Qinhuai River flows from south to north and is regarded as the mother river of Nanjing.

This study focuses on the Central Urban Area (CUA) of Nanjing, as outlined in the city's strategic planning documents (NMPG, 2022). The CUA of Nanjing is the core area of the Nanjing metropolitan area and the main area for carrying out the functions of the Nanjing Center city. It is composed of two parts: the Jiangnan Old Region (South of Yangtze) and the Jiangbei New Region (North of Yangtze) (Refer to Figure 3.2). The planned area of the CUA is 804 square kilometres, and the planned urban population will reach 7.85 million. CUA is the core carrying area for Nanjing to improve the city's level and enhance its first-class status. The document mentioned that the Jiangnan region is the core area of the world's cultural city, and the Nanjing government insists on improving the environmental quality of the old city and strengthening the support of the new district functions and public facilities. The planned area of the Jiangnan region is 579 square kilometres, and the planned urban population is expected to reach 6.05 million. The Jiangbei new region is a key development area for building an ecological tourism circle, centered around the river, with an ecological greenway structure that integrates landscape and cultural resources. The planned area of the Jiangbei new CUA is 223 square kilometres, and the planned urban population is expected to reach 1.8 million. This area represents the core of Nanjing's urban development and is central to understanding the dynamics of LUS. The Jiangnan region, known for its cultural significance, and the Jiangbei new region, a key area for ecological and tourism development, together provide a comprehensive view of the city's leisure spaces. This includes traditional parks, innovative waterfront areas, and lively urban squares. Furthermore, in the Jiangnan region, a significant zone is the Old City Area (OCA), delineated by the orange boundary line in Figure 3.2(C). The OCA is characterized by a convergence of functional areas, elevated population density, and a concentration of high-quality resources, making it an indispensable region for analyzing the urban structure of Nanjing.

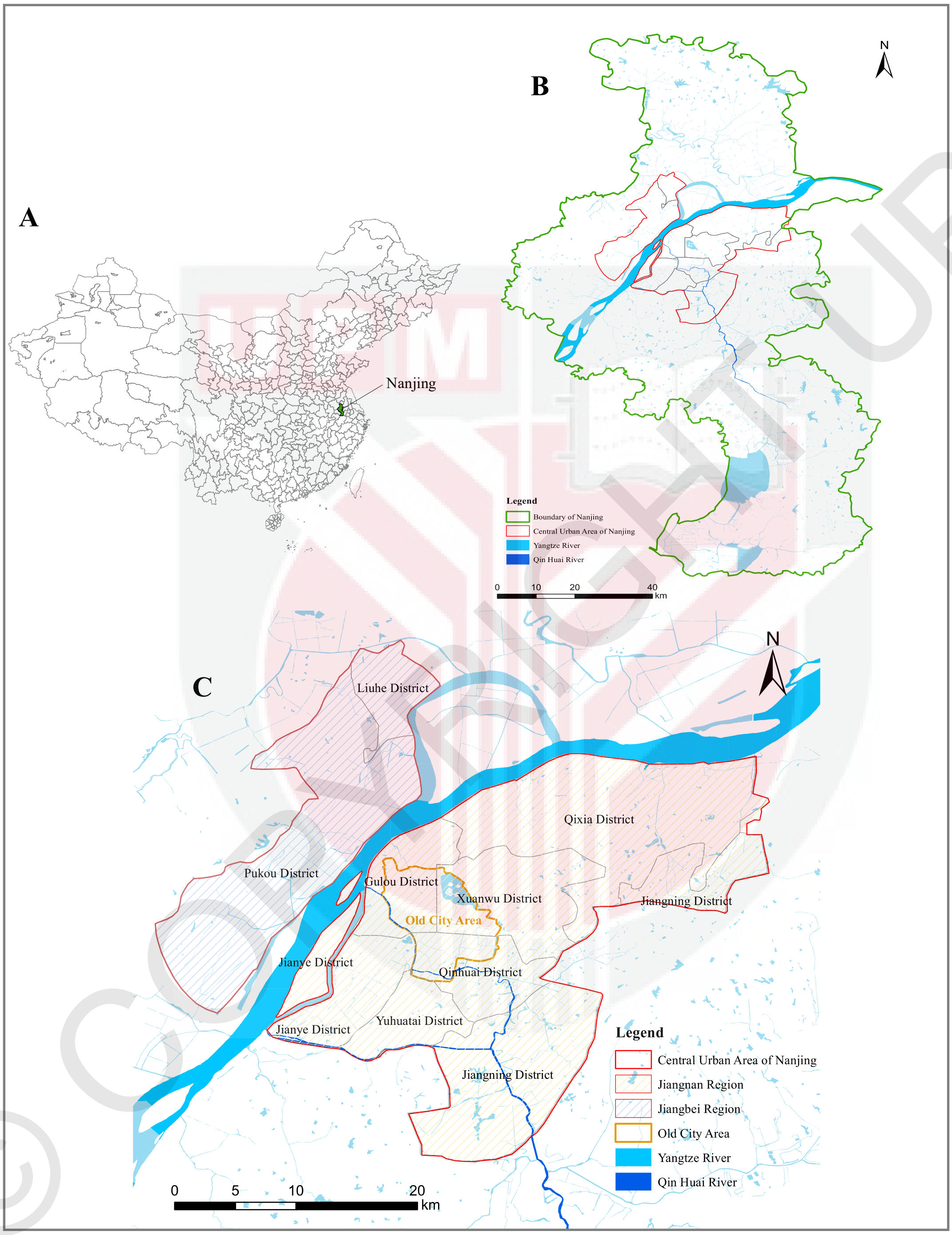


Figure 3.2 : The Location of Nanjing in China (A), The Location of CUA in Nanjing (B), The Distribution of Subdistricts of CUA (C)
(Source: Author 2024)

This focused approach to Nanjing's CUA enables an in-depth analysis of the interaction between urban development and leisure space vitality, providing insights into how these spaces enhance the quality of urban life. Nanjing's diverse urban fabric, blending historical and contemporary elements, provides a unique opportunity to explore the vibrancy and utility of LUS in a rapidly urbanizing context.

3.3.2 Location Information Collection of Leisure Urban Spaces

This study primarily uses Point of Interest (POI) and Area of Interest (AOI) data to collect location information for LUS. In August 2023, the data for these two categories were retrieved from the http://ditu.amap.com API using web scraping techniques. AOI data, similar to POI data, typically includes basic information such as name, address, category, and latitude and longitude coordinates. It also includes area boundary coordinates that mark two-dimensional geographic entities on electronic maps. Given the similarities between AOI and POI data, they often originate from the same map platforms.

However, the location information for some LUS cannot be directly obtained from these two data sources. To address this, the study utilizes GIS technology combined with data from social media platforms for location verification and data confirmation. Figure 3 displays the data processing procedure for four types of LUS. The location information for all squares, parks, and blocks can be obtained through POI data. To accurately obtain the location information for leisure blocks, this study incorporates data cleaning and location matching using the Meituan-Dianping (MD) platform. MD is one of China's leading online-to-offline (O2O) platforms, where locals can rate various commercial and leisure locations (J. Zhu et al., 2020). Moreover, its specialized category for leisure blocks addresses the lack of such detailed classifications in traditional map data.

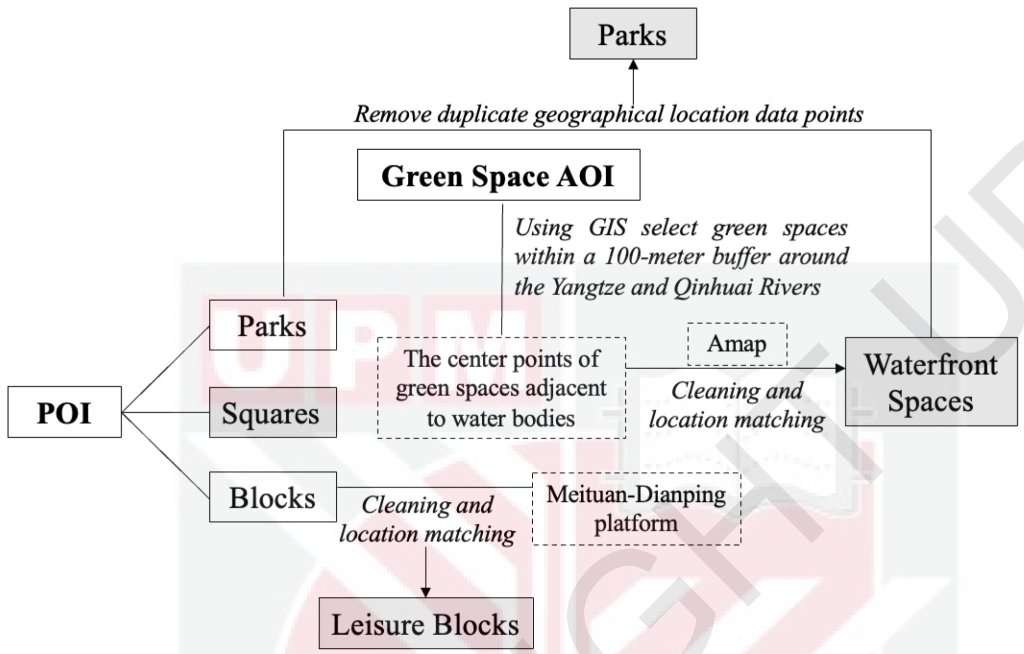


Figure 3.3 : Data Processing Workflow for Various LUS Locations
(Source: Author 2024)

For waterfront spaces, this study defines leisure green spaces around natural water bodies in the research area, such as those near the Yangtze River and the Qinhuai River. Using GIS software, a 100-meter buffer zone is created around these water bodies. The central point location information of green spaces adjacent to the water bodies is identified and cleaned. These points are then matched with positions on Gaode Maps to determine the final location of the waterfront spaces. Park locations are determined by merging park POI with waterfront space location information and removing duplicate geographic data points. Ultimately, the study acquired location data for 407 LUS, including 186 parks, 166 squares, 27 waterfront spaces, and 28 leisure blocks.

3.3.3 Research Spaces Selection

i. Allocation of Sample Size

While conducting spatial research in the CUA of Nanjing, the rational selection and distribution of samples is crucial to ensure the scientific validity and credibility of the study. This research seeks to develop a multidimensional evaluation framework for assessing the vitality of LUS, with a focus on social activities and the built environment. The system is designed to comprehensively identify the characteristics of different spaces in terms of usage, supply, and potential shortcomings. To achieve this goal, the research design integrates methods of multi-source big data analysis and traditional on-site observations, aiming to collect, analyse, and evaluate social activities and features of different LUS comprehensively, thereby delving into the essence of urban space vitality.

Regarding sample selection, 11 research spaces in Nanjing's CUA were meticulously chosen, reflecting the distribution of diverse leisure space types. Specifically, 4 parks, 3 squares, 2 waterfront spaces, and 2 leisure blocks were selected. This sample configuration was based on the overall situation of 186 parks, 166 squares, 27 waterfront spaces, and 26 leisure streets existing within the region (The collection of this data is elaborated in Section 3.3.2, "POI of Leisure Urban Spaces"). Such a sample size and distribution ensure the representativeness and comprehensiveness of the research results.

Methodologically, this study adopts a dual-track parallel strategy, combining big data analysis and on-site observation. Previous big data studies often encompass larger samples. For example, J. Zhu et al. (2020) assessed the vitality of 90 parks, while Chen and Ma (2023) evaluated 22 waterfront spaces. However, the analytical methods employed in this study consider the increase in resource and time costs, challenging the selection of many samples. In contrast, traditional on-site observation methods typically use fewer samples. For example, studies by Banchiero et al. (2020), Molavi et al. (2017), and Mu et al. (2021) typically focus on 1 to 3 samples. These studies tend to analyze a single space type in-depth rather than comparing the commonalities and differences between different space types.

This study aims for a more holistic and integrated data set. Therefore, appropriately increasing the number of samples in on-site observation will help enhance the reliability of the research results. Additionally, following Deborah (2018)'s advice, to ensure the reliability of studies on the use of public spaces, the number of samples for each type of space should not be less than 2. Based on this, we ensure that each type of space includes at least 2 samples among the selected 11 research spaces. Finally, considering the proportion of the four types of spaces in the CUA of Nanjing, this study selects 4 parks, 3 squares, 2 waterfront spaces, and 2 leisure streets as a sample distribution scheme consistent with the actual proportions and scientifically sound. This sample distribution comprehensively covers different types of spaces. It provides solid data support for constructing a multidimensional vitality evaluation framework, thereby capturing the diversity of LUS and providing forward-looking recommendations and strategies for sustainable urban development.

Furthermore, this study also selected 11 sample spaces based on criteria such as the balance of the distribution of LUS and the diversity of types, aiming to reflect the overall construction status, commonalities, and differences of LUS in the CUA of

Nanjing city to some extent. In this process, the criteria of balance and diversity in sample selection ensure that the research results are not limited to a single type or specific area of space but can broadly reflect the composition of leisure spaces throughout the city, thereby providing an in-depth understanding of various aspects of space features.

ii. Principles Guiding the Selection

In selecting research spaces within the CUA of Nanjing, a series of principles were adopted to ensure that the 11 selected research spaces comprehensively and accurately reflect the actual conditions of the city. The following are the main considerations for the choice of research spaces:

a) Different Population Density Distribution: The study paid special attention to the population density distribution in different areas of CUA of Nanjing. Given the significant differences in population density between districts, these variations could profoundly affect urban space usage and demand patterns (Motomura et al., 2022). Therefore, research spaces with different population density characteristics were selected to reveal the commonalities and differences in urban space vitality under various population clustering conditions.

b) Spatially Clustered Areas: Special emphasis was placed on the geographic clustering of selected study area. The chosen study areas exhibit clustered distribution within the city structure, representing area in urban spatial planning that can reveal the potential impact of the urban spatial organization on residents' lifestyles (Tu et al., 2022). Studying these geographically interconnected spaces can provide empirical support for assessing the effectiveness of urban spatial design (Song et al., 2024).

c) Different Spatial Scale: The study considered that differences in spatial scale could lead to variations in usage frequency and preferences (Zhao et al., 2022). Therefore, public spaces of varying scales were chosen for analysis.

This approach helps to grasp the spatial diversity within the study area, aiming to obtain more comprehensive and objective research results.

d) Public Openness: To ensure the fairness and comparability of the research, only urban spaces that are freely accessible to everyone were included. This criterion ensured the accessibility of the research spaces to all social groups, thereby eliminating access restrictions that might arise due to economic or social status (Basu & Nagendra, 2021).

e) Over 10 Reviews on MD: To obtain authentic public perceptions and evaluations of the research spaces, data from MD reviews were used as a selection criterion. Each selected research space required a minimum of 10 user reviews to ensure the adequacy of information for analysis and comparison (Zhu et al., 2020).

This multidimensional selection strategy aims to deepen the understanding of urban space usage and provide insights for urban planning. The scientific selection of samples is crucial to ensuring the accuracy and practicality of the study, enabling the revelation of the complexity of urban spaces, and providing comprehensive recommendations for sustainable urban development.

In the study area, a selection of research spaces was made, and an analysis of their geographical positions and spatial distributions was carried out. ArcGIS software was employed to perform geospatial data preprocessing, which involved coordinate rectification and the amalgamation of data points of the same spatial entities. Subsequently, spatial linkages were established by integrating data from point of interest (POI) sources such as MD. ArcGIS's computational geometry tools were utilized to compute precise spatial areas, thus serving as the foundation for constructing our research space database. Furthermore, as the principle encompasses

"Spatially Clustered Areas", the final selection of the 11 research spaces should be determined after analyzing the spatial distribution of LUS across the entire study area. Therefore, specific space selection and descriptions are included in Section 4.3.1 of Chapter 4.

3.4 Construction of the Vitality Evaluation Framework for Leisure Urban Spaces

This study has designed a multi-source data research method framework (see Table 3.1), conducted at two levels, with a systematic analysis complementing the focus on individual analysis.

Initially, the framework analyzes the spatial distribution characteristics of LUS and various space types (parks, squares, waterfront spaces, leisure blocks) within the study area using ArcGIS 10.8.2 at the system level. On the individual level, the study performs a detailed vitality evaluation of these spaces using a comprehensive evaluation method.

This method serves as both a framework and a practical research technique. It holistically considers various factors and indicators to enable a thorough, multidimensional assessment. This approach emphasizes integrating diverse data types and evaluation techniques, facilitating more complete and accurate results. (Rossi et al., 2004).

Table 3.1 : Evaluation Framework of the Vitality of Leisure Urban Spaces

Level	Analytical Method	Data type	Specific Method	
System Level	GIS Spatial Analysis	Location Points of Leisure Urban Spaces	GIS spatial analysis	Nearest Neighbor Index
				Standard Deviation Ellipse
				Kernel Density Estimation
			The Density of Spaces by Subdistricts	

Level	Dimension	Indicator			Data type	Analytical Method	
Individual Level	Crowd Activity	Y1	Spatial Clustering		BHMD (126 time points-6:00 AM to 11:00 PM over a week)	Heat Value Extraction Using GIS, Excel Statistical Analysis Y2 Value=(Y2-1 value *0.5+ Y2-2 value *0.5)	Comprehensive Evaluation Method
		Y2	Temporal Persistence	Y2-1 Fluctuation Index (50%)			
				Y2-2 High-Intensity Activity Duration (50%)			
		Y3	Group Diversity		MD Review Data	Word Frequency Analysis, Excel Statistical Analysis	
		Y4	Feedback Positivity	Y4-1 Overall Satisfaction (50%)		Text Sentiment Analysis, Excel Statistics Analysis Y4 value=(Y4-1 value*0.5+ Y4-2 value *0.5)	
				Y4-2 Sentiment Scoring (50%)			
	Built Environment	X1	Service Population Density		BHMD (7 time points-12AM over a week)	Heat Value Extraction Using GIS; Excel Statistical Analysis	
		X2	Road Network Density		Transportation Data (Road Network)	GIS Analysis, Excel Statistics Analysis	
		X3	Public Traffic Convenience		Transportation Data (Station Location Point)		
		X4	Surrounding Function Density		POI Data of Urban Function		
		X5	Surrounding Function Mixedness				
		X6	Internal Facility Density		Field Data		
		X7	Internal Facility Mixedness				

3.5 Data Collection and Technique

The multiple-source big data used in this study were mainly obtained through various means such as Python programming language, website API interfaces, official map data downloads, and field surveys.

Table 3.2 : Multi-Source Data Information Summary

Classification	Type	Source	Format	Collection Technique
Static Big Data	Basic Geospatial Data	National Platform for Common Geospatial Information Services (https://www.tianditu.gov.cn)	Vector	Network download
Implicit Big Data	POI Data	Amap (https://lbs.amap.com/)	Excel	API
Dynamic Big Data	Baidu Heat Map Data	Baidu map (https://huiyan.baidu.com/)	Grid	API
Explicit Big Data	Meituan-Dianping Review Data	Meituan-Dianping (http://www.Meituan-Dianping/)	Excel	Web Scraping Tool
Static Big Data	Transportation data	OpenStreetMap (https://www.openstreetmap.org/)	Vector	Network download
Traditional data	Filed Data Collection	Field Survey	Excel Pictures	Mobile GIS Application

The main data includes POI, Baidu heat map data, social media data, basic geospatial data, transportation data, and filed Survey data. See Table 3.2 for a summary of the data. The rationale for selecting these datasets stems from the intent to utilize a diverse and growing range of data sources. This study encompasses a comprehensive range of urban big data types and integrates them with data gathered from field research. Such a multi-source data approach is regarded as both objective and pragmatic, ensuring the accuracy and timeliness of the results. This fusion of varied data sets, ranging from digitally captured urban dynamics to on-the-ground observations, provides a well-rounded perspective, enhancing the reliability and depth of the study’s findings.

3.5.1 Basic Geographical Data

This paper uses the National Platform for Common Geospatial Information Services (https://www.tianditu.gov.cn) to acquire fundamental geographic information. The basic geographic data collected in this study include the following categories: (a) administrative boundaries (covering national, provincial, city, and district levels); (b) natural topographical features (such as the Yangtze River, the Han River, and lakes); (c) road networks (including ring roads, main roads, secondary roads, branch roads, bridges, tunnels, overpasses, and embankment roads); (4) some other data related to this research were also collected, including the green space data, land use.

3.5.2 POI Data

i. POI of Urban Function

POI, short for "Point of Interest", refers to spatial features with geographic identification. Each POI contains information such as name, address, category, latitude, longitude, etc. It includes the precise location and detailed category information of commercial places, life service places, residential areas, administrative agencies, subway stations, bus stations, schools, parks, and other public places. POI is the foundational data of spatial big data. Each POI point can be regarded as a city functional element, and the distribution of POIs can well reflect the distribution of urban functional facilities and spatial structure. As the cornerstone of the navigation industry, POI can be obtained from navigation map software platforms (such as Baidu, Tencent, Amap, or Google Maps), and they collect the data through on-site investigation and photographic recording. The information content is relatively rich, the accuracy is relatively high, and the update is relatively timely. People’s social activities in public spaces can be expressed through their interaction with POI rather than through land use types because the statistical granularity of POI data is much finer than that of land use data. Therefore, POI data is conducive to measuring urban functional characteristics at a finer scale, and it also provides a way to quantify the impact of urban functional characteristics on urban green space. (Xia et al., 2017; J. Zhu et al., 2020). The POI data used in this study is from Amap, one of China's largest electronic map navigation search engines (https://lbs.amap.com/).

According to the Code for Classification of Urban and Rural Land Use and planning standards of development land in China (GB 50137) (Ministry of Housing and Urban-Rural Construction of the People's Republic of China, 2018), The POI types are filtered and aggregated into Six general functional categories, which are Residential communities, Public service, Education, Scenic spot Commercial service, Business office respectively (See Table 3.3). The final data is summarized in Appendix C.

Table 3.3 : Category of POIs in Each Urban Function

Urban Function Type	Subclass
Residential communities	Villa area, dormitory, residential area
Public service	Bank, car repair shop, gas station, public restroom, bank, beauty salon, logistics, post office, agency, telecommunication service centre, laundry, public utilities, information consulting centre, hospital, clinic, sports and fitness
Education	Kindergarten, Primary school, Middle school, University, Training institution, Vocational school, Research institution
Scenic spot	Religions, Memorials, Squares, Parks, etc.
Commercial service	Catering, Shopping, Hospitality, entertainment
Business office	Factory, Agricultural and forestry ranch, Industrial park, Office building.

3.5.3 Baidu Heat Map Data

Baidu Heatmap is a big data visualization product based on Location Based Services (LBS). Its principle involves collecting mobile terminal location data when users access Baidu's search, map, weather, and music services. BHMD is used for site clustering, creating heatmaps where different colours represent varying levels of population concentration. Warmer colours indicate higher population density (as shown in Figure B-1 of the Appendix B). Baidu Heatmap shows different heat value distributions at various scales. With updates every 15 minutes and a user base of hundreds of millions, it provides researchers with real-time and extensive data on dynamic population gatherings, making it highly valuable for urban studies like city planning. Its characteristics of being dynamic, continuous, and easily recognizable make it an effective tool for reflecting spatial-temporal behaviour patterns of people (Huang et al., 2023). The raw data of Baidu Heatmap can be obtained through its official website's API (https://huiyan.baidu.com/). This study will use th BHMD of Nanjing City for one week in 2023 (August 21-27), hourly from 6:00 AM to 11:00 PM (a total of 126 time points), as the foundational data for analyzing the spatial-temporal behaviours of crowds in Nanjing's LUS. Besides, Due to the difficulty in obtaining high-precision data on population in China. This study used the average heat values at 12:00 AM over a week (7-time points) within the space service range to represent the population density.

3.5.4 Meituan-Dianping Review Data

This study selects the ratings and reviews texts from MD (http://www.Meituan-Dianping) as its data source. MD is one of China's largest Online-to-Offline (O2O) platforms, facilitating public ratings, reviews, and photo sharing about tourist attractions and businesses. All information on MD is publicly uploaded user-generated content, with each review comprising the user's name, review date, text describing their experience, and a satisfaction rating for the visited location (refer to Figure B-3 of Appendix B). The utilization of this social media data presents two notable advantages: Firstly, the platform's extensive user base, which, as of 2023, had surpassed 677.9 million monthly active users, approximately 48.1% of China's total population (Meituan, 2023), offers a robust objectivity for this research. Secondly, given that the data is freely downloadable at intervals as needed, this approach minimizes time and financial costs and is not subject to privacy limitations. Although MD's check-in data does not cover all LUS and reviews for some smaller leisure spaces are limited, it has been proven that MD, as one of the most popular geotagged data types, is highly beneficial for studying public activities in urban spaces (J. Zhu et al., 2020). Furthermore, sentiment analysis of user reviews on MD has been validated by scholars to effectively capture the positivity in public feedback following participation in activities (Sui et al., 2020). Therefore, this paper uses social media data as the basis for group diversity and feedback positivity in crowd activity. The study employed the web scraping tool Octoparse (https://www.bazhuayu.com) to collect MD review data for 11 research spaces, recording space names, review dates, ratings, and texts from January 1, 2020, to August 17, 2023, ultimately obtaining data from 15,358 reviews across these spaces.

3.5.5 Transportation Data

The study involves crawling transportation data in the research area through OpenStreetMap (OSM) (https://www.openstreetmap.org/), including driving roads, pedestrian walkways, bicycle lanes, and bus and subway station locations. OSM road network data currently provides the most widely used and representative volunteer geographic information projects aimed at establishing a free and open map data source. The data type is in vector format, which meets the research requirements of this article. First, other data layers unrelated to roads are removed. Secondly, the road data in the research area is vectorized and visually analyzed in a GIS platform. Finally, the study will conduct a clustering analysis of roads at different levels in the processed research area to form road data sets for each level.

3.5.6 Field Data Collection

In addition to collecting the above big data, this paper will conduct a field investigation on 11 research spaces. Based on the vitality evaluation indicator framework established in this study, it is evident that the internal facilities of space are crucial components, and such high-precision data cannot typically be obtained through big data approaches. Furthermore, considering the study focuses on LUS, a detailed classification of facilities based on leisure activities is essential. Therefore, this paper posits that field data collection is more appropriate. The primary focus of the study is to tally the locations and quantities of internal facilities in these spaces, providing data for indicators of facility density and their degree of mix. Chapter 2's exploration of LUS reveals that city leisure activities predominantly fall into four categories: sightseeing, sports, cultural and consumption activities, and s. Accordingly, this paper categorizes the internal facilities within these spaces into these four groups and summarizes the specific facilities included in each category of leisure activity (as shown in Table 3.4).

Table 3.4 : Category of Leisure Facilities

Leisure Type	Leisure Facilities
Sightseeing	Leisure chair, Scenic Lookout, Public art installation, Rest area, Pavilion, Bridge, Sculpture, Micro landscape, Pond, Corridor pavilion, Camping site, Sightseeing boat, Fountain, Sightseeing vehicle
Sport	Fitness equipment, Movement zone, Children's equipment, Walking trail, Ball Park, Running track
Culture	Historical site, Exhibition venue, Art studio, Museum, Cultural experience hall, Performing arts venue, library, Gallery, Memorial Hall, Cultural corridor, Religious venue
Consumption	Commodity stand, Snack stall, Beverage shop, Shopping store, Vending machine, Hotel accommodation, SPA, KTV, and Photography service.

In urban research, regardless of the scale of the space under study, geographic location and environmental monitoring are integral components of field surveys. Historically, environmental researchers have employed various tools and methods for site determination and documentation. Among these, mobile geographic computing tools have emerged as an effective means to control the quality of data collected. Numerous studies have demonstrated the efficiency of using smartphone applications with GIS capabilities for file data collection (Bârliba et al., 2017; Nowak et al., 2020). Therefore, this study has chosen to use a Chinese-developed mobile application, GeoQuater, to collect data on leisure facilities within the research spaces, including the latitude and longitude of each facility and photographs. GeoQuater is a location-based mobile data collection application (https://m.geoquater.com/) with features including positioning, recording of coordinates, and photography. Figure B-2 in the Appendix B displays a screenshot of this research's application interface post-field survey. The field survey was conducted as follows:

a) 11 data folders were created in the GeoQuater app, corresponding to each research space, with four categories within each folder: Sightseeing, Sport, Culture, and Consumption.

b) The survey sequence was established following the principle of proximity, planning an effective route to connect the 11 sample spaces, and minimizing travel distance and time. Flexibility was maintained throughout the survey to adjust the route or plan as needed. iii. The field survey was conducted during daylight hours from August 27 to 31, 2023. During this time, information regarding the facilities, including their names and coordinates, was diligently recorded using the GeoQuater app, and photographs were stored in the designated folders. Alongside this survey process, a paper version of the facility classification table (Table 3.2) was constantly referred to to accurately verify and categorise each facility.

c) Upon completing the survey, the data were imported into ArcGIS software to verify spatial location information. Adjustments were made to any inaccuracies.

d) Finally, the distribution of the number of facilities in each research space was tallied; detailed statistics and photos can be found in Appendix E.

3.5.7 Population Data

Population data forms a crucial foundation for the urban spatial pattern analysis and sample selection in the study area. However, detailed population distribution data for Nanjing city is not publicly available, as the official government only discloses population figures for each district (Nanjing GOV, 2024). The study area encompasses nine districts, with four traditional Jiangnan region districts—Qinhuai, Xuanwu, Gulou, and Jianye—almost entirely covered. In contrast, the remaining five districts are partially included. To estimate population figures for each district, this study used proportional area calculations based on the research region's geographical boundaries. Subsequently, population density for each district was calculated and visualized using ArcGIS software, as shown in Figure 4.3. The population within this study area is approximately 3.7884 million, accounting for roughly 40% of the total population of Nanjing city.

3.5.8 The Reliability and Validation of Data

i. Reliability

According to Sharma et al (2021), reliability refers to the likelihood of the software functioning smoothly without any failure under specified conditions over a given period. The data collection software used in this study is mature and has been tested. If the software and platform can effectively collect the required data, it demonstrates the liability. Thus, there is no need for additional reliability testing in this study.

ii. Validation

Although testing of the data collection tool is not required for this study, it is still necessary to ensure the validity of the data sources. Following the process designed by Gao et al. (2016) for validating big data, this study has established a specific process, as illustrated in Figure 3.4, to ensure data validity.

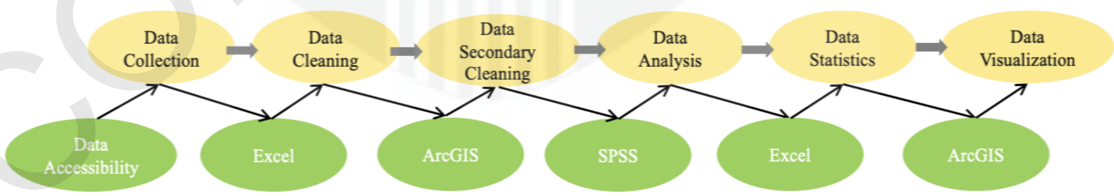


Figure 3.4 : Big Data Validation Process
(Source: Author 2024)

(a) Data Cleaning: To guarantee the validity of the data sources, the collected data will undergo initial cleaning, including: a) Handling Missing Values: Identifying and addressing missing values in the data, which may involve deleting data with missing values, filling in missing values, or using interpolation methods to estimate missing values. b) Data Deduplication: Detecting and removing duplicate records to ensure data uniqueness. c) Removing Irrelevant Information: Eliminating irrelevant data such as advertisements, blank entries, and data lacking meaningful features, like excessively short text or purely symbolic characters.

(b) Secondary Data Cleaning: Importing geographically relevant and initially cleaned data into ArcGIS for a secondary cleaning, retaining only data within the research area, eliminating invalid data, and exporting it in Excel format. This stage essentially ensures the validity.

(c) Data Analysis: Analyzing the secondarily cleaned data using SPSS software.

(d) Data Statistics: Summarize the data analysis results in tables for easy importation into GIS for further analysis.

(e) Data Visualization: Finally, the data will be visualized using ArcGIS for visual representation.

3.6 Data Analysis Method and Technique

According to various vitality evaluation indicators, the paper presents different analysis methods, including GIS analysis, Excel statistical analysis, Python word frequency analysis, and Python sentiment analysis.

3.6.1 GIS Spatial Analysis with Location Points of Leisure Urban Spaces

Before comprehensively evaluating vitality in 11 designated research spaces, this investigation considers it imperative to conduct a spatial analysis of existing LUS within the study area. The initial step involves mapping the distribution of LUS within the urban level, enabling the identification of regions with varying leisure densities. Moreover, such spatial evaluation assists in discerning potential hotspots and underutilized areas, thereby offering pivotal insights for urban design and developmental strategies. Furthermore, this spatial scrutiny is a precursor to subsequent data gathering and analytical endeavours. The initial investigation identifies specific areas necessitating detailed examination or focused attention, fostering a tactical approach to research. This method not only amplifies research efficiency but also assures the collection of more pertinent and contextually relevant data, thus providing a holistic and precise viewpoint for vitality evaluation. This discourse utilizes a triad of GIS methodologies for its analysis, encompassing Average Nearest Neighbor (ANN) Analysis, Standard Deviation Ellipse (SDE) Analysis, and Kernel Density Estimation (KDE). These tools are integral for evaluating the accumulation of spatial points within urban leisure contexts, including parks, squares, waterfront spaces, and leisure blocks. Each technique offers unique insights into the spatial distribution patterns of these locales. The amalgamation of these methods enables a profound understanding of the clustering dynamics of spatial points in leisure environments. Such comprehensive analysis facilitates the optimal allocation of leisure amenities, enhances urban living standards, and promotes sustainable city development. These spatial analysis instruments are indispensable in urban planning and societal progression, ensuring adept planning and governance of urban leisure zones. This research operationalizes these analytic methodologies via ArcGIS 10.8.2.

3.6.1.1 Nearest Neighbor Index (NNI)

The NNI describes distribution patterns by measuring the distance between the nearest points (Clark & Evans, 1954). By measuring the distance from each location point to its nearest neighbour and comparing these distances with the expected values of a random distribution, it can be determined whether the location points tend to be clustered or dispersed (He et al., 2021; Li et al., 2021; Wang et al., 2023)with the basic principle illustrated in Figure 3.5. The Nearest Neighbor Ratio, denoted as R, interprets the distribution; the smaller the value of R, the more clustered the distribution. If R > 1, the spatial distribution is dispersed; if R = 1, it is random; if R < 1, it is clustered. The formula (1) is as follows:

$$R = \frac{r_{obs}}{r_{exp}} = \frac{\frac{1}{n}\sum_{i=1}^{n} d_{min}(i)}{\frac{0.5}{\sqrt{\frac{n}{A}}}} \quad (1)$$

where R is the NNI value; r_{obs} is the observed average nearest neighbor distance; r_{exp} is the expected average nearest distance; A is the size of the study area; $d_{min}(i)$ represents the distance from each point to its closest neighbouring point.

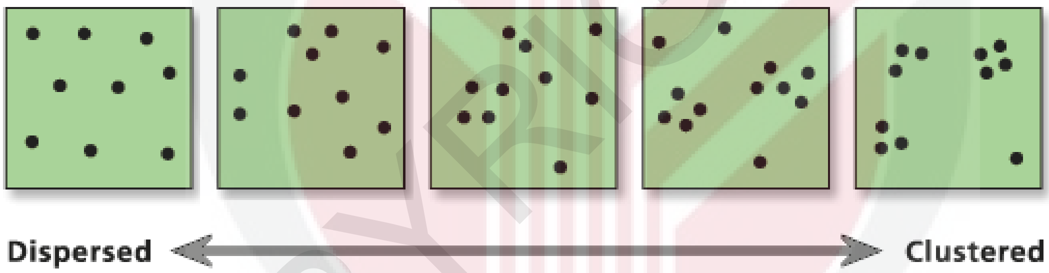


Figure 3.5 : Illustration of Spatial Pattern Calculation Using Nearest Neighbor Analysis on ArcGIS
(Source: ESRI, 2023)

The analysis procedure involves opening the ArcGIS Toolbox, a spatial statistics tool, and the average nearest neighbor tool in ArcGIS software. The output of this tool is an analytical report comprising five values: Nearest Neighbor Index (NNI), Expected Mean Distance, Observed Mean Distance, p-value, and z-score. The Nearest Neighbor Index (NNI) is derived by dividing the Observed Mean Distance by the Expected Mean Distance, indicating the degree of dispersion or clustering. If the ratio exceeds

1, the spatial distribution pattern of the points is dispersed; otherwise, it is clustered. The p-value is employed to ascertain statistical significance. A smaller p-value (typically less than 0.05) suggests that the observed spatial pattern clustering or uniform distribution) is unlikely to be a product of randomness. The z-score, a standardized score, reflects the deviation between the observed mean distance and the expected mean distance under random circumstances. A positive z-score denotes a trend towards clustering, whereas a negative z-score indicates a trend towards uniformity or dispersion.

3.6.1.2 Standard Deviation Ellipse (SDE)

SDE, first introduced by Lefever in 1926, is a spatial statistical method that reveals the multidimensional characteristics of geographic feature distributions (Lefever, 1926). SDE involves the dispersion of data points and their primary trend direction, ultimately forming an ellipse. This method has been extensively integrated into GIS analyses to reveal spatial relationships of geographic features (Y. Zhang et al., 2022). The underlying principle of this method is exemplified in Figure 3.6.

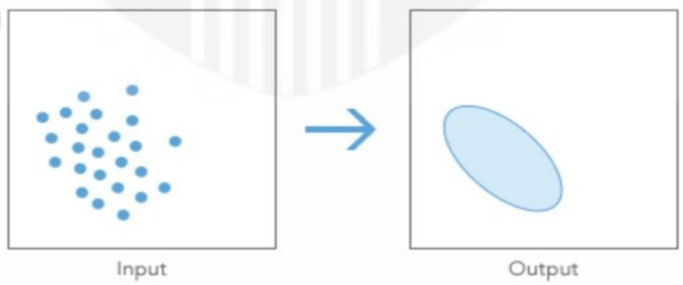


Figure 3.6 : Illustration of Spatial Pattern Calculation Using Directional Distribution (Standard Deviational Ellipse) on ArcGIS
(Source: ESRI, 2023b)

The calculation of SDE depends on several key parameters: the centre of the ellipse reflects the relative position and change of the centroid of the geographic features; the orientation angle indicates the main trend direction; the standard deviations in the X and Y directions represent the dispersion of spatial features in the primary and secondary trend directions, respectively. Their ratio reveals the pattern of dispersion (Wang et al., 2023; Zhong et al., 2019). The formula (2) is as follows:

$$SDE_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2}$$

$$SDE_y = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \overline{y})^2} \tag{2}$$

where x_i and y_i denote the coordinates of each element i; $\{\overline{x}, \overline{y}\}$ represents the mean centre the elements; and n is the total number of elements.

Within the ArcGIS software, the analysis procedure commences with sequential activation of tools: ArcGIS Toolbox-Spatial Statistics Tools-Analyzing Patterns-Directional Distribution. The approach involves conducting three distinctive analyses, encompassing the overarching LUS location points and individual location points across varied spatial categories. After completing these analyses, a quintet of standard deviational ellipse outcomes will be visualized on the map, each uniquely portraying the spatial distribution patterns of the data points. These include the central coordinates of the distribution and the respective lengths of each ellipse's major and minor axes.

3.6.1.3 Kernel Density Estimation (KDE)

KDE is an interpolation technique used to compute the probability density function of a random variable, widely applied for estimating the spatial density distribution of geographic features (Bowman & Azzalini, 1997). As a common statistical method for analyzing point feature distributions, KDE visually displays the distribution of discrete measurements in a continuous area. This method is extensively used in studies of spatial distribution characteristics, helping to analyze and understand geographical phenomena by revealing the spatial distribution patterns and characteristics of point features (He et al., 2021; Wang et al., 2023; Y. Zhang et al., 2023). Through kernel density analysis, this study can identify the hotspots of LUS in the study area and help assess the coverage of service facilities. The underlying principle of this method is exemplified in Figure 3.7.

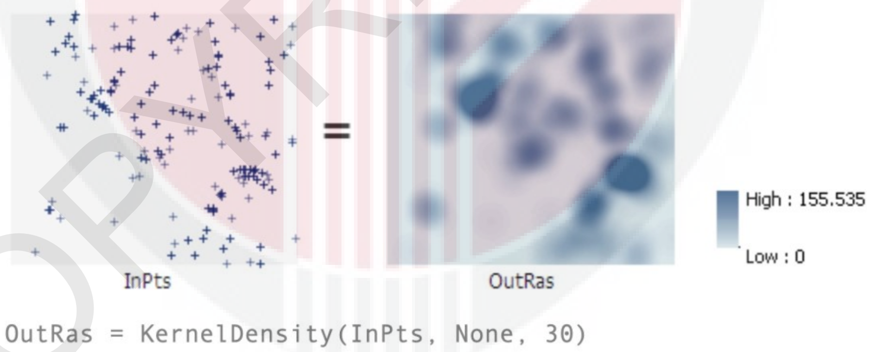


Figure 3.7 : Illustration of Spatial Pattern Calculation Using Nuclear Density Analysis on ArcGIS
(Source: ESRI, 2023c)

The higher the kernel density value, the more concentrated the point distribution; the lower the value, the more dispersed the distribution. The formula (3) is as follows:

$$\hat{f}(x,y) = \frac{3}{nh^2\pi}\sum_{i=1}^{n}\left[1 - \left(\frac{(x-x_i)^2+(y-y_i)^2}{h^2}\right)\right]^2 \quad (3)$$

$\hat{f}(x, y)$ represents the estimated density value at the location (x, y); n is the total number of data points; are the coordinates of the i-th point; h is the bandwidth, controlling the smoothness k is the kernel function, determining how each point contributes to the density estimate.

The analysis steps involve sequentially opening ArcGIS Toolbox-Spatial Analyst Tools-Density Analysis-Kernel Density Analysis in the ArcGIS software. Parameters such as output cell size and search radius need to be set. After continuous testing, this paper used an output cell size of 30 and a search radius of 200. The POI layers of the overall leisure urban space and various spatial POI layers are analyzed. After the analysis is completed, the standard deviation ellipse analysis results will be displayed on the map. Upon completion of the study, we can view the results of kernel density circle analysis, which are typically presented in the form of raster datasets, allowing for a visual inspection of the density distribution of features.

3.6.2 Network Big Data Analysis

3.6.2.1 Heat Value Extraction Using GIS

A detailed explanation of the principles behind the population location data in Baidu Heat Maps is necessary to understand better the origin of the heat values for each research space. Baidu Maps divides the map into a 200x200 grid (as shown by the blue solid lines in Figure 3.8 (A) and counts the number of terminals that have used the location SDK within a certain period (set to one hour by the platform). For example, in the yellow area of the following figure, the heat value is assigned to the centroid if there are 7 terminal location data points during that period. This data is presented in a tabular format, including location points and their corresponding heat values. Multiple coordinate systems are available for these locations; this study utilizes the WGS84 coordinate system. Based on this principle, ArcGIS 10.8.2 is used to obtain the heat values of each research space. The specific steps are as follows: a) Data Import: Baidu heat map point source data, research space AOI data and research area AOI data were imported into ArcGIS.

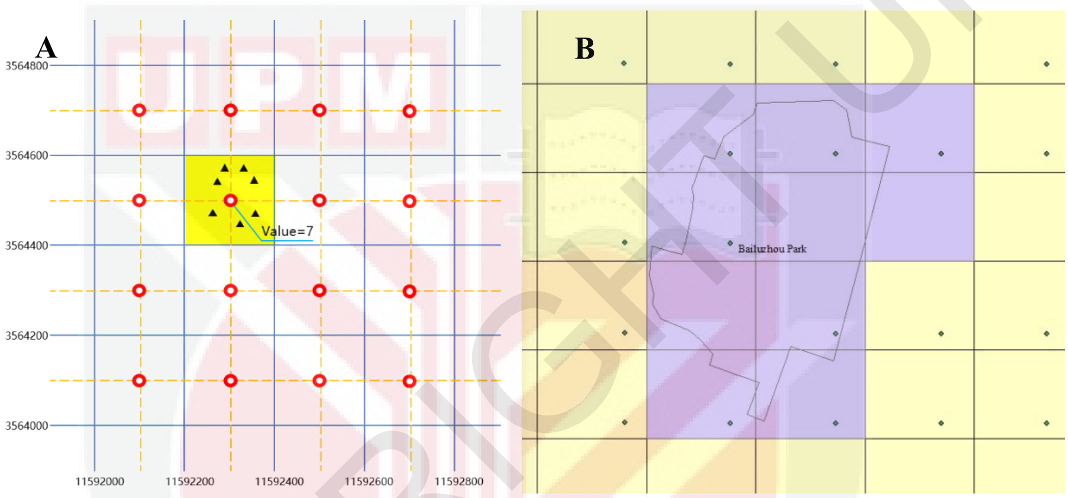


Figure 3.8 : BHMD of, Example Diagram Illustrating the Principle of Location Points(A); Example Diagram of Heat Data for Research Spaces(B)
(Source: Author 2024)

b) Spatial Division: Using the "Create Fishnet" tool in ArcGIS, the study area is divided into a 200x200 grid, forming a grid-like structure similar to a fishing net, as shown in the yellow part of Figure 3.8 (C). c) Grid Selection: Select the corresponding grids covered by the 11 research space area data one by one, as shown in the purple part of Figure 3.8, and export the research space grid data. d) Spatial Intersection: Use the "Intersect" tool to intersect each selected research space grid data with Baidu Heat Map point data from various periods to obtain heat value information within each research space grid, as shown by the point data in the purple part of Figure 3.8. e)

Value Accumulation: Sequentially accumulate the heat values of different data points obtained from the intersection in the 11 research spaces to calculate the total heat value of each research space, as shown by the total value of the points in the purple part of Figure 3.8. f) Data Output: Finally, obtain the heat value data for the 11 research spaces, which reflects the distribution and density of Baidu Heat Map points in each research space. The specific heat value data for each period in each research space is detailed in Appendix D.

3.6.2.2 Word Frequency Analysis

This paper extracts the nouns and their occurrences that reflect the type of leisure companionship in online review texts by conducting word frequency analysis of the specified keywords. Word frequency analysis is a standard text mining technique that can assess the repetition frequency of individual words in a corpus (Brysbaert et al., 2018). The main reason and importance of using word frequency analysis in this paper is that the primary user group of MD falls within the age range of 20 to 45 years. The leisure habits of teenagers and elderly individuals are usually associated with this age group. Therefore, by analyzing the review data from MD, we can effectively encompass information about social relationships involving teenagers and older people. Compared to tag notation methods, word frequency analysis can avoid the tedious task of manually tagging large volumes of the web. Based on the classification of leisure travel structural types in tourism research, this paper classifies leisure companionship types into Family, Couple, Friends, Organized collectives, and oneself, five major types, of which keywords related to social relationships that may appear in social media reviews are listed in Table 3.5. It is noted that there are linguistic differences between Chinese and English, which result in many Chinese nouns being represented by only one word in English. For example, in Chinese, "女儿", "姑娘" and "闺女" are all translated as "Daughter" in English. Therefore, the English translation vocabulary may not fully cover all the key terms in this paper. This study is dedicated to conducting a thorough analysis of comment texts across various research dimensions, with a critical step being the quantitative statistical assessment of selected keywords' frequency. Upon completion of the preliminary statistics, we will further process the data to eliminate redundancy and potential overlapping meanings in vocabulary statistics, thereby enhancing the accuracy and reliability of the data obtained.

Table 3.5 : Keyword Statistics of Leisure Companionship Types in Reviews

Group Types	Key Words (Chinese)	Translation (English)
Family	孩子,小孩,小朋友,宝宝,儿童,遛娃,儿子,女儿,姑娘,闺女,一家人,家里人,孙子,孙女,老人,爸,妈,父母,爷爷,奶奶	child, kid, little friend, baby, stroll with a child, son, daughter, girl, family, household members, grandson, granddaughter, elderly, dad, mom, parents, grandfather, grandmother
Couple	女朋友,男朋友,老公,老婆,媳妇,对象,情侣,爱人,伴侣,未婚妻,未婚夫	girlfriend, boyfriend, husband, wife, daughter-in-law, partner, lover, fiancé, fiancée
Friends	闺蜜,姐妹,兄弟,舍友,室友,朋友,同学,铁子,哥们,姐们,bro,胖友,伙伴,同桌,同伴,好友,挚友	close friend, sister, brother, roommate, friend, classmate, buddy, bro, pal, buddy, friend, partner, desk mate, companion, friend, intimate friend
Organized Collectives	团队,团建,旅行团,团员,旅游团,组织,社团,集体,单位组织,学校组织	team, team building, tour group, member, organization, association, collective, organizational unit, school organization
Oneself	自己,独自,一个人	oneself, alone
Overlapping Words	自己一个人,女孩子,男孩子,孩子,女朋友,男朋友,朋友	/

In handling overlapping vocabulary, we adhere to a specific set of rules: For the terms "自己" (oneself) and "一个人" (alone), they are counted separately when they appear individually. However, when these two words are combined as "自己一个人" (by oneself), we subtract the occurrence of this phrase from the total count of both words to eliminate statistical repetition. The statistics for the term "孩子" (child) should encompass the counts of "女孩子" (girl) and "男孩子" (boy). Therefore, to avoid duplication, we do not count "女孩子" and "男孩子" separately, but instead, include them in the total count for "孩子". Similarly, the count for the term "朋友" (friend) will consist of the frequencies of "女朋友" (girlfriend) and "男朋友" (boyfriend). In the statistics, we exclude the counts of "女朋友" and "男朋友" from the total count of "朋友" to ensure that the frequency reflects the use of the word "friend" in a non-gender-specific context. Through this rigourous data processing procedure, this study can more accurately depict the habits and trends of different groups using specific vocabulary in comment texts. See Appendix E for the specific Python code (Figure D-1).

3.6.2.3 Text Sentiment Analysis

A sentiment analysis method based on sentiment lexicon matching was applied to analyze the collected web reviews. This method has been used in attraction theme mining (W. Chen et al., 2020; Feng et al., 2022). This study uses the Python programming language to process the textual data of web reviews. It analyzes the collected web reviews to obtain the sentiment positivity scores of user reviews in each space. The specific idea is as follows:1) Firstly, the BosonNLP dictionary was used to construct a thesaurus containing negation, degree adverbs, stop words and emotion words. 2) Secondly, the text of the commentary was divided into words using the Jiaba word separation program.3) Extract sentiment, negation, degree adverbs, and deactivation words from the documents using various dictionaries. 4) The sentiment score of the review is calculated after removing the deactivated words from each review. The calculation rules are: determine whether there is a negation or degree adverb before each sentiment word, and divide the sentiment word into a sentiment group together with the negation or degree adverb before it; multiply the sentiment weight of the sentiment word by -1 if there is a negation before the sentiment word, and multiply the degree weight of the degree adverb if there is a degree adverb before the sentiment word; finally, add up the scores of all sentiment groups in each review. The sentiment score of each review is obtained by adding up the scores of all sentiment phrases, with sentiment values greater than 0 being classified as positive and those less than 0 being classified as negative. The absolute magnitude of the sentiment score reflects the degree of positivity or negativity. See Appendix E for the specific Python code (Figure D-2). The specific calculation is shown in formula (4).

$$SV = \sum_{i=1}^{N} v_i \cdot m_i \tag{4}$$

Where SV is the sentiment value for the text, is the base sentiment value of word i and is the modifier for word i, which is determined by the associated degree adverbs and negation words. The values for and are obtained from the BosonNLP dictionary, N is the number of sentiment-bearing words in the text.

3.6.2.4 Spatial Service Range Determining

Within the vitality evaluation indicator system developed for this study, a critical element in evaluating vitality through the built environment dimension is the surrounding context, or more specifically, the spatial service range. The leisure service range of public spaces is determined by the service distance (radius) around the space (L. Zhang et al., 2018). Typically, this service radius is defined by planners based on the area and characteristics of the space, yet a universally standardized scientific criterion is currently absent. Focusing on Nanjing, this study is grounded in the mandates outlined in the city's policy documents. Territorial Spatial Master Planning of Nanjing (2021-2035) stipulates on page 6 that 2035 there should be a 98% coverage of green and public spaces within a 5-minute walking radius in the CUA (NMPG, 2022). On average, a five-minute walk correlates to about 500 meters. Supporting this, existing research indicates distance as a key factor in the use of public spaces, with most users within a 500-meter radius of these areas (Giles-Corti et al., 2005). Consequently, this paper suggests considering a 500-meter radius buffer as the spatial service range.

In the dimension of the built environment, the evaluation of factors such as service coverage rate, transport accessibility, and surrounding function all depend on this data. The study extends into peripheral areas beyond the research spaces (within a 500-meter range), utilizing the "Buffer" tool in ArcGIS software to process the surface data of each research space with a 500-meter buffer zone. Subsequently, this processed data is exported as the surface data of the external service ranges surrounding the research spaces. It's important to note that approximately half of the external service ranges adjacent to waterfront spaces are water systems. To ensure objectivity in the results, the study employs the "intersect inverse" tool to exclude the water system portion from the external service ranges of waterfront spaces. This process yields the service range for the research space, with the area of each service range obtainable from the attribute table.

3.6.3 Statistical Calculation for Each Indicator

This section will elaborate on how each indicator is measured, where the dependent variable (DV) is crowd activity, which includes four indicators. The independent variable (IV) is the built environment, which consists of spatial supportiveness and functional diversity and contains seven different indicators, the details of which are summarized in Table 3.1.

3.6.3.1 Calculation of Crowd Activity Indicators

i. Spatial Clustering

The average activity intensity per unit area of each research space is calculated using Formula (5):

$$SC_i = \frac{\sum_{i=1}^{n} PA_i}{n * A_i} \tag{5}$$

Where is the activity intensity per unit area for space *i* at a given time scale, is the total heat values in space is the area of space, n=126

ii. Temporal Persistence

(a) Fluctuation Index:

The fluctuation index is the variation of activity value in the LUS for a week, measured as the standard deviation of the activity value for each day of the week. The measure is the stability index S (Stabilization) (Liu & Lai, 2019), which can be calculated using the STDEV function in Excel, using the formula (6)

$$i = \sqrt{\frac{1}{n}\sum_{j=1}^{n} (xi - r)^2} \tag{6}$$

Where fi is the standard deviation of activity intensity over days for a spatial cell, is the activity at a moment, and is the average activity over moments. measures data dispersion: a smaller *S*indicates less dispersion, and a larger indicates more.

(b) High-Intensity Activity Duration:

This index is determined by the cumulative duration of reaching and sustaining a certain activity value in each space, as calculated by Formula (7):

$$T_i = \sum D_i\,(D_{it});$$
$$had_i(had_{it}) = \begin{cases} 1, if \;\; D_{it} > \theta \\ 0, if \;\; D_{it} \leq \theta \end{cases} \tag{7}$$

Where is the High-Intensity Activity Duration index for space. is the activity value at hour (t ∈ [0, 126]), is the threshold determined by the average activity per area per moment over a week. A larger indicates more efficient space usage.

iii. Group Diversity

Leisure companionship mixing index Gmix is established according to the "Shannon entropy" index. This is calculated using Formula (8):

$$\text{GD}=\frac{\sum_{i=1}^{k} R_1[In(R_1]}{In(k)} \tag{8}$$

Where GD from 0 to 1 and measures group diversity in a space, where is the proportion of the ith group; k = 5. Higher values signify greater diversity.

iv. Feedback Positivity

(c) Overall Satisfaction:

The value for each sample space is derived from the average of the ratings (The score ranges from 0 to 5) given by users in the review data. This is calculated using Formula (9):

$$os_i \frac{\sum_{t=1} os_{it}}{p_i} \tag{9}$$

Where measures the average satisfaction of space i, where are individual satisfaction scores and is the number of reviewers. Higher indicates better feedback.

(d) Sentiment Scoring:

The average value of sentiment scoring for each space is calculated by Formula (10) as:

$$ss_i \frac{\sum_{t=1} H_{it}}{p_i} \tag{10}$$

Where is the sentiment score for space i, averaging sentiment values from user reviews. is the number of reviewers. A higher indicates more positive feedback.

3.6.3.2 Calculation of Built Environment Indicators

The independent variable indicators are composed of built environment, which are the internal mechanism of space vitality and are divided into two main aspects, Spatial

Supportiveness and Functional diversity, which contain a total of seven indicators. In this section, the calculation and quantification of each indicator are described in detail.

i. Service Population Density

Due to the difficulty in obtaining high-precision data on population in China. In this study, the average of the heat values at 12AM over a week (7 time points) within the space service range was used as represent the population density. The specific calculation formula (11) is as follows:

$$SD_{\mathrm{i}} = \frac{\mathrm{P_i}}{\mathrm{SA_i}} \tag{11}$$

is the population density within 500m of space i, is the total population number within 500m of space i, and is the area of service range within 500m of space i. The larger is, the higher service coverage rate in the leisure urban space.

ii. Road Network Density

This article imports the road network vector data obtained by crawling Oms website into the ArcGIS software and uses the "intersect" tool to calculate the length of roads within a 500-meter radius around each research space. The formula (12) for calculating road network density index is as follows:

$$\mathrm{RD_i} = \frac{\mathrm{RL_i}}{\mathrm{SA_i}} \tag{12}$$

is the road network density within 500m of space i, is the total road length within 500m of space i, and is the area of service range within 500m of space i. The larger is, the higher the density of the road network within 500 m of space i and the higher the accessibility of road traffic in the leisure urban space.

iii. Public Traffic Convenience

The indicator is defined as the density of bus and metro stations within a 500-meter buffer zone, that is, the number of bus and subway stations per hectare within a 500-meter buffer zone. In ArcGIS software, the geometry calculation, spatial join, and field calculator tools are used to calculate the density of bus stations within a 500-meter radius of urban parks. The formula for calculating the public traffic convenience index is as follows (13):

$$\mathrm{PTC_i} = \frac{\mathrm{PT_i}}{\mathrm{SA_i}} \tag{13}$$

represents the public traffic convenience index within a 500-meter buffer zone around space i, which is the density of bus and subway stations within 500 square meters per hectare. is the number of bus stations within a 500-meter buffer zone space i, and represents the area of the service range within 500 meters around space i. The larger the value, the higher the density of bus stations within the 500-meter buffer zone around space i, and the better the public traffic convenience.

iv. Surrounding Function Density

In terms of POI-based peripheral functional density, this paper calculates the total number of facility POIs within 500 meters of each leisure urban space, using data on the POIs of the various types of facilities within the study area. The calculation formula (14) for the indicator is as follows:

$$\mathrm{SFD_i} = \frac{\mathrm{SF_i}}{\mathrm{SA_i}} \tag{14}$$

refers to the urban functional density index within a 500-meter radius around space i. represents the total number of functions within the 500-meter service radius of space i, while refers to the area of the 500-meter service zone around space i. The larger the value of , the greater the functional density within the 500-meter radius of space i, indicating a greater concentration of facilities within that spatial range

v. Surrounding Function Mixedness

The Shannon Entropy Index algorithm was used in the measurement of the POI-based mix of surrounding functions. The index is calculated using the following formula (15):

$$SFX_i = \sum_{t=1}^{N_i} \left\{ \left(\frac{P_n}{P_i}\right) * 1n\left(\frac{P_n}{P_i}\right) \right\} \tag{15}$$

is an indicator of the mixing degree of urban functions in the 500m buffer around space i. is the sum of all function types within the 500m surrounding space i, is the number of functions of type n within the 500m surrounding space i, and is the number of all functions around space i. As mentioned earlier, there are seven types of POI-based urban functions, so the in this paper is 5. The higher the value of the higher the degree of mixing of POI-based urban functions, and vice versa. The Spatial Join Tool in ArcGIS 10.3 will be used to calculated the number of different POIs within a 500 m buffer of the leisure urban space according to POI category.

vi. Internal Facility Density

The formula for calculating the density of internal facilities is the same as the surrounding functional density mentioned above. The specific formula (16) is as follows:

$$IFD_i = \frac{IF_i}{A_i} \tag{16}$$

is the density index of facilities in space i, i is the number of all facilities in space i, and is the area of space i. the larger it is, the greater the facility density inside space i, indicating that the facilities in this space are more concentrated.

vii. Internal Facility Mixedness

The formula for calculating the mixedness of internal facilities is the same as the surrounding functional mixedness mentioned above. The specific formula (17) is as follows:

$$IFX_i = \sum_{t=1}^{M_i} \left\{ \left(\frac{F_n}{F_i} \right) * 1n \left(\frac{F_n}{F_i} \right) \right\} \tag{17}$$

is an index of the mix of facilities within space i. is the sum of all facility types within space i, is the number of facilities of type n within the space, and is the number of all facilities within space i. As mentioned earlier, there are four types of facilities in a leisure urban space, so the in this paper is 4. The higher value, the higher the degree of facility mixing within the space, and vice versa. The number of each type of facility within the different leisure urban spaces will be counted by using the POIs, Satellite map and field investigation.

3.6.4 Data Normalization

For ease of analysis between indicators, it is necessary to standardize the data before performing Pearson correlation analysis. This study has chosen min-max normalization, which aims to scale the numerical range of all features to a fixed interval, usually from 0 to 1. Min-max normalization is very sensitive to outliers, as outliers can affect the calculated minimum and maximum values. Therefore, this study has already conducted an outlier test and found no anomalies, allowing for the use of this data processing method. It is worth noting that in this study, the external representation of vitality includes the temporal persistence indicator (Y2), which consists of two measures, Y2-1 and Y2-2, each accounting for half of the weight. The first one (Y2-1) is the fluctuation index of activity clustering. A higher value of this index means more instability in activity concentration over time, and a lower value should imply higher vitality. Therefore, Y2-1 should be negatively correlated with the independent variables. However, for the overall correlation analysis, this study has chosen to use the normalization data processing method, aligning all values within the 0-1 range. The specific Formulas (18) are as follows, with the first representing the processing formula for positive indicators and the second for negative indicators. Except for the Y2-1, all other indicators use the first formula for data processing:

$$X_{ij} = \frac{X_j - X_{min}}{X_{max} - X_{min}}$$

(Processing formula for positive indicators)

$$X_{ij} = \frac{X_{max} - X_j}{X_{max} - X_{min}}$$

(Processing formula for positive indicators) (18)

is the processed value, Xj is the original value, is the minimum value in the data set, and is the maximum value in the data set.

3.6.5 Correlation Analysis

Correlation analysis is used to determine the degree of association between indicators, helping researchers understand the strength and direction of these relationships. This paper aims to analyze the correlation between the external representation (crowd activity) and internal mechanisms (built environment) of leisure urban space vitality to validate the theoretical framework established in Chapter 2. Specifically, this study will explore the correlation between the built environment (X) and crowd activity (Y), as well as how different built environment factors affect crowd activity.

To this end, the paper will use the commonly applied Pearson correlation coefficient for analysis. The Pearson correlation coefficient, proposed by Karl Pearson in the 1880s based on the ideas of Francis Galton, is a method in statistical research to measure the strength of linear correlation between two variables, X and Y (Sedgwick, 2012). This measure of linear relationship is suitable for predictions where a direct proportion or inverse proportion relationship is expected between variables. In contrast, Spearman's rank correlation is more suited to monotonic relationships and may not be appropriate for the theoretical model of this study. Additionally, the Pearson method requires the data to be normally distributed, which is consistent with the data preprocessing conditions of this study. Importantly, the Pearson coefficient provides not only the strength of the relationship but also its direction, which is crucial for understanding the dynamic relationship between the built environment and crowd activity.

This paper will conduct correlation analysis using IBM SPSS Statistics 28 to determine the correlation coefficients between different indicators of the built environment (IV) and crowd activity (DV). These coefficients will be used to judge whether the influence of internal mechanism factors on external representation factors is significant, promotional (positive correlation), or deterrent (negative correlation). The calculation formula of the Pearson correlation coefficient (Formula 19) is shown below:

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - Y)^2}} \tag{19}$$

n represents the sample size, represents the value of the independent variable, represents the value of the dependent variable, and r represents the correlation coefficient between the variables. The range of the Pearson correlation coefficient is [-1, 1]. A value of 0 indicates that the two variables are uncorrelated. The closer the value is to -1, the stronger the negative correlation, and the closer it is to 1, the stronger the positive correlation. The Pearson correlation coefficient can be classified into seven levels: when $r \leq 0$, there is no correlation; when $0 < |r| \leq 0.3$, there is a weak correlation; when $0.3 \leq |r| \leq 0.5$, there is a low correlation; when $0.5 \leq |r| \leq 0.7$, there is a moderate correlation; when $0.7 \leq |r| \leq 0.9$, there is a high correlation; when $0.9 \leq |r| < 1$, there is a significant correlation; and when $|r| = 1$, there is a perfect linear correlation.

3.6.6 Weight Calculation

To achieve the goal of establishing a complete evaluation framework, weight calculation is a critical step. Weight calculation helps to transform subjective judgments into quantitative indicators, making the evaluation process more objective and scientific. By computing weights, decision-makers can more accurately quantify the importance of different indicators, thereby reducing the impact of subjective bias on the evaluation results. In comprehensive evaluation, there are many methods to determine weights, and different weights often represent different meanings and mathematical characteristics of indicators. By combining the evaluation indicator system with corresponding weights, a final evaluation framework for LUS is formed.

Indicator weights measure the relative importance of indicators in the overall evaluation.

In this study, to calculate the weights of each indicator and ensure the objectivity and accuracy of the results, it is considered reasonable to select two methods for calculating weights and use the average of these two as the final indicator weights for this research system. This paper selects the Entropy Method and CRITIC Weighting Method. The Entropy Method quantifies the dispersion and objectivity of data and can effectively assess the information carried by each indicator, thus determining its weight. The CRITIC Weighting Method complements this by considering the correlations between indicators and analyzing the conflicts among them. It captures the variability of each indicator and emphasizes the independent information content between them. Combining these two methods utilizes the inherent statistical characteristics of the data while considering the interactions between indicators, thereby providing a more comprehensive and balanced evaluation (Mukhametzyanov, 2021). Based on the classification of indicators in the indicator system, the weights of evaluation indicators and vitality factors were calculated. The weight results of the 11 indicators were obtained by averaging the results of the two methods. These results were then combined with the indicator system to form the final evaluation framework for the vitality of LUS.

3.6.6.1 Entropy Method

The Entropy Method is a statistical approach used for calculating weights, widely applied in multi-criteria decision analysis. The fundamental idea of the Entropy Method is to measure the uncertainty or diversity of the information content of each indicator by calculating its entropy value, thereby determining the weight of each indicator. This method posits that indicators with lower entropy values provide more effective information and therefore should carry greater weight (Y. Zhu et al., 2020). The entropy of each indicator can be calculated using the following formula (20):

$$W_j = \frac{1-\frac{1}{\ln(n)}\sum_{i=1}^{n} p_{ij}\ln(p_{ij})}{\sum_{j=1}^{m}(1-\frac{1}{\ln(n)}\sum_{i=1}^{n} p_{ij}\ln(p_{ij})} \tag{20}$$

Where n is the number of samples, represents the proportion of the i-th sample on the j-th indicator, and when $p_{ij} = 0$, by convention, $0ln(0) = 0$. m is the total number of indicators.

3.6.6.2 CRITIC Weighting Method

The CRITIC Weighting Method is a decision support technique used to determine the relative importance or weights of attributes in multi-attribute decision analysis. The key to this method lies in identifying attributes that exhibit both high variability and high conflict, as these attributes play a more significant role in the decision-making process (Mukhametzyanov, 2021). The basic steps and formula for calculating weights using the CRITIC method are as follows:

Calculating the standard deviation between attributes: Compute the standard deviation for each attribute. A larger standard deviation indicates greater variability of the attribute among different choices.

Calculating the correlation coefficient between attributes: For each pair of attributes, calculate their correlation coefficient. This can be done using Pearson correlation coefficient.

Calculating the information content of each attribute: The information content of each attribute is determined by its variability and conflict. The formula for calculating the weight W_j of the *j*-th attribute is:

$$\mathrm{W}_j = \frac{\sigma_{\mathrm{j}} \times \sum_{k=1,k\neq j}^{n} |r_{\mathrm{jk}}|}{\sum_{j=1}^{m} C_j \times \sum_{k=1,k\neq j}^{n} |r_{\mathrm{jk}}|} \tag{21}$$

Where W_j is the information content of the j-th attribute, σ_j is the standard deviation of the j-th attribute, r_{jk} is the correlation coefficient between attributes j and k. m is the total number of samples.

3.7 Expert Validation

The data collection methods and analysis techniques employed in this study strictly adhere to academic research standards, ensuring the objectivity and transparency of the research. Expert validation was adopted as the primary validation tool to further enhance the scientific validity and practical value of the assessment of LUS vitality. While the validation process typically includes comparing actual situations, soliciting expert opinions, and re-analyzing data, this study's reliance on large-scale data analytics made extensive field surveys and data re-analysis impractically burdensome. Therefore, expert validation, a highly efficient strategy, was selected, utilizing experts' experience and systematic methods to confirm or validate the research findings' accuracy, reliability, and quality. This ensured the rationality and credibility of the assessment results and provided a deep understanding of the evaluated subjects. Through this rigourous validation process, it was possible to confirm whether the study's key findings are universally applicable across various LUS environments, significantly informing strategies to enhance the vitality of LUS.

Considering this, leveraging the empirical results from the central urban area of Nanjing, the study employed a Likert scale for expert evaluation validation. The Likert scale, with its standardized format of closed-ended questions, quantifies experts' levels of agreement with the findings, capturing the subtle differences and professional insights into urban planning and design evaluations. This method was chosen for its advantages—simplicity in reflecting expert opinions, ease of statistical analysis, and reduced fatigue effects due to prolonged response times (Taherdoost, 2019). The questionnaire featured a five-level rating scale ranging from "strongly disagree" to "strongly agree." aiming to capture a comprehensive evaluation of each research outcome by the experts.

Relevant studies have shown that selecting eight experts to validate research findings is an effective approach (O'Keefe & O'Leary, 1993; Suh & Ahn, 2022). Considering the diversity of the questionnaire content and the professional fields it needed to cover, the validation process involved eight local experts from Nanjing, whose expertise and practical experience span theoretical research, policy formulation, market practice, and community involvement. This included four university scholars, two urban planning professionals, and two officials from the government's natural resources and planning bureau. This combination of experts ensured that the study benefited from a multidimensional analysis and assessment, deeply informed by the experts' theoretical understanding and practical experience with urban planning in Nanjing.

To establish contact with the experts, the author sent formal emails to each potential participant, explaining the purpose of the study, the validation process, and the specific role the experts would play in reviewing the research findings. Each expert was invited to participate voluntarily and was assured of the confidentiality and anonymity of their responses. The invitation included a detailed description of the questionnaire structure and how their feedback would be used to validate the study's conclusions. Once the experts confirmed their participation, the author arranged follow-up communications, providing them with the questionnaires and guidance on completing the evaluation. The detailed backgrounds of the experts, the questionnaire's content, and the ratings' results are be provided in Appendix H.

3.8 Summary

This chapter summarizes the research methods, processes, and methodologies adopted for data collection and analysis in this study. The research method framework combines multi-source data, mainly based on big data, supplemented by field research data. The research method framework combines multi-source data, mainly based on big data, supplemented by field research data. The big data includes primary geospatial data, POI data, Baidu heat map data, social media data, and transportation data. In contrast, the field research data primarily collects location information of facilities within the space. The study conducts a systematic GIS spatial distribution analysis of LUS in the study area at the system level, employing methods such as average nearest neighbour analysis, standard deviational ellipse analysis, and kernel density analysis. A detailed vitality evaluation analysis of 11 research spaces is conducted at the individual level using GIS analysis, Excel statistical analysis, word frequency analysis, and text sentiment analysis. After data normalization, Pearson correlation analysis is performed on four indicators of crowd activity and seven indicators of the built environment in the vitality evaluation to determine the degree of correlation between the two dimensions. Furthermore, the entropy and CRITIC weighting methods are used to calculate the weights of the 11 evaluation indicators, with the average of the weights calculated by both methods determining the final weight of each indicator. Establishing this comprehensive evaluation framework achieves research objective 3 of this study.

CHAPTER 4

DATA ANALYSIS AND FINDINDS

4.1 Introduction

This chapter aims to establish a comprehensive evaluation framework for the vitality of LUS, showcasing data results and new findings from research across various levels and evaluation indicators. The analysis primarily revolves around examining the vitality of LUS at both the systemic and individual levels. The first part of this chapter focuses on systemic-level research, where the spatial aggregation and distribution characteristics for location points of LUS are deeply analyzed using GIS technology. To gain a more comprehensive understanding of the existing spatial layout's characteristics and potential flaws, additional visual maps were utilized for comparative analysis, covering aspects such as population density distribution, spatiotemporal activity distribution, land use, and service. The second part conducts a detailed descriptive analysis of 11 selected research spaces across four crowd activity and seven built environment evaluation indicators. This section aims to delve into the current status, characteristics, and differences in crowd activity in these LUS, and how these indicators effectively identify the features of leisure spaces and areas that require improvement. The third part analyses the correlation between various crowd activity indicators and built environment indicators, aiming to reveal the impact of specific environmental features in enhancing or limiting urban crowd activity. The fourth part is dedicated to determining the relative importance and weight distribution of these 11 indicators within the overall evaluation framework, clarifying the significance of different indicators in evaluating the vitality of LUS. Finally, this chapter successfully constructs a complete evaluation framework for the vitality of LUS, calculating and ranking the final vitality values for the 11 research spaces.

4.2 The Distribution Characteristics of Leisure Urban Spaces in the Central City Area of Nanjing

This section analyzes the aggregation and distribution characteristics of LUS in Nanjing's CUA based on data points from different types of LUS.

4.2.1 The Characteristics of Spatial Clustering in the Whole Area

4.2.1.1 Nearest Neighbour Analysis

Nearest Neighbor Analysis indicates a pronounced clustering trend within LUS. Key metrics elucidate the distribution patterns within the study area. Specifically, according to Table 4.1, the observed average distance is approximately 612.29 meters, whereas the expected average distance for a random distribution is 1175.94 meters. This results in a significant Nearest Neighbor Ratio of about 0.52, highlighting a high degree of spatial clustering of leisure activities. The statistical significance of these results is further supported by a Z-value of -18.5 and a P-value of 0, indicating that the observed clustering is not a random occurrence but highly statistically significant.

Different types of LUS exhibit varying clustering characteristics. Parks and squares show significant clustering, with Nearest Neighbor Index (NNI) values of 0.65 and 0.58, respectively, and Z-values and a P-value of 0 significantly support this clustering. These results indicate strategic arrangements in urban planning for these spaces, evidently influenced by careful landscape design and urban layout. In contrast, waterfront spaces have an NNI of 0.77, with a Z-value of -2.3 and a P-value of 0.07, displaying a relatively weak clustering trend, suggesting a distribution close to random but still slightly inclined towards clustering. Leisure blocks nearly exhibit a random distribution, with an NNI of 0.99, a Z-value of -0.12, and a P-value of 0.9, showing a more uniform distribution pattern across these spaces.

Table 4.1 : Nearest Neighbor Analysis Results for LUS in Nanjing's CUA

	Average observational distance (m)	**Expected average distance (m)**	**NNI (R)**	**Z-value**	**P-value**	**Spatial distribution type**
Overall	612.29	1175.94	0.52	-18.5	0	clustered
Park	779.13	1199.82	0.65	-9.15	0	clustered
Square	775.17	1346.89	0.58	-10.46	0	clustered
Waterfront Space	1338.97	1735.60	0.77	-2.3	0.02	weakly clustered
Leisure Block	1766.75	1788.38	0.99	-0.12	0.9	Random

4.2.1.2 Standard Deviation Ellipse Analysis

SDE analysis reveals the spatial distribution characteristics and directional trends of different leisure spaces within the study area. These spaces are relatively centralized around the central geographical coordinates but differ in rotation angles and distribution ranges (see Figure 4.1). As shown in Table 4.2, the overall LUS cover an average area of 545.98 square kilometres, accounting for 68% of Nanjing's CUA (802 square kilometres). This indicates that these spaces are widely distributed in the CUA and are significant in residents' daily lives. The standard deviations for the X-axis and Y-axis are both 0.109, suggesting a relatively balanced distribution within the CUA of Nanjing, with a clear directional tilt from southeast to northwest at 132.43 degrees.

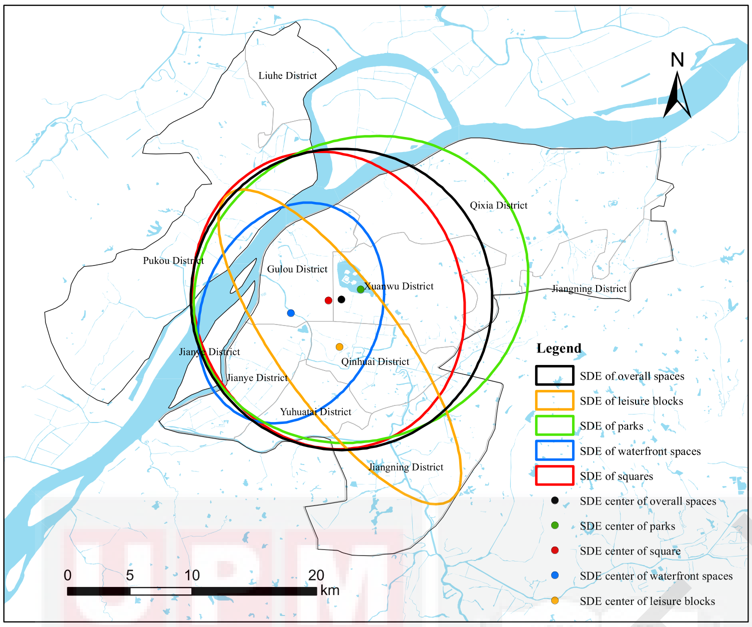


Figure 4.1 : Standard Deviation Ellipse of Leisure Urban Spaces in Nanjing's CUA
(Source: Author 2024)

LUS show significant clustering, primarily concentrated in the Jiangnan region's Gulou, Xuanwu, Jianye, Qinhuai, and Yuhuatai districts. The centroids of all types of LUS are located in the Jiangnan region, demonstrating a commonality in their layout, being close to the main urban functional areas and densely populated districts. The analysis results further reveal the distribution characteristics and directional trends of different types of LUS in Nanjing. Parks occupy the largest area, at 614.44 square kilometres, slightly above the city's overall average, with a rotation angle of 65.99 degrees, suggesting an east-west orientation. The standard deviation ellipse area for squares is 485.42 square kilometres, with a central position (X: 118.79, Y: 32.06) consistent with the overall level and a rotation angle of 159.81 degrees tilting northwest, possibly reflecting its integration with the urban structure. Waterfront spaces are relatively concentrated, covering 242.05 square kilometres, distributed along a north-south direction (rotation angle of 23.89 degrees), consistent with the linear characteristics of water bodies. The distribution of leisure blocks is the most concentrated, covering an area of 275.76 square kilometres, primarily along a southeast-northwest direction (rotation angle of 144.10 degrees), with the centre located at the southernmost point (X: 118.78, Y: 32.03).

Table 4.2 : Standard Deviation Ellipse Analysis Results for LUS in Nanjing's CUA

	Overall	Parks	Squares	Waterfront Spaces	Leisure Blocks
Area (Km2)	545.9836	614.4414	485.4175	242.0485	275.7554
Center X	118.7848	118.7989	118.7855	118.7483	118.7836
Center Y	32.0595	32.0667	32. 0588	32.0497	32.0251
XStdDist	0.1093	0.1233	0.0970	0.0638	0.0439
YStdDist	0.1087	0.1084	0.1090	0.0826	0.1369
Rotation	132.4345	65.9951	159.8054	23.8854	144.0990

Note: In this table, XStdDist represents the standard deviation distribution of the dataset along the X-axis, indicating variability in horizontal data points relative to the mean. YStdDist denotes the standard deviation distribution along the Y-axis, reflecting vertical data point variability

In summary, Parks and squares in Nanjing's CUA cover large areas with notable directionality, indicating their strategic deployment in urban planning to fulfil residents' daily leisure needs. Waterfront spaces, though smaller, are strategically placed along the city's waterways, highlighting the influence of water resources on leisure space planning. Leisure blocks are highly concentrated and serve as commercial and entertainment hubs, effectively generating a clustering effect. Despite the overall uniform distribution of leisure spaces in the central district, the limited range of waterfront spaces and leisure blocks suggests potential for future expansion.

4.2.1.3 Kernel Density Distribution

KDE analysis provides a clearer representation of the unit density of elements within their surrounding neighbourhoods. As seen in Figure 4.2, the CUA of Nanjing exhibits distinct spatial characteristics in the distribution of LUS, presenting a "one core, multiple points" pattern. LUS are densely distributed and exhibit strong spatial continuity at the intersection of the Gulou, Qinhuai, and Xuanwu districts within the Old City Area (OCA), forming the most densely clustered area in large groups, with wide-ranging, high-density, and strong continuity spreading outward. Beyond this high-density cluster, other areas also feature smaller clustered centres, such as the Liuhe district in the northeast and the Qixia district in the southeast. Some new urban areas, such as the Jianye, Pukou, and Jiangning districts, show lower sprawl and diffusion density.

Parks are primarily concentrated in the OCA and the urban new areas in the northeast, mainly consisting of two connected high-density cores represented by the Qinhuai and Yuhuatai districts and a high-density core in the Jiangning district to the northeast, forming three similarly sized clustered centres. In the OCA, parks are densely distributed, providing convenient leisure spots despite their smaller size. The southern Yuhuatai district has many parks with larger areas, forming a significant leisure green network. In the eastern Qixia, southeastern Jiangning, and northwestern Pukou districts, parks are more sparsely distributed but offer expansive outdoor activity spaces. The northern Liuhe and Pukou districts have fewer parks, but these open areas are generally suitable for park development.

Squares are mainly concentrated in the core areas of the OCA and the northern new urban districts. At the intersection of the Gulou, Qinhuai, and Xuanwu districts within the OCA, squares are densely distributed, often in commercial areas and key nodes, providing convenient social and leisure places. In the south (Jianye, Yuhuatai, and Jiangning districts), squares are widely distributed, with new development projects squares fostering community interaction. There are fewer squares in the east and north (Qixia and Liuhe districts), but they cover larger areas that support community activities. In the western Pukou district, square distribution is sparse but still provides important public spaces at key locations. The distribution of squares is focused on core areas, with a significant presence in both old and new urban districts, reflecting their importance in urban public life, similar to the distribution characteristics of parks.

Waterfront spaces form distinct clusters in areas adjacent to water bodies Yangtze River and Qinhuai River, consisting of a large cluster centre in the middle of the Yangtze, two smaller centres, and a small cluster centre along the Qinhuai River. Waterfront spaces are densely distributed in the Jiangnan region's Gulou, Jianye, and Yuhuatai districts, offering a wealth of water-based activities and leisure places. In the western Pukou district, waterfront spaces along the north bank of the Yangtze provide unique waterfront landscapes and recreational opportunities. In the eastern and southern new development areas, such as Qixia, Jiangning, and Liuhe districts, waterfront spaces are relatively sparse but still provide important leisure resources at some key locations.

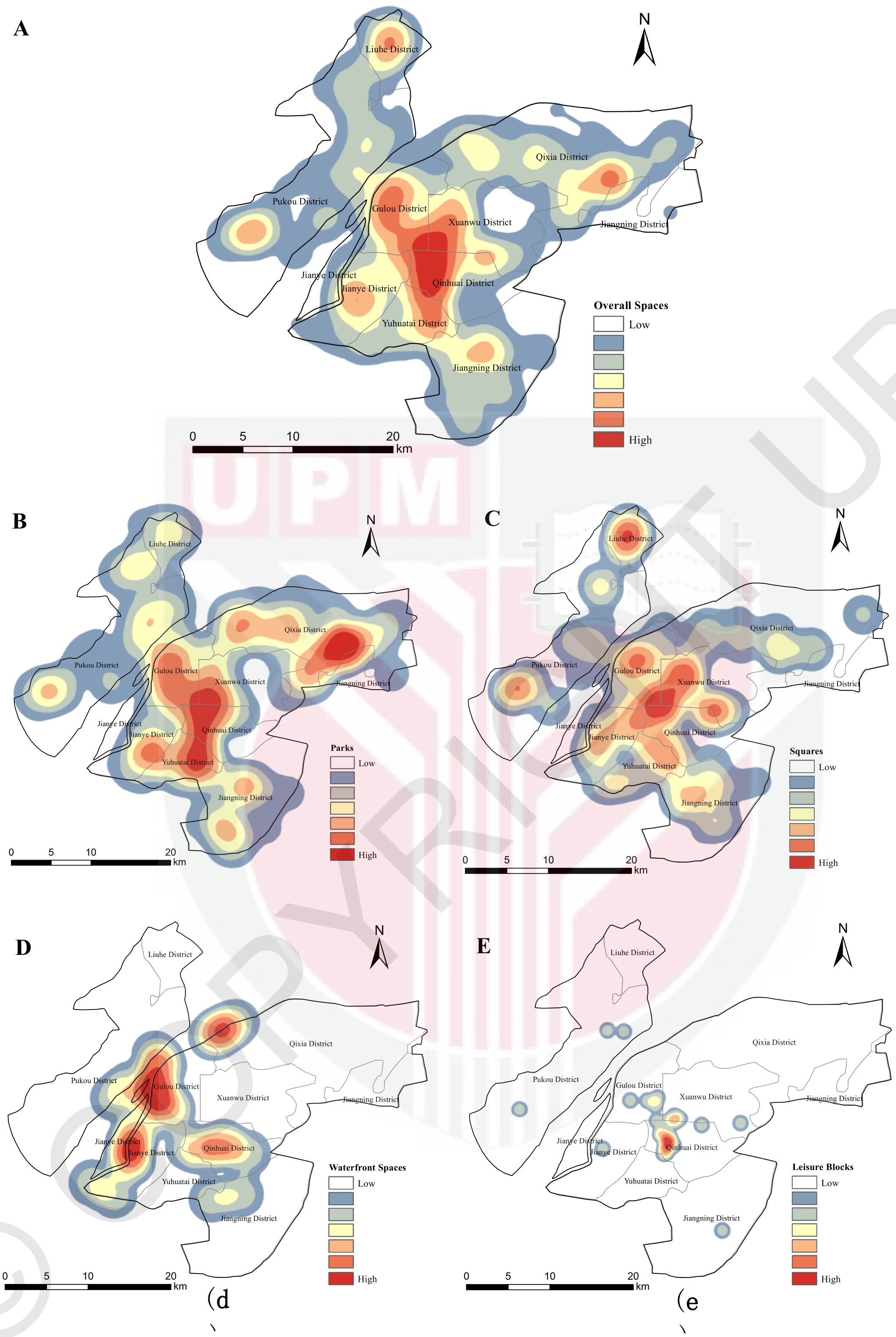


Figure 4.2 : Nuclear Density Distribution of Overall LUS (A), Parks (B), Squares(C), Waterfront Spaces(D), Leisure Blocks (E) in Nanjing's CUA
(Source: Author 2024)

Leisure blocks are primarily concentrated in the OCA, particularly in the Gulou and Qinhuai districts, often in commercially bustling areas. These areas serve as primary venues for leisure and entertainment, offering diverse social and cultural activities. A few leisure blocks exist in the Jianye, Xuanwu, and Pukou districts, with almost no supply in other areas. Overall, the siting of leisure blocks is similar to squares, concentrated in areas of frequent commercial and social activities, but their distribution is more focused, and there is very little supply in newly developed areas.

4.2.2 The Characteristics of Spatial Distribution by Subdistricts

4.2.2.1 The Population Density by Subdistricts

The population density map of Nanjing's metropolitan region provides a clear visualization of residential distribution and implicitly highlights the clustering and distribution characteristics of LUS. To better understand the population spread, Figure 4.3 uses different shades to represent varying population densities, while numerical annotations indicate the actual population quantities. The central district, marked by a dark brown shade indicating the highest density (ranging from 5,269 to 14,402 inhabitants per square kilometer), reflects a high degree of urbanisation. This urban core, characterized by a concentration of commercial, administrative, and densely populated residential areas, likely suggests a corresponding concentration of leisure spaces, such as parks and squares, designed to serve the high population density.

Moving outward from this core, the transition to lighter shades signifies a decrease in population density, ranging from 3,224 to 5,268, then 1,926 to 3,223, and 922 to 1,915 inhabitants per square kilometre. This gradation likely reflects a corresponding shift in leisure space characteristics—from highly concentrated leisure nodes within the city

Center to more dispersed leisure areas in the outskirts. These intermediary zones may feature a mix of medium-density residential and commercial developments, with parks, squares, and waterfront spaces interspersed to cater to the recreational needs of these populations.

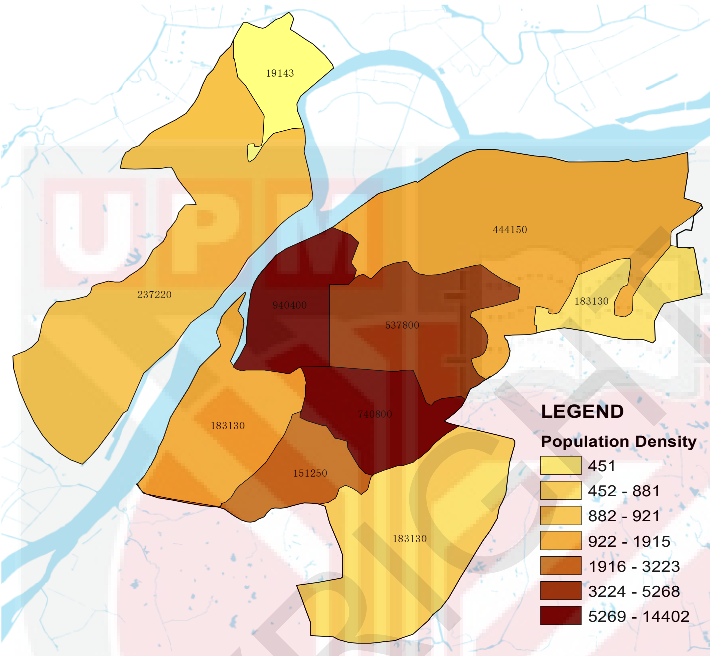


Figure 4.3 : The Quantity and Density of Population of Subdistricts in Nanjing's CUA
(Source: Author 2024)

The periphery, illustrated in the palest tones indicating the lowest population densities of 451 to 881 individuals per square kilometre, may correspond to more extensive but less densely populated leisure spaces, such as larger suburban parks and leisure blocks that accommodate the spatial preferences of suburban and peri-urban residents. This intricate interplay between population density and the distribution of leisure spaces holds significant importance. It highlights a potential correlation where higher population densities in urban centres coincide with a more significant clustering of leisure spaces. Conversely, the suburban and peri-urban fringes, with their lower densities, are associated with more extensive and less clustered leisure amenities. Understanding this relationship is crucial for urban planners and policymakers as they strive to create balanced, accessible, and sustainable leisure environments that serve the population's well-being across the entire urban gradient of Nanjing.

4.2.2.2 The Density of Leisure Urban Spaces by Subdistricts

Delving into the regional level, the layout of leisure spaces in the historical CUAs of the Jiangnan region is notably dense. Take Gulou District, for instance; with its high population and concentration of leisure spaces, it reaps the benefits of its central location and long urban development history. This affords a variety of leisure opportunities to its residents, including parks, squares, and waterfront spaces. While Qinhuai District may not rival Gulou in leisure space density, it boasts a distinct advantage in leisure block offerings, directly reflecting its rich historical and cultural essence. Conversely, Xuanwu District, despite its high population density, does not feature prominently in terms of leisure space availability. These districts, rich in cultural heritage and crowded, are at the forefront of Nanjing's urbanisation and tertiary sector growth. Nevertheless, they exhibit disparities in the provision of leisure spaces.

In the surrounding urban regions, characterized by their extensive territories and sparser population, leisure and tourism resources are more widely dispersed. Such spatial expanses are conducive to developing large natural leisure areas, including parks and open spaces like squares. Data from Figure 4.4 indicates that park density in the Qixia and Jiangning districts is comparatively high, mirroring the abundance of natural leisure resources. In parallel, the notable density of squares in the Qixia and Liuhe districts underscores a proactive stance toward planning open areas.

The development of waterfront spaces and leisure blocks should align with the geographical context. Given that waterfront spaces are tied to the presence of natural water bodies, such as the Yangtze and Qinhuai rivers, they are less common in districts like Liuhe, Xuanwu, and Yuhuatai, with Xuanwu notably devoid of such spaces due to the absence of these rivers. The concentration of waterfront spaces in Gulou District is attributed to its proximity to the Yangtze River. Pukou District, despite possessing waterfront spaces, sees a diluted density because of its vastness. Leisure blocks are typically integrated into existing historical and cultural neighbourhoods or areas with active art scenes. For example, the old urban area of Qinhuai District displays a significantly higher density of leisure blocks than other districts. Conversely, Liuhe, Qixia, and Yuhuatai districts do not feature such leisure blocks.

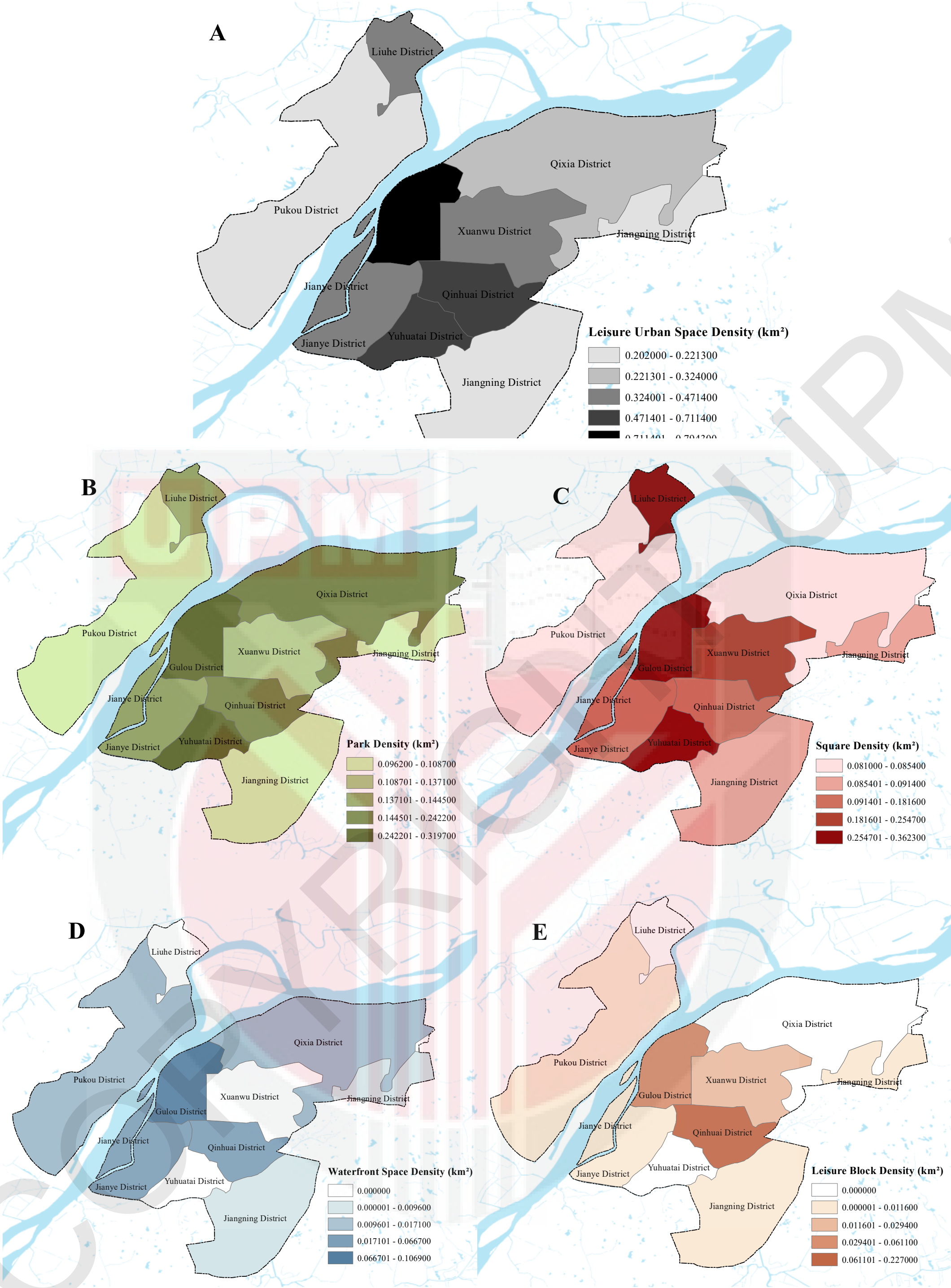


Figure 4.4 : The Density of, Overall Leisure Urban Spaces (A), Parks (B), Squares (C), Waterfront Spaces (D), and Leisure Blocks (E), by Subdistricts in the CUA in Nanjing's CUA
(Source: Author 2024)

4.2.2.3 Correlation and Disparities between Population Density and Leisure Space Distribution

In Nanjing, a distinct pattern emerges in the distribution of leisure resources: a high concentration in the central urban districts tapering off towards the peripheral regions. This pattern aligns closely with the varying degrees of population density mapped in Figure 4.3, where darker shades indicate areas with the densest population. Such areas are typically furnished with an array of leisure spaces, underscoring the principle that high-density areas are often well-equipped with amenities to support the recreational needs of their population. Nonetheless, a deeper analysis of Figure 4.4, which delineates the density of different leisure spaces, reveals that the provision of these amenities does not always directly correspond to the population density. For instance, while central districts exhibit a high density of parks and squares catering to the needs of their dense populations, the distribution of waterfront spaces and leisure blocks is more nuanced. Waterfront spaces (D) are most prevalent along the river, reflecting geographical constraints more than population distribution. Similarly, the distribution of leisure blocks (E) suggests a planning approach prioritizing cultural and historical value over sheer population numbers.

4.2.3 Analysis of Service Coverage Blind Areas

The Nanjing government is committed to creating a high-quality, livable, 15-minute living circle, which puts human needs at the forefront and strives for harmonious transportation spaces with the urban spatial layout. Within this framework, the reasonable arrangement of LUS is seen as a pivotal strategy for achieving a leisure-oriented city, as articulated by the Nanjing Municipal Urban Planning Bureau in 2022. Therefore, it is essential to analyze the spread of LUS within a 15-minute walk (1500 meters) in the main urban area of Nanjing to assess whether it fulfils the daily leisure requirements of its residents.

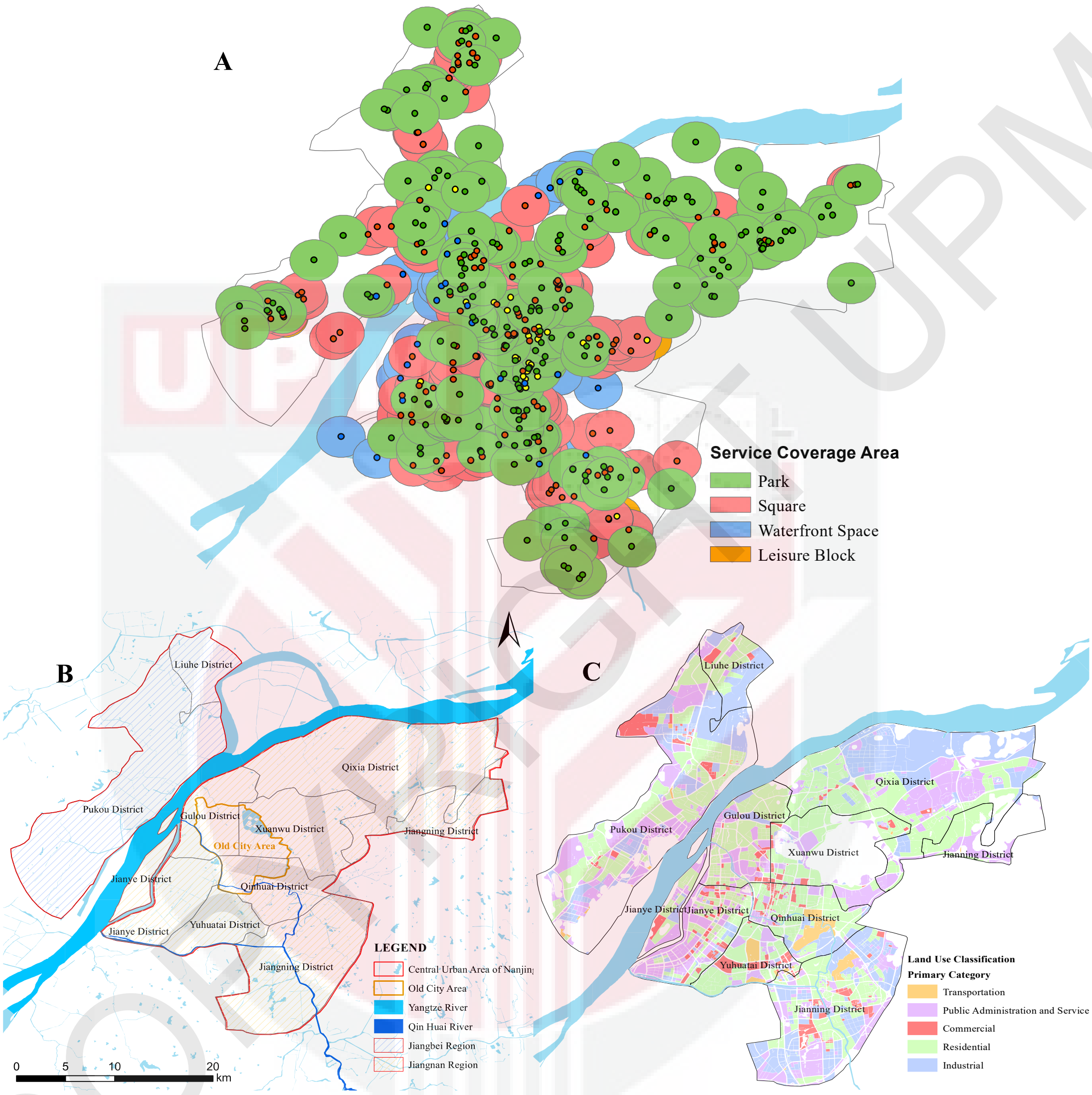


Figure 4.5 : Service Coverage Area (1500m) of LUS (A), Subdistrict Distribution (B), Land Use Patterns (C), in Nanjing's CUA
(Source: Author 2024)

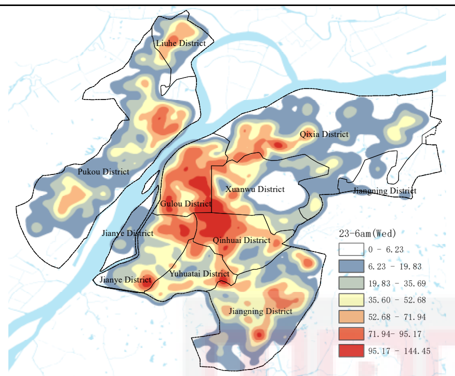
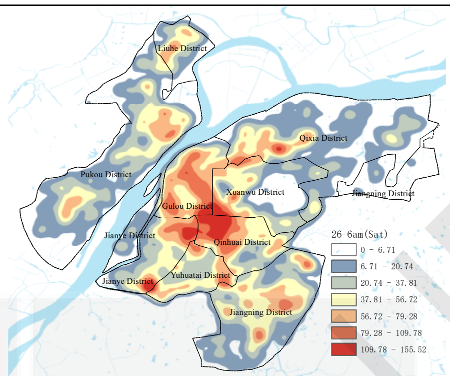
As shown in Figure 4.5(A), the service radius of LUS generally covers Nanjing's main urban area, yet some gaps are evident. As depicted in Figure (B), these gaps predominantly exist in OCA, such as Xuanwu District, as well as in some new urban areas like Qixia District, Pukou District, Liuhe District, and Jiangning District. To further understand the causes of these service gaps, this study also considers the distribution of land use in the analyzed regions (refer to Figure 4.5(C).

The analysis pinpoints the primary gaps and their underlying reasons: a) Eastern Xuanwu District: This area encompasses the large scenic area of Zhongshan Scenic Area, covering approximately 54 square kilometres, rich in natural landscapes and historical sites. The low activity concentration here is attributed to the large area and scattered distribution of attractions, leading to visitors dispersing among these sites and thus lowering the activity density. However, this area has limited potential for developing new LUS, given Xuanwu District's primary role as an administrative division and a historic city rich in historical landmarks. With 98.8% of Xuanwu District's land already developed, predominantly for residential, public administration, and commercial services, the available land is minimal, and the capacity for spatial resources and spatial load is saturated, lacking sufficient reserves for sustainable development. b) Northern Qixia District: Land use distribution reveals that this area is primarily near water bodies. It hosts several ports, industrial parks, and some mountainous areas. c) Northeastern Jiangning District: This area is undeveloped and does not have specific planning goals or policies; hence, it lacks detailed land use requirements. With low residential density, it mainly comprises mountains and vast undeveloped plains, making it a potential area for focused development. d) Southwestern and Northeastern Pukou District: Both areas are undeveloped zones. Due to limited natural resources, these areas currently contain industrial parks, factories, and a few new or under-construction residential communities, indicating their potential for focused development. e) Pukou and Jiangning Districts, as emerging development areas in the main urban region, have large areas, short development periods, and incomplete supporting infrastructure. This results in higher daily commuting costs for residents and weaker attraction for population agglomeration. The small population density and limited leisure time contribute to lacking LUS in these new districts.

4.2.4 The Spatiotemporal Distribution Characteristics of Population Activity and Its Correlation with Leisure Urban Spaces

The daily pattern of activity concentration in the OCA follows a cycle of high-density distribution with a pronounced core, transitioning back to a contiguous high-density distribution as the day unfolds. (a) Between 6:00 AM and 12:00 PM, the activity density in the OCA is notably higher, indicating a preference for concentrated activities in the morning. The spread of high-density activities likely reflects the morning peak, with people gathering at transportation and commercial hubs. (b) From 12:00 PM to 6:00 PM, the activity density becomes more prominent, especially in areas like Shanxi Road, Zhujiang Road, Xinjiekou, and Confucius Temple commercial circles, with a noticeable shift from a patchy to a more dispersed distribution pattern. (c) Between 6:00 PM and 8:00 PM, activities mainly cluster in the Xinjiekou and Confucius Temple commercial circles, reflecting their popularity for evening dining and entertainment. (d) Finally, from 8:00 PM to 11:00 PM, the pattern in the CUA changes from a core-multi-point aggregation to a contiguous distribution, similar to the observations at 9:00 AM, as citizens wind down their leisure activities and transition into nighttime activities.

Table 4.3 : Spatial Distribution of Population Activity Clustering in Different Time Points

<table>
<tr><th>Weekday</th><th>Weekend</th></tr>
<tr><td colspan="2">6:00 AM</td></tr>
<tr><td>
</td><td>
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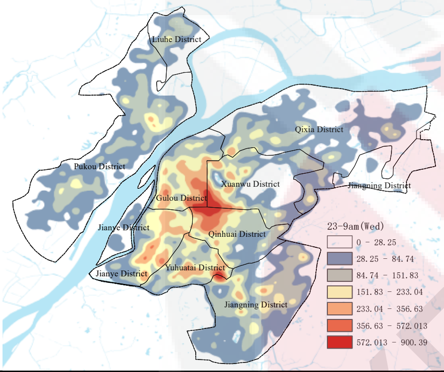
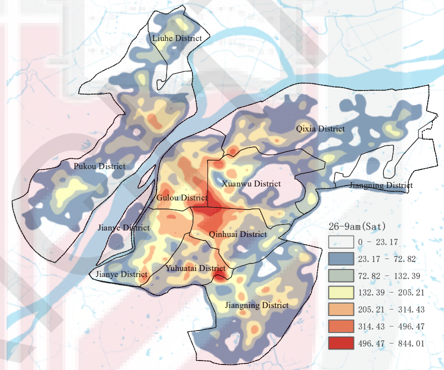
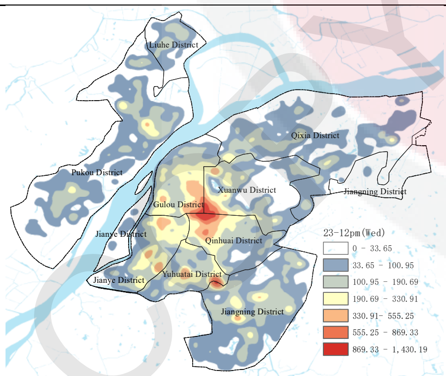
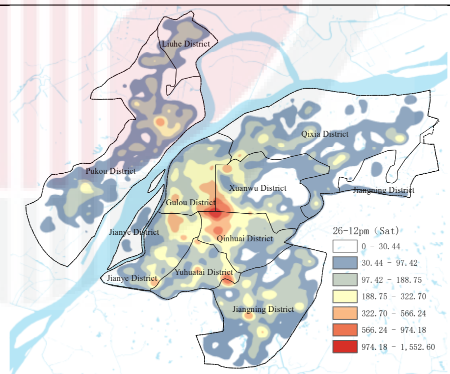
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">12:00 PM</td></tr>
<tr><td>
</td><td>
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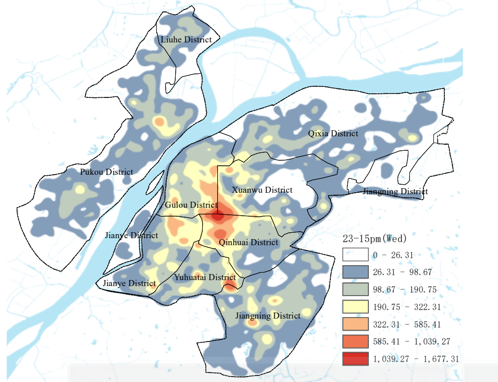
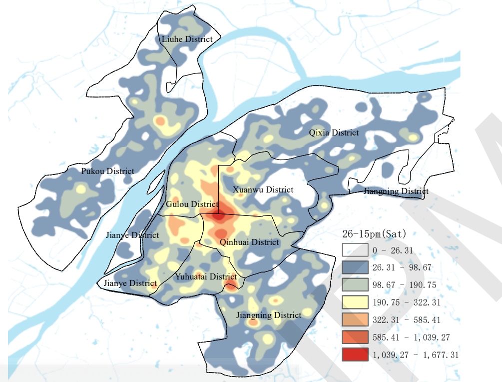
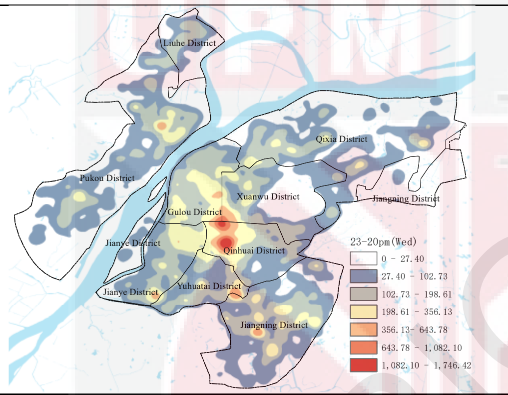
Table 4.3 : Continued

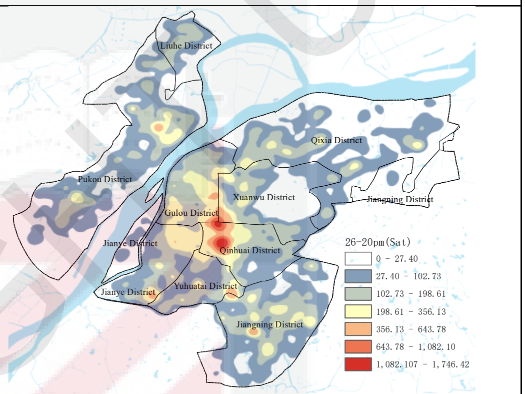
3:00 PM



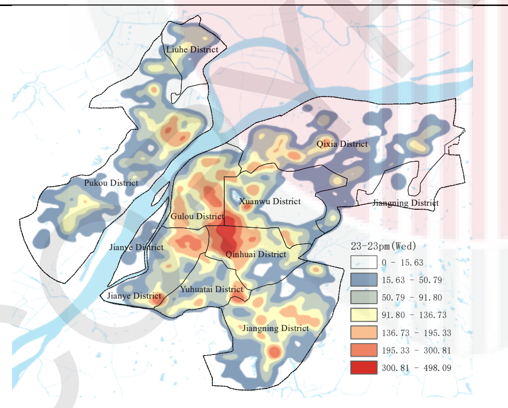


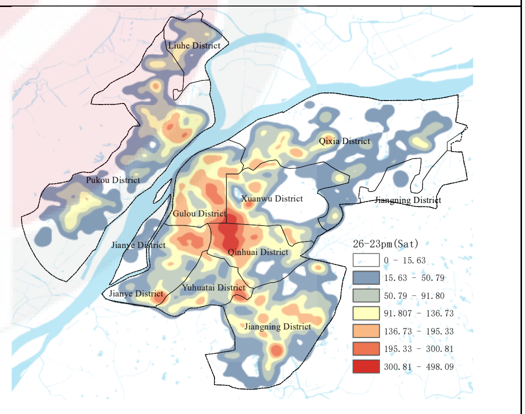
8:00 PM





11:00 PM





Analyzing the relationship between the spatial distribution of leisure spaces (LUS) and public activity patterns is crucial for urban planners. This study examines the correlation between leisure space placement and activity intensity, focusing on data from a specific time—Wednesday at 9 AM. Figure 4.1 reveals that areas with high population activity closely align with high-density leisure spaces, particularly in the three OCA. These spaces not only attract people but also facilitate substantial public engagement, indicating their integration into the urban fabric and the potential for increased use. The densest activity occurs at the intersections of the three OCA, with a minor concentration in the southeastern Yuhuatai District. The highest density of leisure spaces extends across these central areas and parts of Qinhuai District, with activity dispersing outward. In contrast, peripheral areas show medium-level aggregation, suggesting lower accessibility or appeal. High-accessibility zones exhibit greater public activity, underscoring the importance of strategic leisure space placement in urban planning.

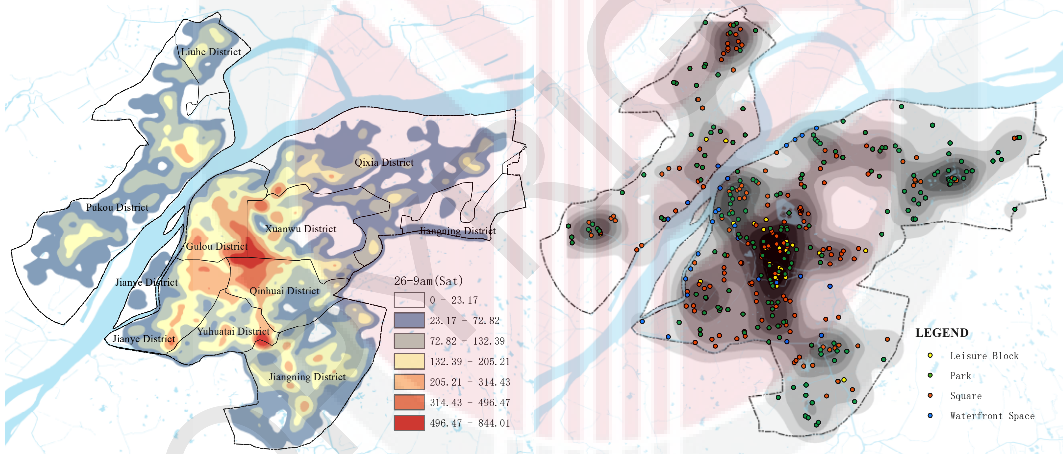


Figure 4.6 : Spatial Distribution of, Population Activity Clustering at 9:00 AM on Weekday (A), Leisure Urban Spaces(B), in Nanjing's CUA
(Source: Author 2024)

4.3 Analysis of Evaluation Results across Multiple Indicators in the Vitality of Research Spaces

This section presents a detailed descriptive analysis of the statistical results and performance across various evaluation indicators for 11 research spaces and different types of spaces.

4.3.1 Overview of the Selected Research Spaces

Figure 4.7 illustrates the locations of the 11 research spaces selected for this study.

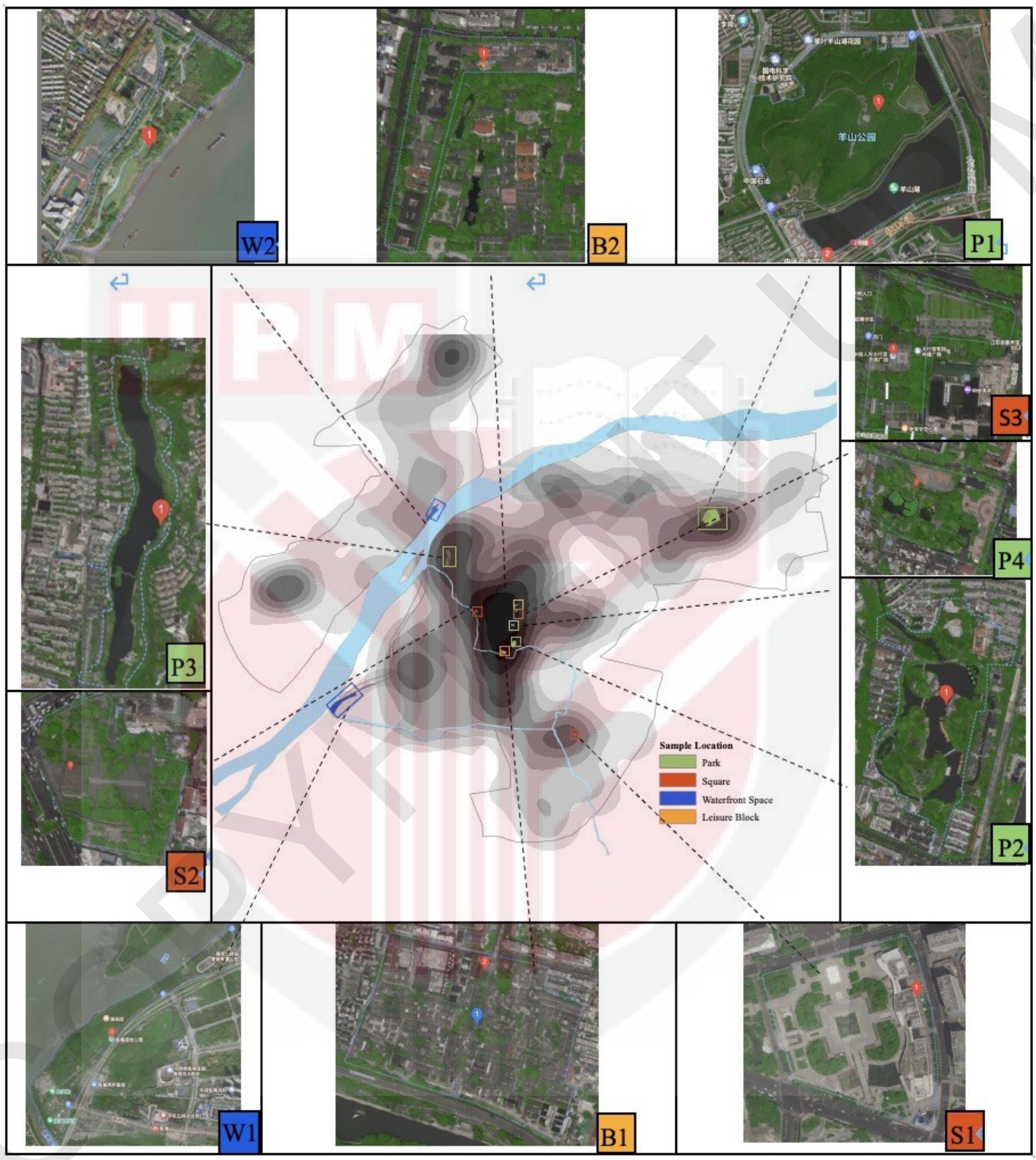


Figure 4.7 : The Locations of Research Spaces
(Source: Author 2024)

To enable a more comprehensive inquiry into these spatial entities, each was assigned a unique numerical identifier and sorted based on their respective areas, as delineated in Table 4.4. Specifically, the parks were designated as P1, P2, P3, and P4; squares as S1, S2, and S3; waterfront spaces as W1 and W2; and leisure blocks as B1 and B2.

Table 4.4 : Overview of Basic Information of 11 Research Spaces

Space Type	Code	Name	Area (ha)	Service Range (ha)	District
Park	P1	Yangshan Park	186.22	416.89	Qixia
	P2	Bailuzhou Park	19.14	219.40	Qinhuai
	P3	Xiaotaoyuan Park	15.84	346.85	Gulou
	P4	Zhenghe Park	3.30	154.28	Qinhuai
Square	S1	Tianyin Square	9.47	181.28	Jiangning
	S2	Hanzhongmen Square	4.37	158.74	Qinhuai
	S3	Daxinggong Square	1.37	104.57	Xuanwu
Waterfront Space	W1	Yuzui Waterfront	85.91	320.55	Jianye
	W2	Qiaobei Waterfront	47.34	231.09	Pukou
Leisure Block	B1	Laomendong Block	14.84	204.31	Qinhuai
	B2	1912 Block	4.40	191.46	Xuanwu

4.3.2 Analysis of the Indicators of Crowd Activity

This section provides a detailed descriptive analysis of the four indicators of crowd activity. The computed values for all indicators are compiled in Appendix G-1.

4.3.2.1 Spatial Clustering

This section analyzes the aggregation and distribution characteristics of crowd activity across various LUS in Nanjing's CUA. The value of spatial clustering in activity is derived from the average crowd activity density observed within each research space over a week. This analysis categorizes activity clustering into six levels using the natural break method in ArcGIS, visually represented in Figure 4.8(A).

(a) Overall Performance:

The analysis shows notable variation in activity density across the research spaces. As shown in Table 4.5, only four spaces (36% of the total) exhibit activity clustering above the sample mean (12.73), with Daxinggong Square (S3) having the highest density of 55.12, more than four times the average. The lowest activity density is observed in Yuzui Waterfront (W1), with only 0.18. Most spaces, especially those in the city center, show higher activity during weekends, except for two locations. This pattern suggests a prevalent issue of underutilization in many research spaces. Additionally, over 80% of these spaces experience heightened weekend activity, except for S2 and P3, highlighting a distinction in activities during weekdays and weekends.

Table 4.5 : Statistics of the Indicator of Spatial Clustering in Each Research Space

Code	Name	A Week	Weekdays	Weekends
S3	Daxinggong Square	55.12	51.45	65.84
B2	1912 Block	26.56	25.83	28.96
S1	Tianyin Square	17.54	16.95	19.38
S2	Hanzhongmen Square	14.48	15.18	12.17
B1	Laomendong Block	11.91	11.49	13.17
P4	Zhenghe Park	7.53	7.42	7.82
P2	Bailuzhou Park	3.05	3.02	3.19
P3	Xiaotaoyuan Park	2.78	2.84	2.67
W2	Qiaobei Waterfront	0.67	0.64	0.75
P1	Yangshan Park	0.19	0.19	0.20
W1	Yuzui Waterfront	0.18	0.18	0.19

(b) Spatial Distribution Characteristics:

The distribution of activity clustering, as shown in Figure 4.8(A), tends to decrease from the city Center towards the outskirts.

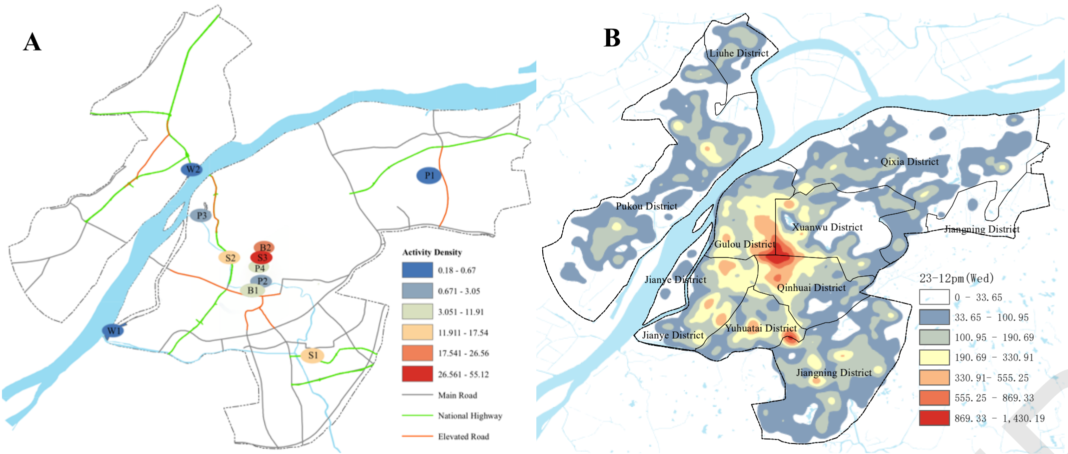


Figure 4.8 : Spatial Distribution of, the Value of Spatial Clustering in Research Spaces (A), Population Activity (B), in Nanjing's CUA
(Source: Author 2024)

This pattern reflects the general spatial distribution of crowd activity in the study area, particularly during midday (Figure 4.8(B)). The high activity clusters, particularly in spaces like S3 and B2, are strategically located at the convergence of densely populated OCA. The second ring, encompassing S2, B1, and P4, shows moderate activity. However, the deviation in activity clustering in P4 and S1 suggests influences beyond mere location, possibly related to unique attractions within these spaces.

(c) Performance across Different Space Types:

An analysis over 7 days (Table 4.6) reveals minor variations between weekdays and weekends, with slightly higher averages during weekends. Leisure blocks and squares demonstrate a higher average activity clustering intensity than waterfront spaces. Leisure blocks and squares excel in activity clustering, reaching highs of 19.26 and 18.43, respectively. This is attributed to their accessibility and openness, making them hubs for various social, cultural, and commercial activities. Parks, with a lower activity density of 11.75, still play a vital role in urban life, offering natural retreats within the city. The reduced clustering intensity in waterfront spaces might be due to their geographical location and the seasonal nature of their attractiveness.

Table 4.6 : Comparative Descriptive Statistics of Spatial Clustering in Various LUS

Type/ Description	Maximum	Minimum	Mean	`Standard deviation
A Week	55.12	0.18	12.73	16.42
Workdays	51.45	0.18	12.29	15.41
Weekends	65.84	0.19	14.03	19.45
Park	7.53	0.19	3.39	3.05
Square	55.12	14.48	29.05	22.63
Waterfront Space	0.67	0.18	0.43	0.35
Leisure Block	26.56	11.91	19.24	10.36

The standard deviation analysis for activity clustering uniformity (Table 4.6) indicates that a lower standard deviation correlates with more balanced spatial clustering. Weekdays exhibit more balanced activity clustering compared to weekends. Waterfront spaces display the most uniform clustering, followed by squares and parks, with leisure blocks showing the most minor balance. The internal variance within waterfront spaces is the least, with a standard deviation 0.35. The variance in activity clustering across LUS in Nanjing's CUA is considerable, both among different space types and within the same category, indicating that various factors beyond just space type influence activity clustering levels.

4.3.2.2 Temporal Persistence

Temporal stability involves assessing two key metrics. The first is the 'fluctuation index,' which calculates the standard deviation of activity values within a research space over a week, reflecting the consistency of activity levels. The second metric is 'duration of high-intensity activity,' representing the total duration within a week that the space exhibits above-threshold activity intensity.

i. Fluctuation Index

The fluctuation index quantifies the variability of activity heat values at different times throughout a week within each space. Contrary to other metrics, a lower fluctuation index suggests a more stable pattern of activity, indicating that indices should be ranked from the most to the least stable. The findings are as follows:

(a) Overall Performance:

Table 4.7 shows notable variation in weekly activity heat value fluctuations across spaces. Six spaces have fluctuations below the average, with the lowest recorded in P4 (Zhenghe Park), W1 (Yuzui Waterfront), and W2 (Qiaobei Waterfront) at 9.42, 9.69, and 11.72, respectively. In contrast, B1 (Laomendong Block) exhibits the highest variability, with a fluctuation index of 106.58, nearly three times the average of 41.42. Other areas with high variability include B2 (1912 Block) and S1 (Tianyin Square), with indices of 80.53 and 79.23. Figure 4.9 further illustrates that spaces on the urban fringe show more consistent activity heat values.

When correlated with the land use distribution map of Nanjing's central urban region (Figure 4.9(B)), it is evident that the activity levels of LUS in proximity to commercial districts are more markedly affected by temporal fluctuations. Significantly, Zhenghe Park (P4), located within a commercial area, exhibits minimal variability, reflecting its role as a reliable leisure space for residents.

Table 4.7 : Statistics of the Fluctuation Index for the Indicator of Temporal Persistence in Each Research Space

Code	Name	A Week	Weekdays	Weekends
P4	Zhenghe Park	9.42	10.03	7.73
W1	Yuzui Waterfront	9.69	10.08	8.80
W2	Qiaobei Waterfront	11.72	11.59	11.47
P1	Yangshan Park	14.83	14.87	14.92
P3	Xiaotaoyuan Park	14.85	15.68	12.46
P2	Bailuzhou Park	18.28	18.04	19.03
S2	Hanzhongmen Square	42.58	46.92	28.86
S3	Daxinggong Square	67.61	65.31	72.13
B2	1912 Block	79.23	82.65	70.42
S1	Tianyin Square	80.53	75.87	90.56
B1	Laomendong Block	106.58	108.66	101.0

(b) Spatial Distribution Characteristics:

The spatial distribution of temporal persistence values within the research spaces is illustrated in Figure 4.9(A).

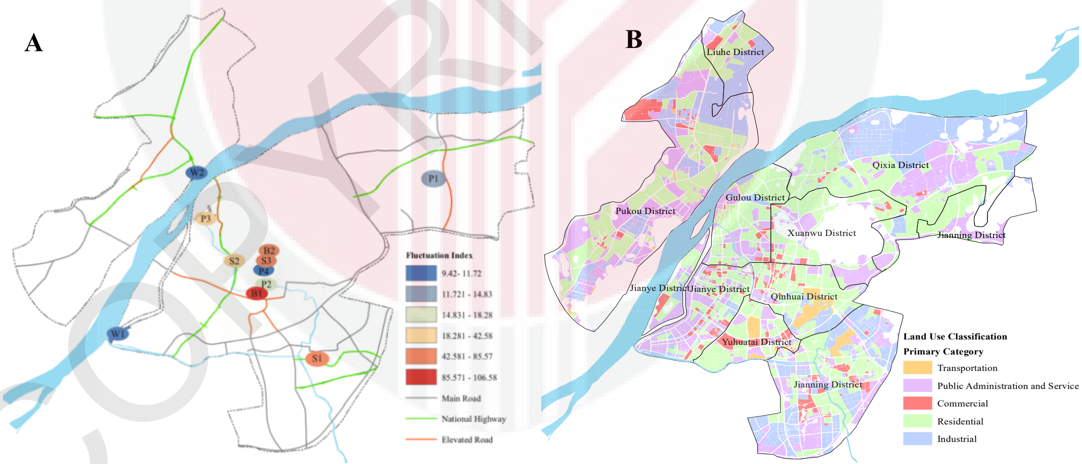


Figure 4.9 : Spatial Distribution of the Value of Fluctuation Index in Research Spaces (A), Land Use (B), in Nanjing's CUA
(Source: Author 2024)

(c) Performance across Different Space Types:

Across the broad range of LUS, the coefficient of variation in activity numbers does not significantly differ between weekdays and weekends or when viewed over the entire week (refer in Table 4.8).

Table 4.8 : Comparative Descriptive Statistics of Fluctuation Index of Activity in Various LUS

Type/ Description	Maximum	Minimum	Mean
A Week	106.58	9.42	41.42
Workdays	108.66	10.03	41.79
Weekends	101.00	7.73	39.87
Park	14.85	9.42	14.34
Square	80.53	42.58	63.57
Waterfront Space	11.72	9.69	10.70
Leisure Block	106.58	79.23	92.91

However, marked contrasts emerge when comparing different types of spaces. Waterfront areas display the most stable temporal activity with an average coefficient of variation of 10.70, and parks follow at 14.34. Squares and leisure blocks show more significant variability, with coefficients of 63.57 and 92.91, respectively. Furthermore, all parks (P) and waterfront spaces (W) record coefficients of variation below the general average, signifying relative temporal stability in these spaces.

(d) Temporal Variability Characteristics:

Figure 4.10 delineates the day-to-day variability in average activity values for various spaces across the week. The data highlights distinct patterns and disparities in activity levels between weekdays and weekends and from day to day. This suggests diverse cyclical changes in resident activities, with some spaces sharing similar patterns of activity value trends. Consequently, the research spaces are categorized based on the nature of their weekly activity value trends into three primary types: "/", "A", "M", and "—", representing various fluctuation patterns:

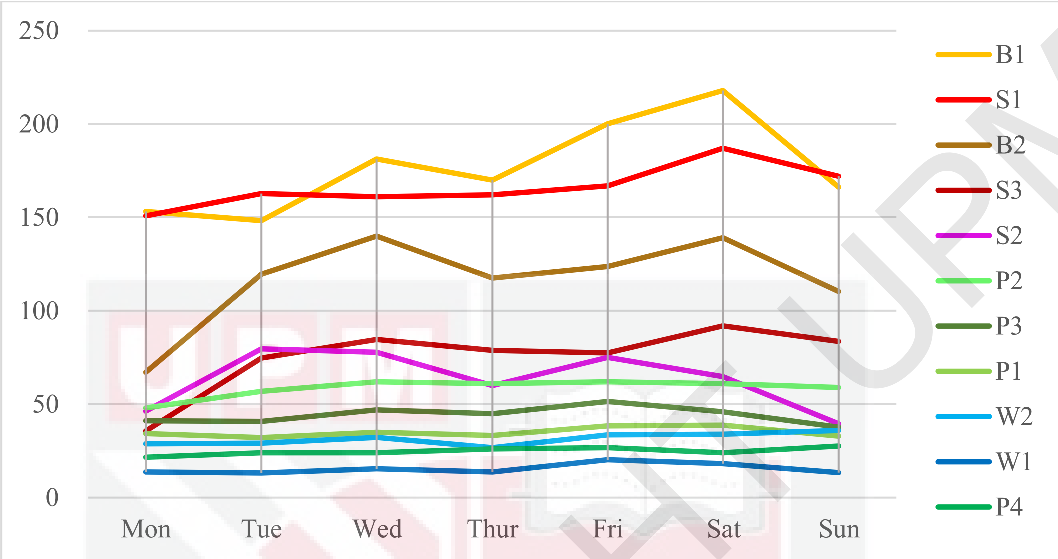


Figure 4.10 : Daily Fluctuation Curve of Activity Values in Each Research Space Throughout a Week
(Source: Author 2024)

The "/" Type represents a steadily increasing trend in activity values, with potential occasional drops, exemplified by B1, which peaks on Saturday.

The "A" Type is characterized by a low-activity plateau, followed by a spike and subsequent decline, as seen in spaces like S1 and S3, which peak on Saturday.

The "M" Type features dual activity peaks during the week, observed in spaces such as B2 on Wednesday and Saturday and S2 on Tuesday and Friday.

The "—" Type displays minor fluctuations within a confined range, indicating a steady activity throughout the week, typically seen in parks and waterfront spaces.

In addition to daily variability, the hourly fluctuation amplitude is scrutinized to comprehend the popularity of various space types across different times. Figure 4.11 illustrates these characteristic hourly trends from early morning to late evening, revealing distinct activity patterns across space types.

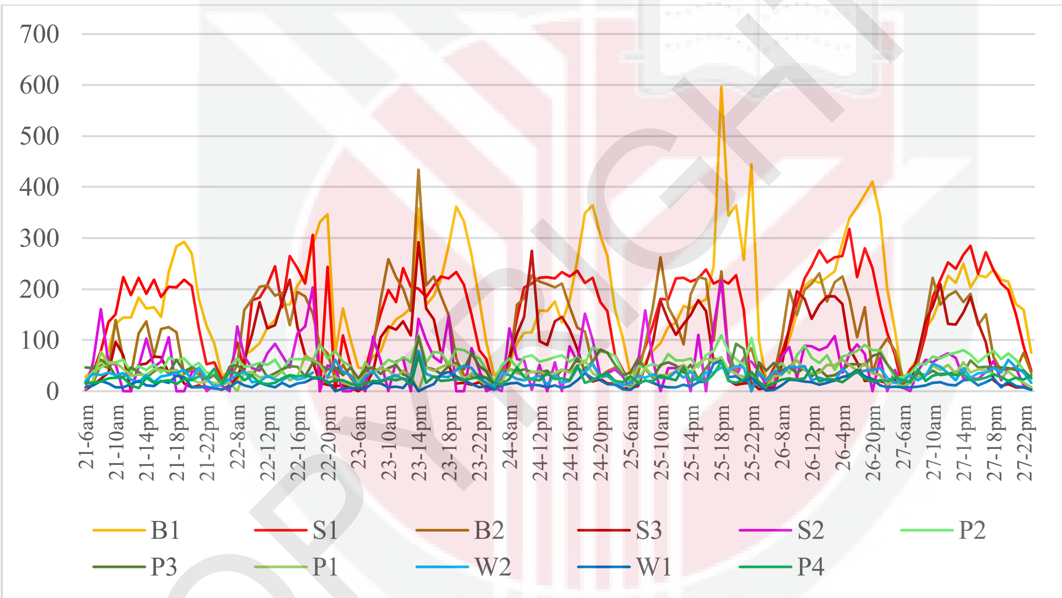


Figure 4.11 : Hourly Fluctuation Curve of Activity Values in Each Research Space Throughout a Week
(Source: Author 2024)

Leisure blocks, for example, experience sharp increases in visitor numbers post-5 PM on weekdays, peaking after dinner time, then diminishing. At the same time, weekends show a more gradual ascent from morning until post-dinner, indicating vibrant evening activities and steady weekend engagement. Conversely, peak activities in squares predominantly occur during daytime hours, rising from morning through early evening, then tapering off. However, with smaller fluctuation amplitudes, parks and waterfront spaces do not exhibit a pronounced pattern, underscoring their consistent activity levels irrespective of time, providing a stable and ongoing urban refuge.

ii. High-Intensity Activity Duration

This index measures the total hours in a week (126 hours) when activity in a space exceeds the average level. Due to minimal variance across spaces, the natural break method is not used for categorization. Instead, spaces are divided into two groups: those with mean durations below (blue) or above (red) the average.

(a) Overall Performance:

Table 4.9 reveals that the differences in the High-Intensity Activity Persistence Index among the research spaces are relatively small, yet more than 70% (eight spaces) have a weekly cumulative duration of high-intensity activity exceeding the mean of 61.45 hours.

Table 4.9 : Statistics of the High-Intensity Activity Duration for the Indicator of Temporal Persistence in Each Research Space

Code	Name	A Week	Weekdays	Weekends
P4	Zhenghe Park	68	37	31
W1	Yuzui Waterfront	66	34	32
P2	Bailuzhou Park	64	43	21
P1	Yangshan Park	64	44	22
B2	1912 Block	63	42	21
B1	Laomendong Block	63	32	30
S1	Tianyin Square	62	52	10
W2	Qiaobei Waterfront	62	44	13
P3	Xiaotaoyuan Park	57	29	26
S2	Hanzhongmen Square	55	37	15
S3	Daxinggong Square	52	52	10

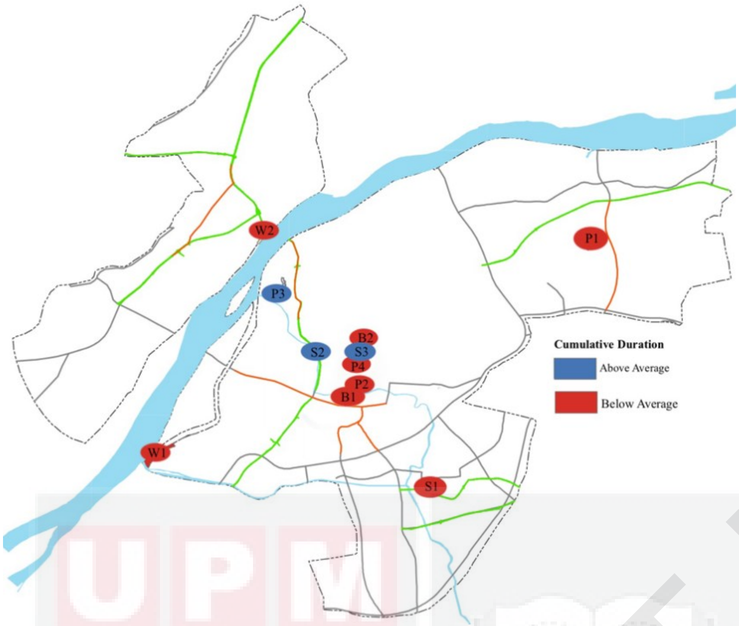


Figure 4.12 : Spatial Distribution of Different Levels of High-Intensity Activity Duration in Research Spaces
(Source: Author 2024)

Leading this index is P4 (Zhenghe Park), with 68 hours of high-intensity activity, which is approximately 10% above the mean. Only P3 (Xiaotaoyuan Park), S2 (Hanzhongmen Square), and S3 (Daxinggong Square) fall below the average, with S3 registering the lowest at 52 hours—nearly 9.45 hours under the mean. Figure 4.12 illustrates that these spaces include two squares and a park in the Jiangnan CUA, suggesting that the index is not spatially dependent.

(b) Performance across Different Space Types:

According to Table 4.10, squares demonstrate the broadest range in the duration of high-intensity activity, with cumulative hours varying from 52 to 62 hours.

Additionally, squares have one of the lower standard deviations in weekly active duration, at 5.13, indicating a degree of uniformity within this space type. This points to the coexistence of squares with varying efficiency in space utilization—some with high and others with low durations of intense activity. Contrarily, leisure blocks display a more consistent level of development in high-intensity activity duration.

Table 4.10 : Comparative Descriptive Statistics of High-Intensity Activity Duration for the Indicator of Temporal Persistence in Each Research Space

Type/ Description	Maximum	Minimum	Mean	Standard Deviation
Overall	68	52	61.45	4.82
Park	68	57	63.25	4.5
Square	62	52	56.33	5.13
Waterfront Space	66	62	64	2.83
Leisure Block	63	63	63	0

4.3.2.3 Group Diversity

Group diversity is assessed by quantifying the variety of group types frequenting a space. This is achieved by analyzing keywords associated with different crowd types from MD review data, with detailed data statistics in Appendix E (Table E-1).

(a) Overall Performance:

Reviewing Figure 4.13 shows that over half of the research spaces (six in total) display a group diversity level above the mean of 0.99 (Table 4.11). This indicates that while most leisure spaces in central Nanjing cater to diverse groups, there is potential for enhancement in fostering group heterogeneity.

(b) Spatial Distribution Characteristics:

The pattern emerging from Figure 4.14 suggests a decline in group diversity moving away from the city centre. Except for P2, areas within the old city Center exhibit higher group diversity. This pattern infers that the diversity of groups in LUS is influenced by their proximity to the Central Urban Areas.

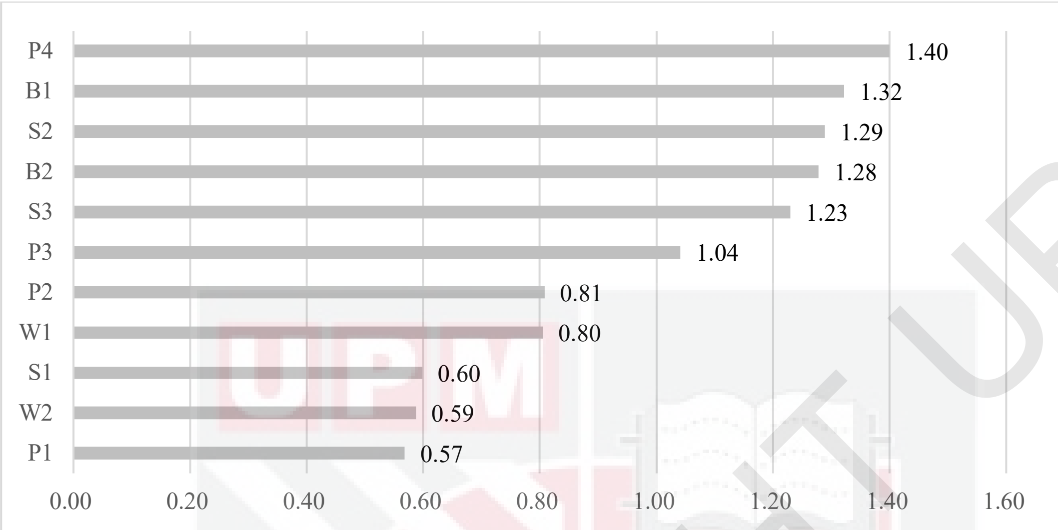


Figure 4.13 : Ranking of the Value of Group Diversity in Research Spaces
(Source: Author 2024)

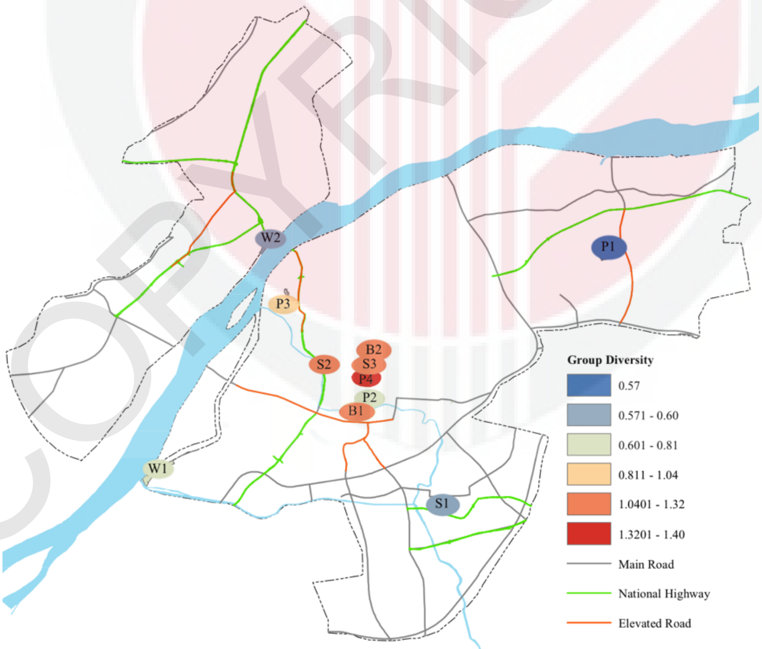


Figure 4.14 : Spatial Distribution of Different Levels of Group Diversity in Research Spaces
(Source: Author 2024)

(c) Performance across Different Space Types:]

A comparison of the Group Diversity across space types shows significant disparities (see Table 4.11). Leisure blocks and Squares score higher than the sample mean of 0.99, with averages of 1.30 and 1.04, respectively. Leisure blocks have low variance (standard deviation of 0.3), indicating consistent attraction of diverse groups. Squares, however, show more variability, with some areas like S1 lagging in diversity (Figure 4.13). Parks and waterfront spaces have lower averages of 0.95 and 0.69, suggesting a narrower appeal. Further analysis of demographic proportions will enhance understanding of each space's inclusivity.

Table 4.11 : Statistics of the Indicator of Group Diversity in Each Research Space

Type/ Description	Maximum	Minimum	Mean	Standard Deviation
Overall	1.40	0.57	0.99	0.33
Park	1.40	0.57	0.95	0.35
Square	1.29	0.60	1.04	0.38
Waterfront Space	0.8	0.59	0.69	0.15
Leisure Block	1.32	1.28	1.30	0.03

(d) Group Distribution Characteristics:

Figure 4.15 presents the distribution of visitor groups across research spaces, revealing three key patterns: a) Family and friend groups dominate leisure participation, with family groups exceeding 30% in all spaces and surpassing 60% in P3, P2, W1, S1, W2, and P1, while friend groups show particularly strong presence (over 30%) in leisure blocks B1 and B2; b) Solo visitors maintain a consistent presence across most spaces, peaking at 33% in S3 and remaining above 20% in B1, P4, and B2, though dropping to just 4% in some locations; c) Couples and organized groups show limited engagement, with couples reaching only 11% participation in P4 and S2, while organized groups appear in just a few spaces with maximum 4% presence in S2. The analysis further highlights how space type influences visitation patterns, with leisure blocks attracting younger friend groups, parks/squares being family-oriented, and waterfronts maintaining a balanced mix of visitor types.

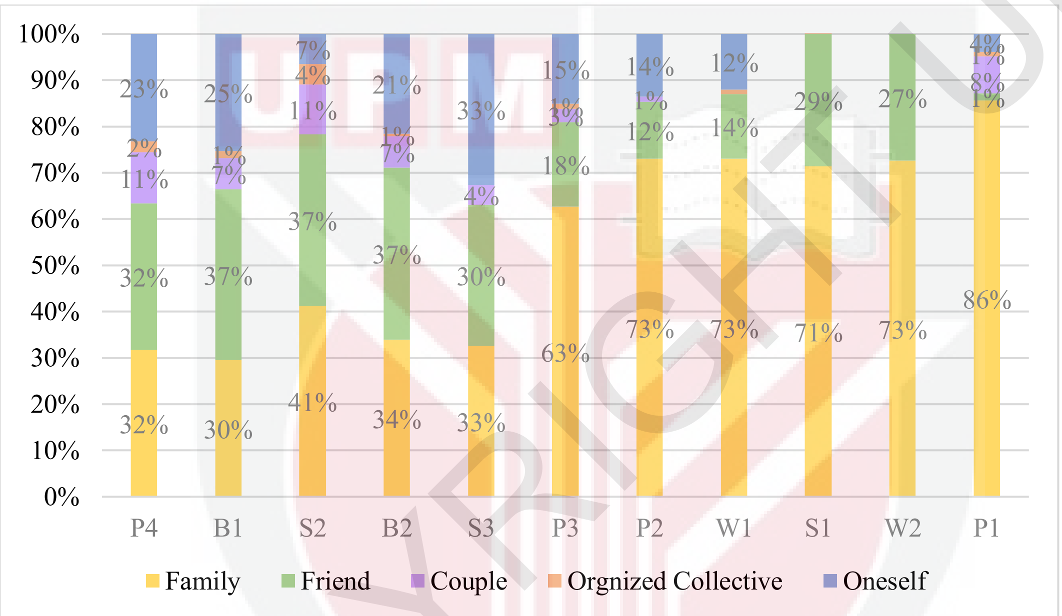


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Figure 4.15 : Proportion of Different Types of Companion Groups in Each Research Space
(Source: Author 2024)

4.3.2.4 Feedback Positivity

The evaluation of Feedback Positivity in leisure spaces encompasses the overall satisfaction rating and the sentiment scoring of user reviews. Appendix E (Table E-2) provides detailed data for this analysis.

i. Overall Satisfaction

(a) Overall Performance:

The satisfaction levels in most research spaces are commendably high, with the majority surpassing the average score of 4.52 (Table 4.12). However, some spaces do fall below this benchmark (Figure 4.16). Notably, over 70% of the spaces (8 in total) score above the average in visitor satisfaction, with Xiaotaoyuan Park (P3) at 4.74. Spaces like S1 (4.25), W1 (4.21), and P2 (4.17) are below the average, with P2 having the lowest score, reaching only 88% of the average. This suggests a need for revitalization and enhancements in these underperforming areas. Figure 4.17 shows the geographic distribution of the values, with no apparent spatial distribution characteristics evident.

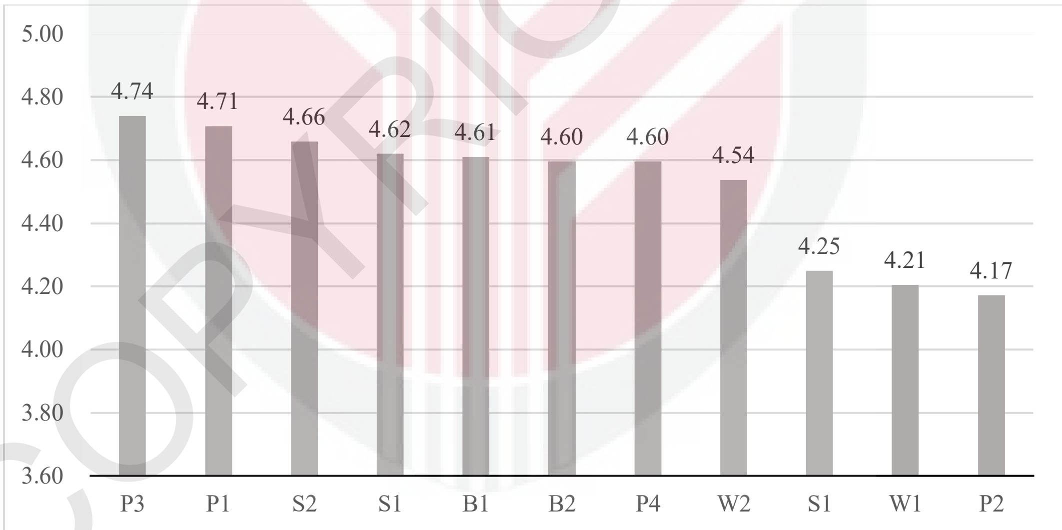

Figure 4.16 : Ranking of the Value of Overall Satisfaction in Research Spaces
(Source: Author 2024)

(b) Performance across Different Space Types:

Waterfront spaces average 4.37, the lowest satisfaction level among all types and below the overall average of 4.52 (Table 4.12), indicating a disparity between current offerings and public expectations in Nanjing's CUA despite an average score higher than the overall (4.55), Parks shows a wide range in satisfaction (standard deviation of 0.26), with the highest and lowest satisfaction scores coming from both categories. This variability suggests a diverse range of experiences and expectations among park visitors. With the highest average satisfaction score and a low standard deviation (0.1), leisure blocks indicate superior performance in meeting user satisfaction.

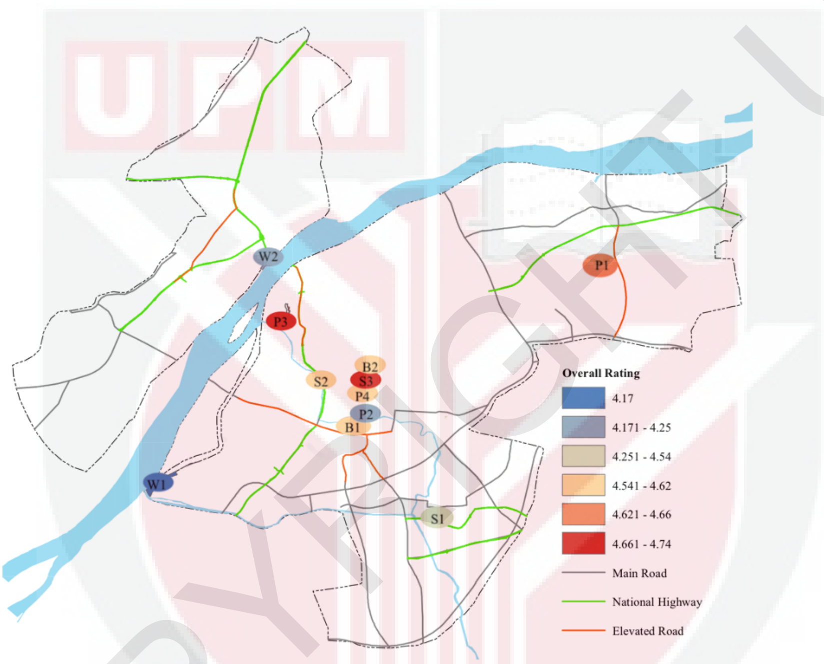

Figure 4.17 : Spatial Distribution of Different Levels of Overall Satisfaction in Research Spaces
(Source: Author 2024)

Table 4.12 : Comparative Descriptive Statistics of Overall Satisfaction of Activity in Various Space

Type/ Description	Maximum	Minimum	Mean	Standard deviation
Overall	4.74	4.17	4.52	0.21
Park	4.74	4.17	4.55	0.26
Square	4.66	4.25	4.50	0.22
Waterfront Space	4.54	4.21	4.37	0.23
Leisure Block	4.62	4.61	4.62	0.01

ii. Sentiment Scoring

(a) Overall Performance:

The sentiment scoring derived from leisure space reviews show significant variation (Figure 4.18, Table 4.13). About 45% of the spaces (5 out of 11) have scores above the average of 21.16, with P3 leading at 29.46, considerably higher than other spaces. The discrepancy among the lower-scoring spaces is relatively tiny but evident. Figure 4.19 shows that the results do not exhibit any clear spatial distribution characteristics. About 45% of the spaces (5 out of 11) have scores above the average of 21.16, with P3 leading at 29.46, considerably higher than other spaces. The discrepancy among the lower-scoring spaces is relatively tiny but evident.

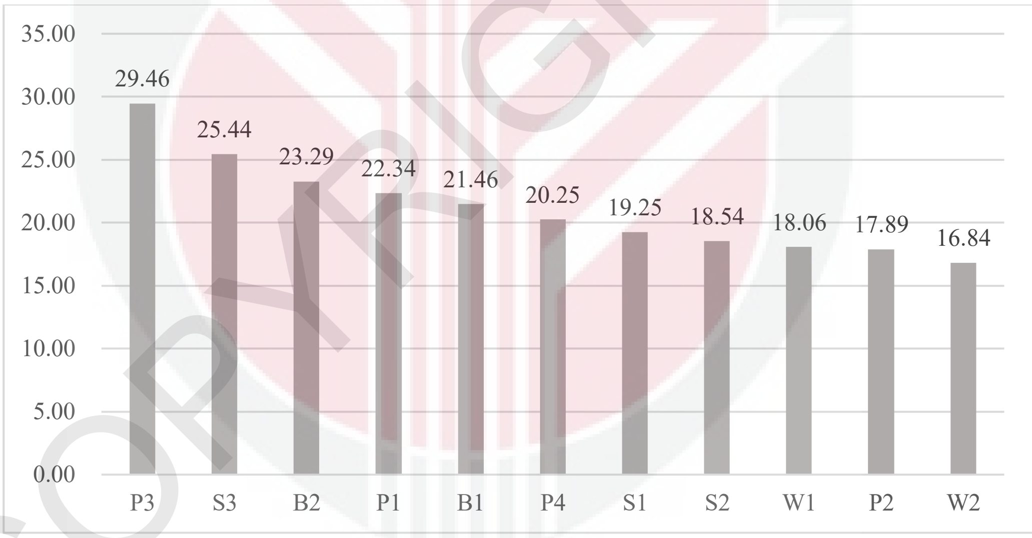

Figure 4.18 : Ranking of the Value of Sentiment Scoring in Research Spaces
(Source: Author 2024)

(b) Performance across Different Space Types:

Leisure blocks score a relatively high average sentiment score of 22.37 (Table 4.13), with a low variation (1.29), indicating positive emotional feedback from users. Parks and squares have similar average scores (21.07 and 20.90, respectively), but parks exhibit a higher standard deviation (5.00), suggesting more varied emotional responses. Waterfront spaces have the lowest average sentiment score at 17.45, indicating a need for improvements in these areas to enhance user experiences. This data underscores the importance of adapting leisure spaces to cater to user expectations and experiences better.

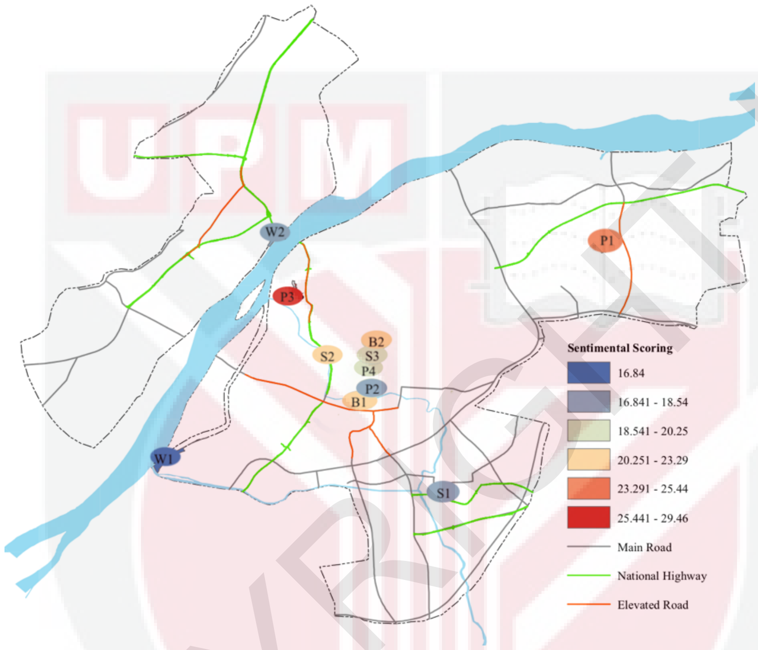

Figure 4.19 : Spatial Distribution of Different Levels of Sentiment Scoring in Research Spaces
(Source: Author 2024)

Table 4.13 : Comparative Descriptive Statistics of Sentiment Scoring of Activity in Various Space

Type/ Description	Maximum	Minimum	Mean	Standard Deviation
Overall	29.46	16.84	21.16	3.79
Park	29.46	17.89	20.90	5.00
Square	25.44	18.54	21.07	3.80
Waterfront Space	18.06	16.84	17.45	0.87
Leisure Block	23.28	21.46	22.37	1.29

(c) The Key Factors Revealed by Positive Feedback in Social Media Reviews:

This frequency analysis reveals several key factors people focus on when evaluating leisure spaces (see Figure 4.20). Notably, the high frequency of photography and cuisine emphasizes the importance of visual enjoyment and culinary experiences in attracting visitors. Additionally, the uniqueness of architectural styles and the richness of local characteristics are vital in attracting visitors. The historical and cultural experiences these spaces offer, as well as their suitability for walking, are also focal points for visitors. Social and entertainment factors, such as spending the day with friends and exploring trendy internet-famous spots, emphasise social interaction and novel experiences. Finally, factors such as environmental atmosphere, timing, convenience, and location also significantly influence the attractiveness of leisure spaces. In summary, these results indicate that when choosing leisure spaces, people not only pursue material pleasures like food and shopping but also place high value on the aesthetic, historical, and cultural aspects of the space and a comprehensive social and leisure experience.

Figure 4.20 : High-Frequency Word Cloud for the Top 5 Sample Spaces by Sentiment Scoring Levels
(Source: Author 2024)

4.3.3 Analysis of the Indicators of Built Environment

This section provides a detailed descriptive analysis of the seven built environment indicators. The computed values for all indicators are compiled in Appendix G-1.

4.3.3.1 Service Population Density

Figure 4.21 shows a particular variation in the service population density values within a 500-meter radius of the study spaces, ranging between 0.08 and 3.49. Over 54% (6 spaces) exceed the average value (1.46). Since the variation in this indicator is related to location rather than space type, Figure 4.22 reveals a decreasing trend from the city centre to the outskirts. The five spaces (S1, P3, W2, P1, and W1) below the average value are all located in the peripheral areas of the city, with values ranging from 0.08 to 0.91, represented in the figure by blue and green colours. The disparities in Service Population Density are more influenced by location than space type.

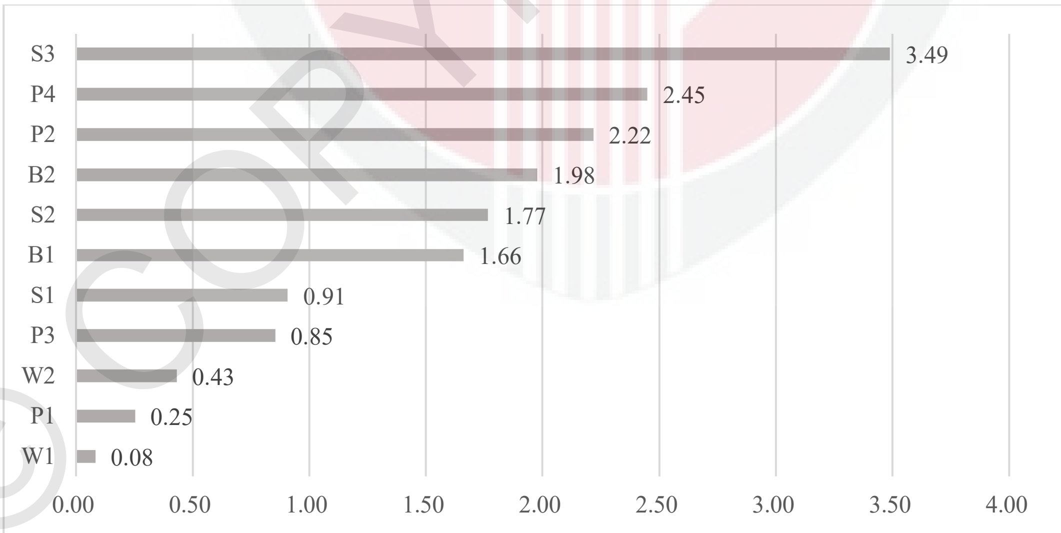

Figure 4.21 : Ranking of the Value of Service Population Density in Research Spaces
(Source: Author 2024)

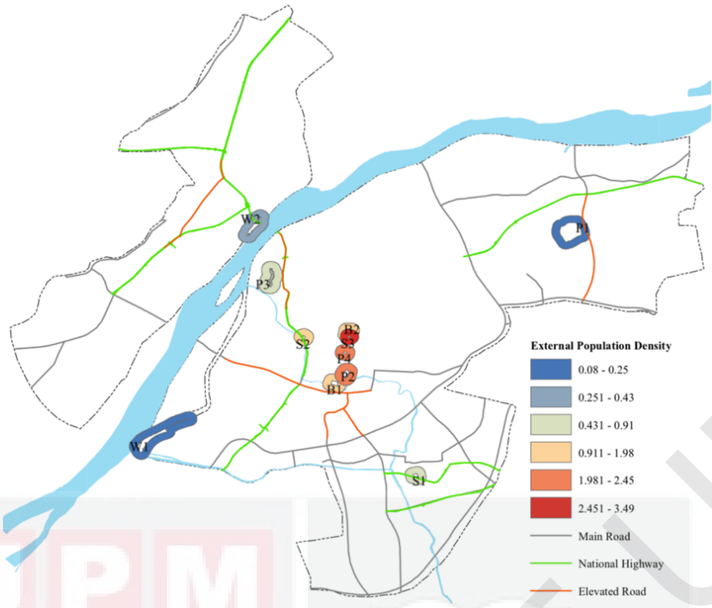

Figure 4.22 : Spatial Distribution of Different Levels of Service Population Density in Research Spaces
(Source: Author 2024)

4.3.3.2 Road Network Density

The Road Network Density indicator is calculated by dividing the total length of roads within a 500-meter radius of each research space by the area covered by this radius. As illustrated in Figure 4.23, the road network densities in the study areas display substantial variation, with values ranging from 65.90 to 168.55. Notably, 5 out of the 11 study areas exceed the average density value of 108.02.

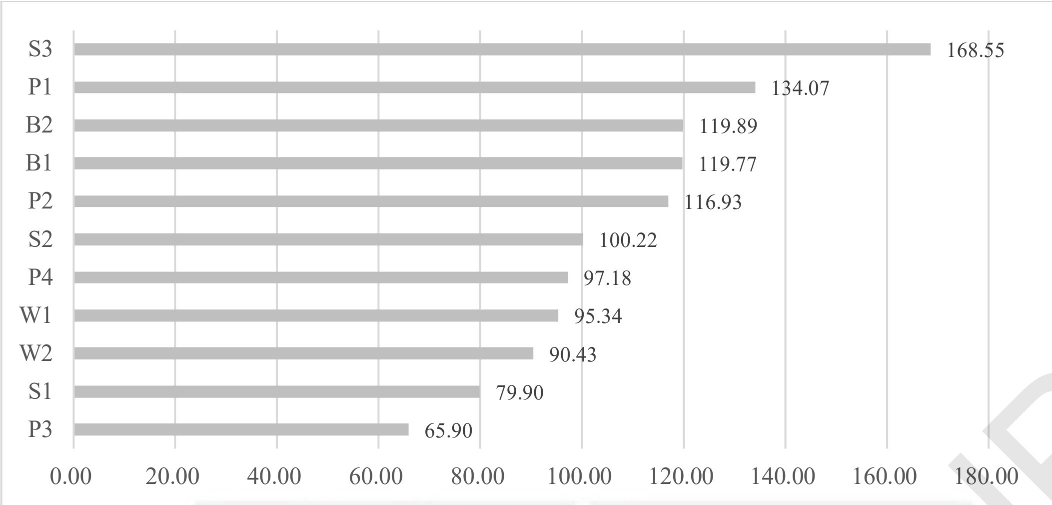

Figure 4.23 : Ranking of the Value of External Road Network Density in Research Spaces
(Source: Author 2024)

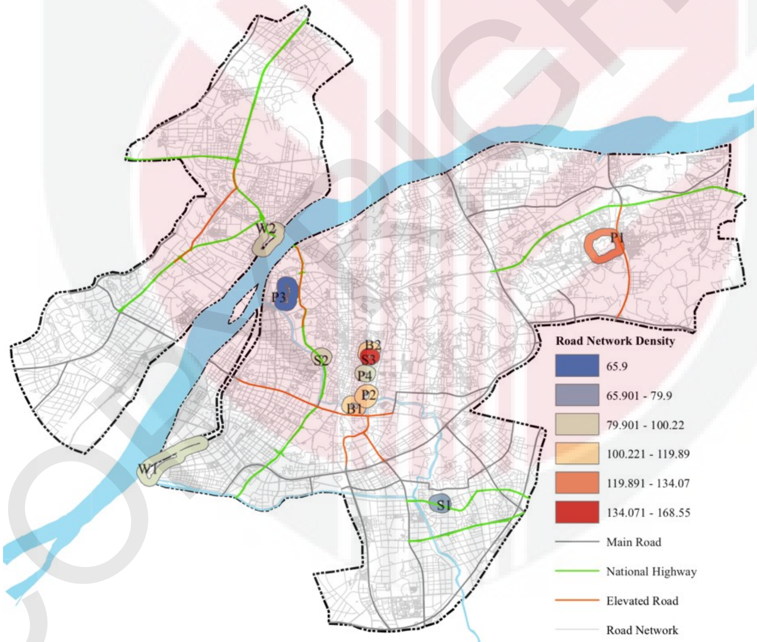

Figure 4.24 : Spatial Distribution of Different Levels of External Road Network Density in Research Spaces
(Source: Author 2024)

4.3.3.3 Public Transport Convenience

This indictor assesses the accessibility of public transport by counting the total number of bus and subway stations within a 500-meter radius of the research spaces. Figure 4.25 reveals significant differences in public transport accessibility across the study spaces, with counts ranging from 4 to 16 stations. More than half of the spaces, accounting for 54% (6 spaces), exceed the average accessibility value of 11.09. Most research spaces are well-served by bus stations, with 8 spaces featuring more bus stations than the average of 9.91. However, metro stations are less common; only 3 spaces exceed the average metro station count of 1.18. Two spaces, P4 and W2, lack nearby metro stations entirely. Figure 4.26 highlights that these spaces are located in areas with less developed transportation networks. Intriguingly, P4 compensates for the absence of metro stations, with the highest number of bus stations (13) among the spaces studied.

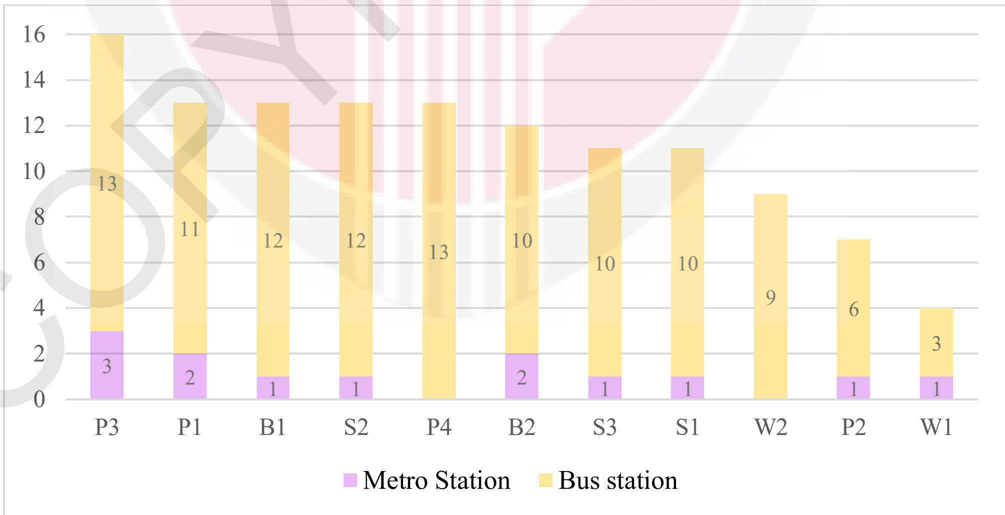

Figure 4.25 : Ranking of the Value of Public Transport Convenience in Research Spaces
(Source: Author 2024)

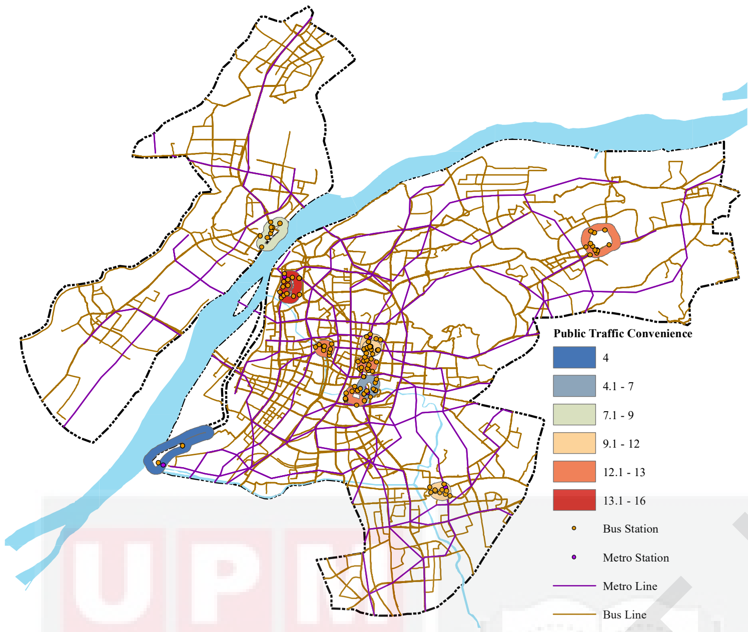

Figure 4.26 : Spatial Distribution of Different Levels of Public Transport Convenience in Research Spaces
(Source: Author 2024)

4.3.3.4 Surrounding Function Density

The density of surrounding functions, calculated using Formula (11), involves dividing the count of urban function POIs within a 500-meter radius of each study space by the service area. Figure 4.28 illustrates that spaces in the southeastern part of the Jiangnan region have notably higher densities. Conversely, the functional density is markedly lower for two waterfront spaces, W1 and W2, and a large park, P1, all located far from the city centre. This reflects less urban development near water bodies and peripheral city areas.

As shown in Figure 4.27, the resulting values vary significantly across spaces, ranging from 0.30 to 21.48, with 6 spaces exceeding the overall average of 8.90.

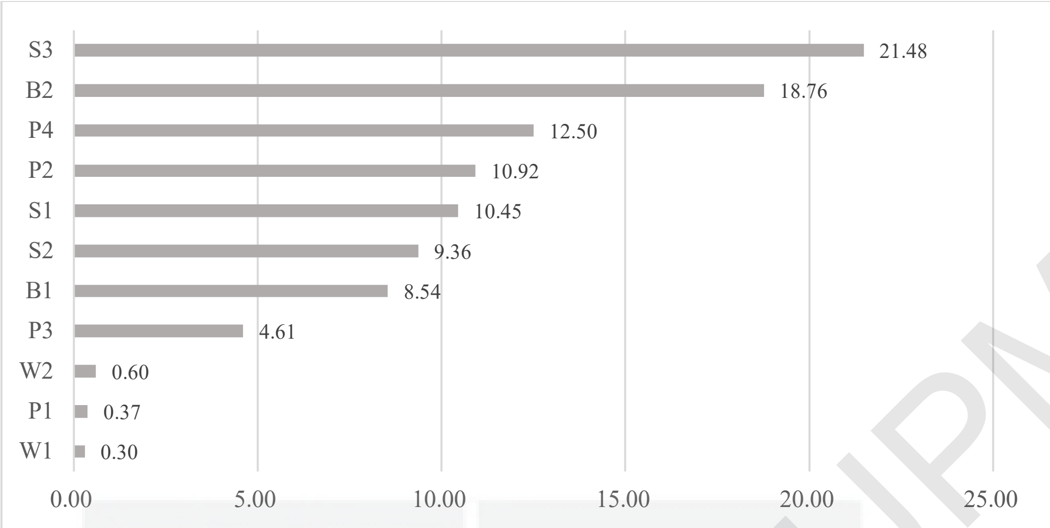

Figure 4.27 : Ranking of the Value of Surrounding Function Density in Research Spaces
(Source: Author 2024)

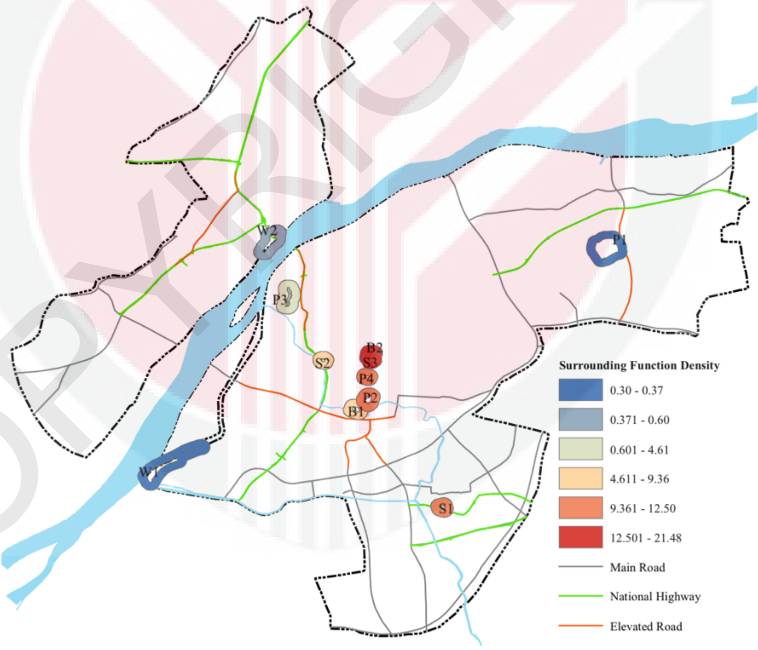

Figure 4.28 : Spatial Distribution of Different Levels of Surrounding Function Density in Research Spaces
(Source: Author 2024)

4.3.3.5 Surrounding Function Mixedness

Figures 4.29 and 4.30 show a relatively low variation in this indicator across different spaces, with 64% (7 spaces) exceeding the average value of 1.36.

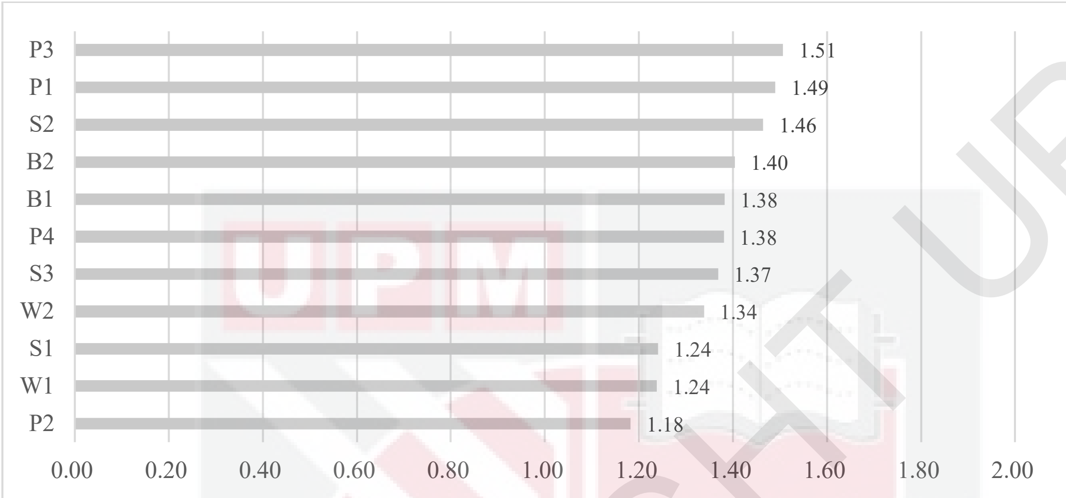

Figure 4.29 : Ranking of the Value of Surrounding Function Mixedness in Research Spaces
(Source: Author 2024)

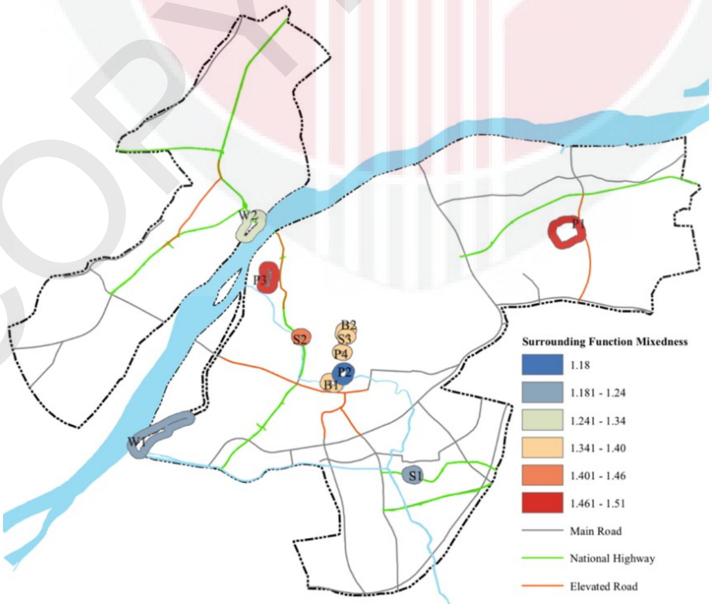

Figure 4.30 : Spatial Distribution of Different Levels of Surrounding Function Mixedness in Research Spaces
(Source: Author 2024

Figure 4.31 presents the distribution of various urban functions around each space. The analysis reveals several patterns: a) Predominance of Public and Commercial Services: Public services are a dominant feature in the surroundings of 11 research spaces, being the most prevalent in 9 out of 11 spaces, excluding P1 and W1. Particularly in S2, B1, P4, S1, and P2, public services exceed 50%. P1 and W1, being more isolated, show a lower reliance on public services. Commercial services are also significant across all spaces, often occupying about 30%. b) Balance in Residential and Educational Functions: These functions are consistently present but in minor proportions, averaging around 3% for residential communities and 2% for educational functions, except in W1. c) Variation in Business Office and Scenic Spot Functions: The proportion of business offices peaks at 27% in P1 but is as low as 4% in S1 and S2. Scenic spots vary, too, with 32% in W1 but only 3% in P1, indicating different functional focuses and socio-economic roles in these areas.

Figure 4.31 : The Proportion of Different Types of Surrounding Functions in Each Research Space
(Source: Author 2024)

4.3.3.6 Internal Facility Density

(a) Overall Performance:

Figure 4.32 shows that only 34% (4 spaces) exceed the average value (11.79). As shown in Figure 4.33, spaces with a lower facility density also demonstrate a decreasing trend in this indicator's value from the city centre to the outskirts (except for P2).

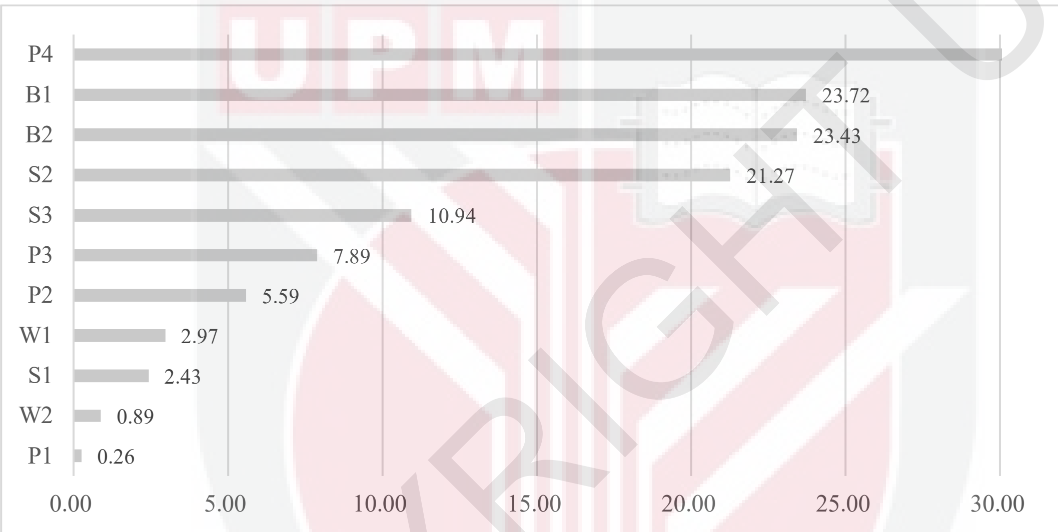

Figure 4.32 : Ranking of the Value of Internal Facility Density in Research Spaces
(Source: Author 2024)

(b) Performance across Different Space Types:

Table 4.14 shows that leisure blocks exhibit the highest average density (23.57), well above the overall average, with minimal variation among them, indicating uniformly high facility density. Waterfront spaces average the lowest density at 1.93, significantly below the overall average, with slight variation among them (standard deviation of 1.47). This suggests a need for improvement in internal construction in most Nanjing waterfront spaces. Squares (11.55) and parks (11.01) average slightly below the overall, but parks show a high standard deviation (10.87), reflecting diverse approaches in balancing leisure facilities with natural elements.

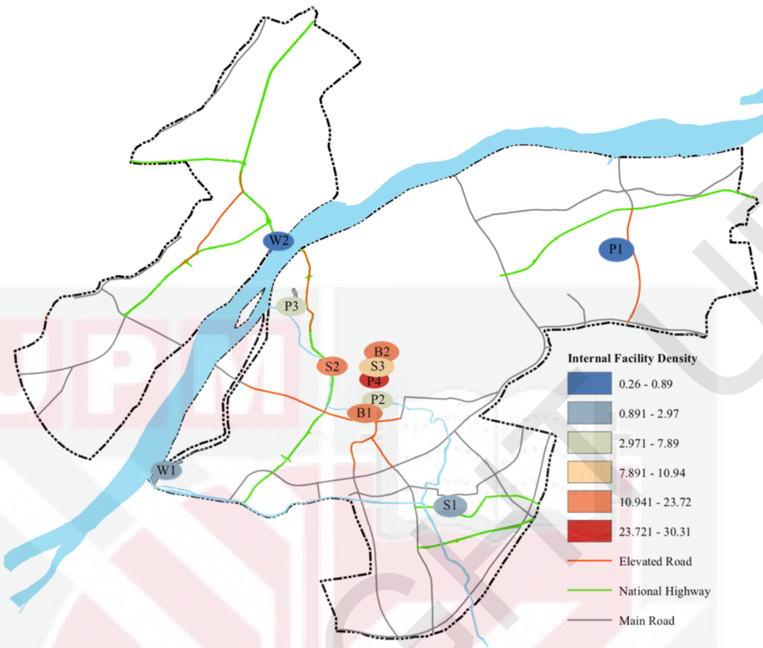

Figure 4.33 : Spatial Distribution of Different Levels of Internal Facility Density in Research Spaces
(Source: Author 2024)

Table 4.14 : Comparative Descriptive Statistics of the Indicator of Internal Facility Density in Various Space

Type/ Description	Maximum	Minimum	Mean	Standard Deviation
Overall	30.31	0.26	11.79	10.87
Park	30.31	0.26	11.01	13.26
Square	21.27	10.94	11.55	9.44
Waterfront Space	2.97	0.89	1.93	1.47
Leisure Block	23.72	23.43	23.57	0.20

4.3.3.7 Internal Facility Mixedness

(a) Overall Performance:

According to Figure 4.34, the diversity in facility types shows less significant variation across spaces, ranging from 0.50 to 0.97, with only 5 spaces exceeding the average mixedness value of 0.72. Unlike facility density, Figure 4.35 indicates no clear spatial distribution trend for mixedness; some peripheral spaces like W1 still score high, suggesting the influence of space type over location.

Figure 4.34 : Ranking of the Value of Internal Facility Mixedness in Research Spaces
(Source: Author 2024)

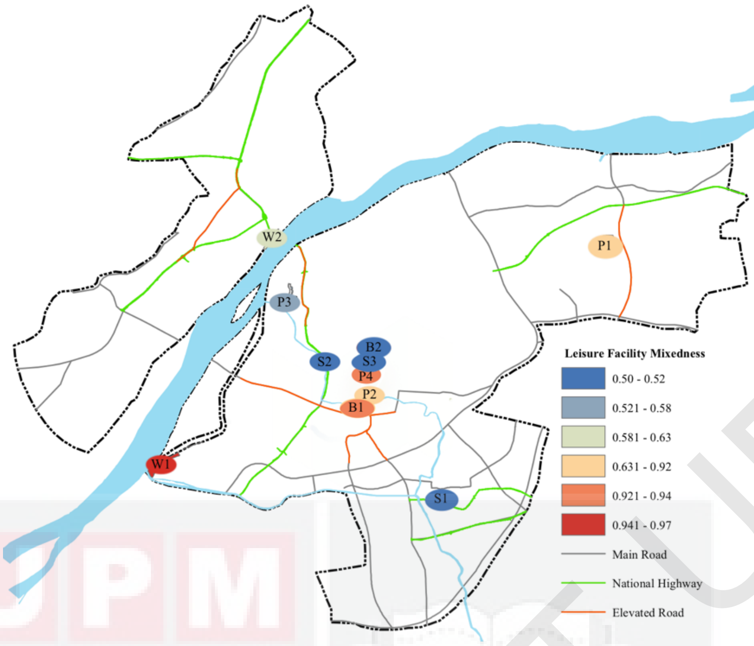

Figure 4.35 : Spatial Distribution of Different Levels of Internal Facility Mixedness in Research Spaces
(Source: Author 2024)

(b) Performance across Different Space Types:

Parks and waterfront spaces typically have higher mixedness levels (averages of 0.84 and 0.80, respectively) than the overall average, with low standard deviations (Table 4.15). Leisure blocks match the overall average but exhibit more variation in mixedness, as indicated by a higher standard deviation (0.30). B2 specifically has lower mixedness. Squares have the lowest average mixedness (0.51) and a uniform standard deviation (0.01), possibly due to their open nature limiting diverse facility offerings.

Table 4.15 : Comparative Descriptive Statistics of the Indicator of Internal Facility Mixedness in Various Space

Type/ Description	Maximum	Minimum	Mean	Standard Deviation
Overall	0.97	0.50	0.72	0.21
Park	0.94	0.58	0.84	0.17
Square	0.52	0.50	0.51	0.01
Waterfront Space	0.97	0.63	0.80	0.24
Leisure Block	0.93	0.50	0.72	0.30

a) Characteristics of Internal Facility Distribution in Different Types of Spaces：

Figure 4.36 shows the proportions and mixedness values of different facilities in each leisure space, revealing key functional trends: a) Dominance of Scenic Viewing Facilities: Scenic viewing facilities dominate 11 spaces, except for leisure blocks and P1. In 8 spaces, these facilities make up over 65%, highlighting a focus on scenic amenities, especially in parks, waterfront spaces, and squares. b) Leisure Blocks Focus on Consumer Facilities: Leisure blocks, particularly B1 and B2, prioritize consumer facilities, with proportions of 61% and 87%, respectively, reflecting their consumption-centered nature. c) Varied Distribution of Sports and Cultural Facilities: Sports facilities account for around 20% in over half of the spaces, peaking at 48% in P1, but are minimal in leisure blocks. Cultural facilities are generally scarce, with B1 having the highest at 16%, and parks and squares underrepresenting cultural amenities.

In essence, Nanjing’s leisure spaces display distinct functional profiles: parks and squares lean towards scenic elements, leisure blocks are consumption-focused, and there’s a noticeable lack of emphasis on cultural facilities in parks, squares, and waterfront spaces. Moreover, the distribution of sports facilities varies wildly, depending on the specific type of leisure space.

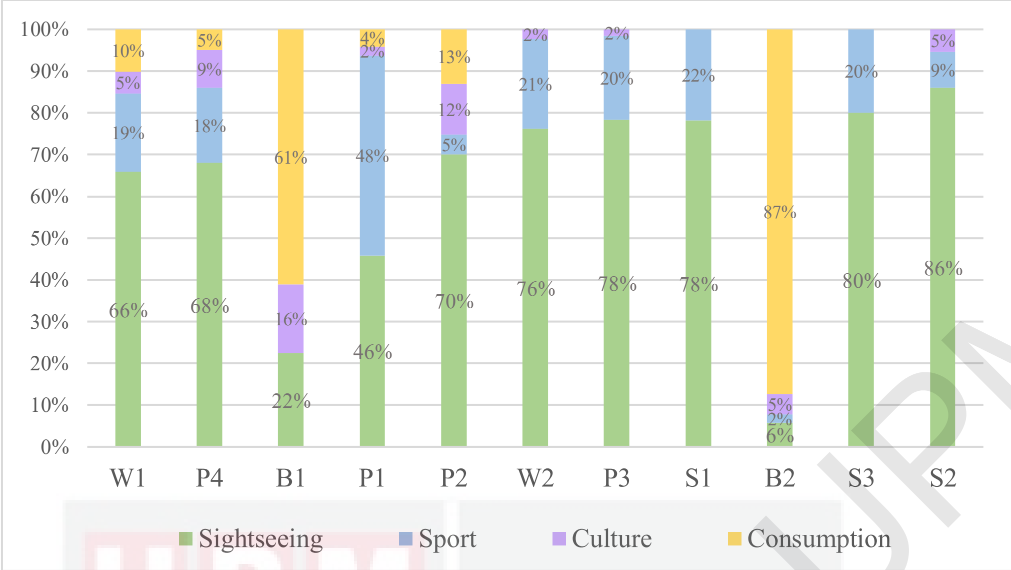

Figure 4.36 : Proportion of Different Types of Internal Facility in Each Research Space
(Source: Author 2024)

4.3.4 Results of Correlation Analysis between Crowd Activity and Built Environment Indicator

This analysis explores the relationship between crowd activity and built environment indicators, using 11 evaluation indicators. Detailed data standardization information can be found in Appendix G (Table G-2). The results reveal that each of the seven independent variables significantly correlates with at least one dependent variable, supporting the statistical significance and validity of the evaluation framework.

Table 4.16 : Statistical Results of Correlation Analysis

Indicators	Y1-Spatial Clustering	Y2-Temporal Persistence	Y3-Group Diversity	Y4-Feedback Positivity
X1-Service Population Density	**0.746(0.008***)**	-0.458(0.157)	**0.701(0.016**)**	0.118(0.729)
X2-External Road Network Density	**0.651(0.030**)**	-0.37(0.262)	0.225(0.506)	0.02(0.954)
X3-Public Transport Convenience	0.148(0.663)	-0.376(0.255)	0.423(0.195)	**0.853(0.001***)**
X4-Surrounding Function Density	**0.852(0.001***)**	-0.567(0.069*)	**0.628(0.038**)**	0.059(0.863)
X5-Surrounding Function Mixedness	0.049(0.886)	-0.238(0.481)	0.357(0.281)	**0.898(0.000***)**
X6- Internal Facility Density	0.267(0.428)	-0.117(0.732)	**0.928(0.000***)**	0.298(0.373)
X7-Internal Facility Mixedness	**0.746(0.008***)**	**0.727(0.011**)**	**0.701(0.016**)**	-0.184(0.588)

Note: ***, **, and *, respectively represent significance levels at 1%, 5%, and 10%.

4.3.4.1 Impact Indicators on Spatial Clustering

The table above shows that the number of X indicators that affect the Y1 (Spatial Clustering) indicator is the highest. Four indicators, X1, X2, X4, and X7, significantly impact it. This result indicates that all indicators related to density have a significant relationship with the spatial clustering of population activities in LUS, namely external service population density, road network density, surrounding function density, and internal facility density. The higher the density of these indicators, the more intense the population activities in the space. X4-Surrounding Function Density has the greatest impact on the Y1 indicator, with a correlation coefficient of 0.852 and a significance level of 0.001, indicating a highly significant correlation between the two indicators. In addition, X1 and X7 also show a positive correlation coefficient of 0.746 and a significance level of 0.008, which also correlates significantly with Y1. Besides, all X indicators have a positive correlation with Y1.

4.3.4.2 Impact Indicators on Temporal Persistence

Y2 (Temporal Persistence) shows varying degrees of significance among the dependent variable indicators. Notably, X7 (Leisure Facility Mixedness) positively correlates with Y2, indicated by a correlation coefficient of 0.727 and a significance level of 0.011. This suggests that a diverse mix of facilities in a space promotes more extended visitor stays. Conversely, other X indicators display a non-significant negative correlation with Y2, implying that an increase in certain spatial features may reduce the duration of activities in leisure spaces. X4 (Surrounding Function Density) mainly exhibits a moderately negative impact on Y2.

4.3.4.3 Impact Indicators on Group Diversity

Y3 (Group Diversity) is significantly correlated with X1, X2, X6, and X7, especially X6 (Leisure Facility Density), which notably influences Y3 with a correlation coefficient of 0.928 and a significance level of 0.000. This indicates a strong relationship between facility density and the diversity of users. The population density in the vicinity (X1) and the mixedness of internal facilities (X7) are critical factors in attracting diverse groups, showing substantial positive correlations.

Y4 (Feedback Positivity) significantly correlates with X3 and X5. This finding underscores the importance of public transportation accessibility and the variety of surrounding functions in generating positive user feedback. On the other hand, X7 shows a non-significant negative correlation with Y4, highlighting that both internal and external aspects of leisure spaces influence user experiences. All X indicators also display a positive correlation with Y4.

4.3.4.4 Impact Indicators on Feedback Positivity

Y4 (Feedback Positivity) significantly correlates with X3 and X5. This finding underscores the importance of public transportation accessibility and the variety of surrounding functions in generating positive user feedback. On the other hand, X7 shows a non-significant negative correlation with Y4, highlighting that both internal and external aspects of leisure spaces influence user experiences. All X indicators also display a positive correlation with Y4.

4.3.5 Determining the Weights of Indicators for the Vitality of Leisure Urban Spaces

This Section delves into the calculation of weights for indicators crucial in evaluating LUS' vitality, utilising the Entropy Method and the CRITIC Weighting Method.

4.3.5.1 Entropy Method

This method calculates the information utility value (d) to complement the information entropy value (e), ranging from 0.718 to 0.942. The lowest entropy value is for Y1, indicating its highest variability among all indicators, while X2 has the highest entropy, suggesting the most minor variability.

The weights derived from these utility values signify the relative impact of each indicator in decision-making. Notably, Y1 emerges as the most influential indicator with the highest weight of 21.571%, while X2 has minimal effect, evidenced by its lowest weight of 4.454%. The findings underscore Y1, X7, and Y3 as pivotal in decision-making due to their higher utility values (See Table 4.17).

Table 4.17 : Entropy Method Weight Calculation Results

Indicators	Entropy Value	Information Utility Value (d)	Weight (%)
Y1	0.718	0.282	21.571
Y2	0.909	0.091	6.966
Y3	0.852	0.148	11.335
Y4	0.893	0.107	8.207
X1	0.932	0.068	5.23
X2	0.942	0.058	4.454
X3	0.907	0.093	7.147
X4	0.919	0.081	6.194
X5	0.877	0.123	9.367
X6	0.913	0.087	6.632
X7	0.831	0.169	12.898

4.3.5.2 CRITIC Weighting Method

According to Table 4.18, X7 shows the highest variability (0.447), denoting substantial variation within the dataset. The conflict measure, indicating the independence of information provided by indicators, ranks Y2 as the highest, showing its strong independence from other indicators. X7, with the highest information content (5.092), emerges as the most informative, warranting the highest weight of 16.96%. Y2 follows, indicating its critical role in decision-making. The CRITIC method highlights X7 and Y2 as key due to their variability and independent information, advocating for their prioritization in analysis and decision-making.

Table 4.18 : CRITIC Weighting Method Calculation Results

Indicators	Indicator Variability	Indicator Conflict	Information Amount	Weight (%)
Y1	0.299	8.018	2.396	7.981
Y2	0.304	12.608	3.827	12.747
Y3	0.393	6.286	2.473	8.238
Y4	0.283	7.587	2.144	7.143
X1	0.31	6.89	2.136	7.116
X2	0.274	8.275	2.268	7.554
X3	0.278	7.722	2.143	7.138
X4	0.337	7.365	2.481	8.265
X5	0.328	8.1	2.658	8.854
X6	0.362	6.641	2.403	8.003
X7	0.447	11.394	5.092	16.96

4.3.5.3 Final Evaluation Framework

Based on the data presented in Table 4.19, the vitality evaluation framework for LUS reveals the following weight rankings: X7 (14.929) and Y1 (14.776) are at the forefront, closely followed by Y2 (9.8565), Y3 (9.7865), and X5 (9.1105). The subsequent ranks are occupied by Y4 (7.675), X6 (7.3175), X4 (7.2295), X3 (7.1425), X1 (6.173), and X2 (6.004).

The most impactful indicators, X7 and Y1, show minimal difference in weight, each accounting for roughly 14% to 15%. This implies that the mixedness of internal facilities and the clustering of crowd activity in spatial features exert the most substantial influence on the vitality of LUS. In the secondary tier of indicators, which includes Y2, Y3, and X5, the weights range from 9% to 10%, signifying the relevance of temporal persistence, group diversity, and the mixedness of surrounding functions. Y4, X6, X4, and X3 comprise the third tier with weights between 7% and 8%. As per the last tier, the least influential indicators are X1 and X2, suggesting that service population density and road network density have the most minor significance in the vitality assessment of LUS.

Table 4.19 : The Final Weight Result of Each Indicator

Indicators		Entropy	Rank	CRITIC	Rank	Weight (%)	Rank
Y1	Spatial Clustering	21.571	1	7.981	7	14.776	2
Y2	Temporal Persistence	6.966	7	12.747	2	9.8565	3
Y3	Group Diversity	11.335	3	8.238	5	9.7865	4
Y4	Feedback Positivity	8.207	5	7.143	9	7.675	6
X1	Service Population Density	5.23	10	7.116	11	6.173	10
X2	Road Network Density	4.454	11	7.554	8	6.004	11
X3	Public Transport Convenience	7.147	6	7.138	10	7.1425	9
X4	Surrounding Function Density	6.194	9	8.265	4	7.2295	8
X5	Surrounding Function Mixedness	9.367	4	8.854	3	9.1105	5
X6	Internal Facility Density	6.632	8	8.003	6	7.3175	7
X7	Internal Facility Mixedness	12.898	2	16.96	1	14.929	1

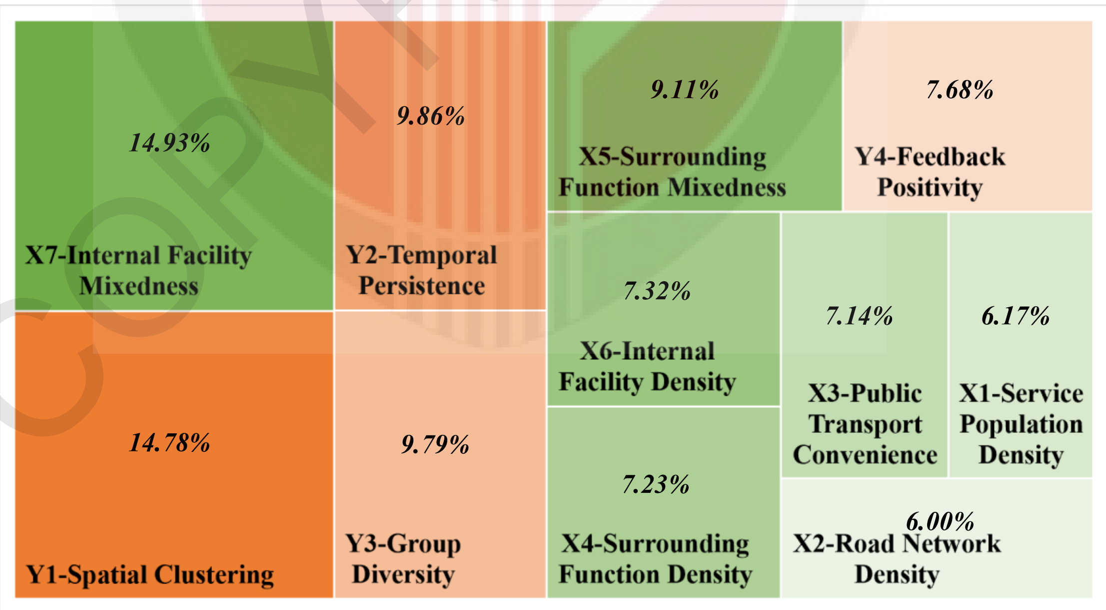

Figure 4.37 : Weight of LUS Vitality Evaluation Indicators at the Individual Level
(Source: Author 2024)

This analysis, underpinned by the data in Table 4.19, suggests that internal and surrounding functional diversity significantly impact the vitality of LUS, with most dimensions of population activity (except feedback positivity) playing a crucial role. Based on this, the current study has developed a comprehensive vitality evaluation framework for LUS, incorporating 11 indicators, each with its weighted proportion. Figure 4.37 shows the composition of the final weights of each indicator of the vitality LUS at the individual level. Orange is the crowd activity dimension and green is the built environment dimension.

4.3.6 Analysis and Classification of Final Vitality Values in Research Spaces

Figure 4.38 illustrates the ranking of vitality values for various research spaces. Using the natural breaks method in ArcGIS software, the final vitality values for each study area were categorized into six levels, and distinct colors were assigned to represent varying levels of vitality. This process generated a spatial distribution map depicting the vitality levels of the study areas (Figure 4.39). The numerical values resulting from weighted calculations for each indicator can be found in Appendix G (Table G-3).

According to Table 4.20, it can be observed that the average vitality of the existing waterfront spaces is relatively low, with only 5.98, and the standard deviation is also low. This indicates a need to enhance the vitality of all waterfront spaces. The average vitality of parks (8.42) is slightly lower than the overall average (9.09), suggesting that the vitality of parks also needs improvement. Although the average vitality of squares is relatively high, the standard deviation is higher than the average, indicating significant variations in the vitality levels of squares. For example, squares like S1, located far from the city centre, still require improvement in vitality.

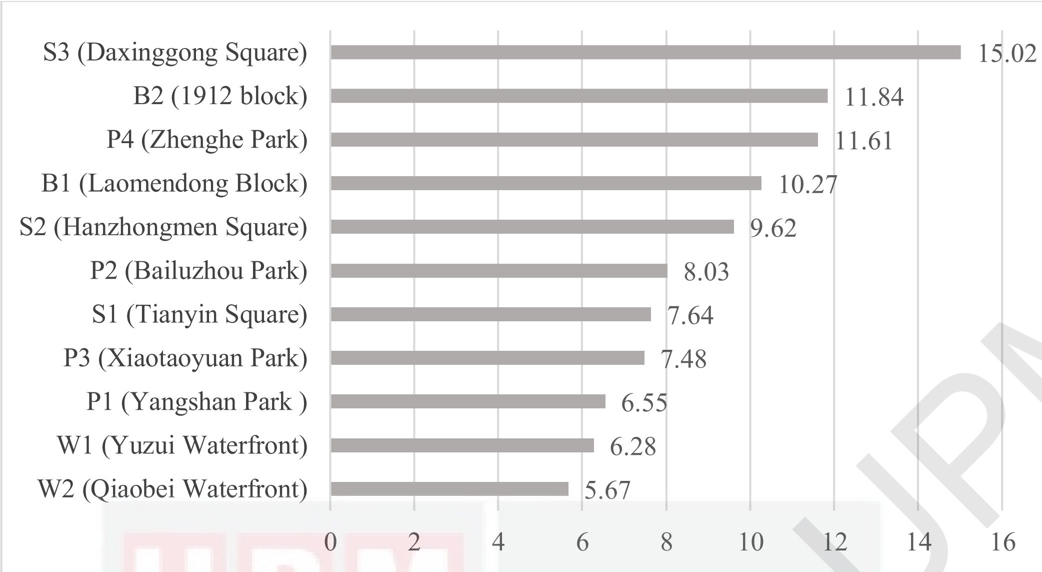

Figure 4.38 : Ranking of the Value of Overall Vitality Value in Research Spaces
(Source: Author 2024)

Figure 4.39 : Spatial Distribution of Different Levels of Overall Vitality in Research Spaces
(Source: Author 2024)

According to the natural break's classification method, this study categorizes Level 2 into a single vitality level, further divided into three types: high, middle, and low. The shortcomings of each space in terms of external representation of vitality and internal mechanism are listed in Table 4.21 for detailed information.

Table 4.20 : Comparative Descriptive Statistics of Overall Vitality Values in Each Research Space

Type/ Description	Maximum	Minimum	Mean	Standard Deviation
Overall	15.02	5.67	9.09	2.87
Park	11.61	6.55	8.42	2.21
Square	15.02	7.64	10.76	3.82
Waterfront Space	6.28	5.67	5.98	0.43
Leisure Block	11.84	10.27	11.06	1.11

Table 4.21 : Classification and Analysis of Vitality Levels and Disadvantageous Indicators in Each Research Space

Vitality level	Space type	Research space	Low-value indicators of external representation	Low value indicators of internal mechanism
High	Square	S3	Y2- Temporal persistence	X7-Internal facility mixedness
	Leisure Block	B2	Y2- Temporal persistence (Fluctuation Index)	X7-Internal facility mixedness
	Park	P4	Balance between each indicator	Balance between each indicator
Middle	Leisure Block	B1	Y2- Temporal persistence (Fluctuation Index)	X7-Internal facility mixedness
	Square	S2	Y2- Temporal persistence	X7-Internal facility mixedness
	Park	P2	Y4- Feedback positivity	X3- Public transport convenience X5-Surrounding function mixedness
	Park	P3	Y1-Spatial clustering Y2- Temporal persistence	X2-External Road network density
	Square	S1	Y2- Temporal persistence Y3- Group Diversity Y4- Feedback positivity(Overall satisfaction)	X2-External Road network density X5-Surrounding function mixedness X6- Internal facility density
Low	Waterfront Space	W1	Y1-Spatial clustering Y4- Feedback positivity	X1-service population density X3- Public transport convenience X4-Surrounding function density X5-Surrounding function mixedness

Table 4.21 : Continued

Park	P1	Y1-Spatial clustering Y3- Group Diversity	X1-service population density X4-Surrounding function density X6- Internal facility density
Waterfront Space	W2	Y1-Spatial clustering Y3- Group Diversity Y4- Feedback positivity (Sentiment scoring)	X1-service population density X4-Surrounding function density X6- Internal facility density

4.4 Expert Validation Survey Results

Upon reviewing the research findings, this paper has subdivided these discoveries into seven sections: Spatial Distribution Characteristics of Leisure Urban Spaces, Overall Vitality Performance, Key Indicators for Vitality Evaluation, Correlation between Crowd Activity and Built Environment, Crowd Activity Patterns, External Function and Internal Facility Supply, Spatial Distribution of Indicator Levels. Each section encompasses between specific findings, with the detailed information provided in Appendix H.

Variations in ratings reflect the differing emphases of professionals from various backgrounds. Academics (Expert 1-4) tend to focus more on the value of theory and innovative planning, often reflected in their higher scores (average of 4.14), indicating widespread support within the academic community for the findings of this study. In contrast, practitioners from urban planning agencies (Expert 5,6) (average scores of 3.76) and government officials (Expert 7,8) (average scores of 3.38) may have higher demands for practical application and policy consistency. Practitioners are concerned with the practical effects and functionality. At the same time, government workers may focus on how planning results align with policy objectives, such as equitable spatial distribution, thus reflecting a preference for policy and public service priorities.

This scoring trend not only reveals broad recognition of the research results but also highlights areas that require further attention and improvement.

Table 4.22 : Comparative Descriptive Statistics of the Expert Scores in Each Questionnaire Section

	i	ii	iii	iv	v	vi	viii
Mean	3.67	3.73	4.46	3.84	4.09	3.86	3.88
Standard deviation	0.41	0.52	0.17	0.45	0.44	0.33	0.67

Overall, the questionnaire scored an average of 3.85, demonstrating that experts generally agree with the findings of this study. Table 4.22 shows each Section's average scores and standard deviations, while Table 4.23 lists detailed scores from different experts. Section III: Key Indicators for Vitality Evaluation received the highest average score and the smallest standard deviation, indicating widespread agreement. However, Section V's average score, while above 4, has a moderate standard deviation, suggesting less consensus on some findings, particularly as Indicator 's average score is only 3, indicating areas that require further research and attention. Other sections, such as I, II, IV, VI, and VII, had average scores ranging from 3.5 to 4, showing a general agreement trend. However, Section I scored the lowest average and had a lower standard deviation, indicating weaker agreement, especially as Indicator b scored only 2.75. Additionally, certain Sections II and IV indicators scored above 3.5 overall, but some experts rated them lower, indicating these findings are contentious. Certain indicators in Sections VI and VII did not surpass a score of 3.5, further emphasizing the need to strengthen the reliability of discoveries in these areas.

Table 4.23 : Statistics of Expert Scoring for Individual Findings in Each Questionnaire Section

No	Experts								Mean
	Ex. 1	Ex.2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	
i. Findings on Spatial Distribution Characteristics of Leisure Urban Spaces									
a	5	5	5	5	4	5	5	5	4.88
b	4	3	3	4	3	2	2	1	2.75
c	3	5	4	2	4	5	5	5	4.13
d	5	3	4	4	5	2	3	3	3.62
e	5	4	4	4	3	2	3	3	3.5
f	3	5	4	3	4	5	2	5	3.88
g	4	3	3	5	3	3	3	2	3.25
h	3	4	4	4	2	5	2	2	3.25
i	5	5	4	3	3	2	2	3	3.38
Mean	4.11	4.11	3.89	3.78	3.44	3.44	3.00	3.22	3.67
ii. Overall Vitality Performance Findings									
a	5	5	4	4	5	4	5	5	4.63
b	4	4	4	5	3	5	3	3	3.88
c	4	5	3	4	3	2	2	1	3.00
d	5	3	4	4	4	3	3	2	3.50
e	4	3	4	5	4	3	2	2	3.38
f	4	4	4	4	3	5	3	5	4.00
Mean	4.33	4.00	3.83	4.33	3.67	3.67	3.00	3.00	3.73
iii. Key Indicators for Vitality Evaluation Findings									
a	5	5	4	4	5	4	4	5	4.50
b	4	3	4	5	4	5	5	3	4.13
c	5	5	5	4	5	4	5	5	4.75
Mean	4.67	4.33	4.33	4.33	4.67	4.33	4.67	4.33	4.46
iv. Findings on the Correlation between Crowd Activity and Built Environment									
a	4	4	4	3	5	3	4	5	4.00
b	5	4	4	3	3	4	3	4	3.75
c	4	5	5	4	5	4	2	3	4.00
d	5	3	3	4	2	4	4	3	3.50
e	5	5	5	3	4	3	2	4	3.88
f	4	3	3	3	3	4	4	5	3.63
g	5	4	4	4	4	3	2	3	3.63
h	4	4	3	4	3	5	3	5	3.88
i	4	5	4	5	4	3	3	4	4.00
j	4	4	4	3	5	3	2	4	3.63
k	4	5	5	4	4	5	3	5	4.38
Mean	4.36	4.18	4.00	3.64	3.82	3.73	2.91	4.09	3.84
iv. Findings on the Correlation between Crowd Activity and Built Environment									
a	4	4	4	3	5	3	4	5	4.00
b	5	4	4	3	3	4	3	4	3.75
c	4	5	5	4	5	4	2	3	4.00
d	5	3	3	4	2	4	4	3	3.50
e	5	5	5	3	4	3	2	4	3.88

Table 4.23 : Continued

f	4	3	3	3	3	4	4	5	3.63
g	5	4	4	4	4	3	2	3	3.63
h	4	4	3	4	3	5	3	5	3.88
i	4	5	4	5	4	3	3	4	4.00
j	4	4	4	3	5	3	2	4	3.63
k	4	5	5	4	4	5	3	5	4.38
Mean	4.36	4.18	4.00	3.64	3.82	3.73	2.91	4.09	3.84
v. Findings on Crowd Activity Patterns									
a	4	3	4	4	4	2	3	2	3.25
b	5	4	4	5	4	3	2	3	3.75
c	4	5	4	4	5	5	5	4	4.50
d	5	5	5	5	5	4	5	5	4.88
Mean	4.5	4.25	4.25	4.5	4.5	3.5	3.75	3.5	4.09
vi. Findings on External Function and Internal Facility Supply									
a	5	5	4	5	5	3	4	4	4.38
b	3	3	4	3	3	4	2	5	3.38
c	5	4	3	4	4	2	2	3	3.38
d	4	5	4	5	3	5	5	2	4.13
e	5	5	4	4	4	3	5	3	4.13
f	3	3	4	4	3	5	2	5	3.63
h	4	5	4	4	5	4	3	3	4.00
Mean	4.14	4.29	3.86	4.14	3.86	3.71	3.29	3.57	3.86
vii. Findings on Spatial Distribution of Indicator Levels									
a	5	5	4	4	4	3	4	3	4.00
b	5	4	4	4	5	3	2	3	3.75
c	5	5	4	5	3	4	3	5	4.25
d	4	4	3	4	5	2	2	3	3.38
e	5	4	3	4	5	4	4	2	3.88
f	5	4	4	5	4	3	3	4	4.00
Mean	4.83	4.33	3.67	4.33	4.33	3.17	3.00	3.33	3.88

During the review and organization of prior analyses, emphasis was placed on the need to revalidate certain key findings, which include, but are not limited to:

V-a: Parks and squares attract more active on weekdays, while waterfront spaces and leisure blocks are more popular on weekends

i-b: In Nanjing's Central Urban Area, different types of leisure urban spaces display varying clustering tendencies. Parks and squares show significant clustering, while waterfront spaces exhibit less clustering, and leisure blocks are distributed randomly.

i-g: Squares: Feature a balanced "one-core, multiple-points" structure primarily in the Old City Area, but have lower attraction and usage outside of this area

i-h: Waterfront Spaces: Clustered around natural water bodies, they offer unique experiences but are less accessible.

ii-c: In Nanjing's Central Urban Area, the overall vitality of leisure urban spaces is classified into high, medium, and low levels, with spaces of medium vitality comprising the majority

ii-e: In the dimension of crowd activity, there is strong performance in the indicators of temporal persistence and overall satisfaction, but deficiencies in the indicators of spatial clustering and sentiment feedback

VI-b: Characteristics of external function supply of leisure urban spaces-Residential and Educational Functions Less Influential

VI-c: Characteristics of external function supply of leisure urban spaces-Significant Variation in the Distribution of Business Offices and Scenic Spots Based on Location

VII-d: The levels of indicator of Service Population Density display spatial trend of decreasing from the city center to the periphery

For findings that received relatively low scores, further research should be conducted to enhance their reliability. In-depth data analysis and field investigations are needed to validate hypotheses such as the usage patterns of leisure spaces on weekdays versus weekends, the distribution of leisure spaces from central to peripheral areas, and the correlation between leisure spaces and crowd activity. It is recommended that future studies include case studies, expert interviews, or other qualitative research methods to explore underlying reasons and to understand the usage patterns of different leisure spaces more accurately throughout the week. Additionally, the findings under Section

III: Key Indicators for Vitality Evaluation, which received consistently high scorings, indicate that these indicators are widely recognized as crucial for vitality assessments and cannot be overlooked in future planning. Attention should also be given to sections with larger standard deviations, as this suggests significant discrepancies in expert opinions. Focused discussions and multifaceted feedback can aid in clarifying issues and forming consensus. Overall, a multidimensional analysis and diversified data collection can enhance the comprehensiveness and effectiveness of research outcomes.

Although some research findings scored lower, the majority of findings were still supported by the expert group, demonstrating the basic effectiveness of the evaluation framework. This not only proves the fundamental validity of the evaluation framework in both theoretical and practical applications but also highlights its adaptability and robustness in complex environments. The support from experts reflects trust in the research methodology and outcomes and indicates that these results can provide valuable insights for urban planning and design practice. Moreover, the presence of lower-scoring indicators offers an opportunity to identify and address potential limitations or biases within the research methods. This continuous self-scrutiny and improvement are a critical aspect of scientific research, ensuring that the work can progress and refine over time. Further research and refinement of these preliminary "low-score" aspects could reveal new insights, aiding in more accurate assessments and optimization of urban space design and functionality.

4.5 Discussion

This study reveals that Nanjing's LUS exhibit a central clustering pattern with sparse peripheries, reflecting strategic urban planning aimed at optimizing spaces for leisure and social activities. This pattern supports the core-periphery structure of urban leisure resource distribution identified in prior studies (Qu et al., 2023; Zhang et al., 2021). The central clustering of parks and squares emphasizes their role in enhancing residents' quality of life, a crucial factor for urban vitality (Wang et al., 2022). These spaces are strategically located in densely populated areas, facilitating easy access for residents. In contrast, waterfront spaces and leisure blocks, while limited in coverage, show significant potential for expansion to meet the growing demands of the population. The overall spatial distribution of LUS is influenced by Nanjing's topography and historical urban development. The city's natural geography and urban planning have been leveraged to maximize coverage and ensure broad accessibility to leisure spaces. The high concentration of LUS in the central districts—particularly around key urban areas—demonstrates a well-planned balance between established and developing zones. Waterfront spaces, although less densely clustered, highlight the increasing importance of urban waterfront development in city planning (Wu et al., 2019). Additionally, leisure blocks are dispersed along historical and cultural streets, often integrated into commercial hubs, suggesting a blend of leisure and commercial activities that attract both residents and tourists. However, further research is needed to explore the spatial characteristics of these leisure blocks in greater detail.

The overlay of population density distribution with LUS density indicates that while denser districts tend to have more leisure spaces, the types and distribution of these spaces are also influenced by geographical features, historical development, and urban planning goals. Understanding this dynamic is crucial for urban planners and policymakers, as they must design leisure spaces that address population density while enhancing the city's cultural and historical fabric (Jing et al., 2018; Liu et al., 2017).

Striking a balance between meeting the quantitative demands of a dense urban population and preserving the qualitative aspects of Nanjing's unique urban landscape is key.

Moreover, the correlation between crowd activity density and LUS distribution highlights that the widespread availability of leisure spaces significantly contributes to increased pedestrian traffic and activity frequency in a region. This effect is especially pronounced in areas with high population density or excellent accessibility, where residents are more likely to engage in social, leisure, and entertainment activities (Shi et al., 2020). These zones often evolve into the city's social and cultural hubs, such as downtown areas, dining districts, or waterfront leisure spots. These vibrant areas, with high activity density, offer quality infrastructure and diverse services, attracting residents and tourists alike (Wang et al., 2022). Furthermore, the correlation between leisure space availability and activity density emphasizes the need for urban planners to ensure the uniform distribution of leisure spaces, enabling all residents to benefit from these amenities. In areas with lower activity density, it may be necessary to increase the number of leisure spaces or improve the accessibility of existing ones to enhance residents' quality of life and stimulate economic activity (Jin et al., 2024). Strategic planning of this nature helps create a more balanced and inclusive urban environment .

This study found that crowd activity density decreases from the city center to the outskirts, a trend consistent with previous studies on parks (J. Zhu et al., 2020), urban green spaces (Dong et al., 2022), and blocks (Y. Yang et al., 2021), and waterfront spaces (Fan et al,2021; Li et al, 2024b). This suggests that geographic location has a stronger influence on crowd activity than space type. Similar urban-to-rural gradients in user diversity were also observed, consistent with Chuang et al. (2023). Additionally, significant temporal fluctuations in crowd activity density were found in commercial areas, aligning with L. Liu et al.(2024), who highlighted the impact of commercial zones on pedestrian flow throughout the day. Consequently, the underutilization of LUS in peripheral urban areas can be addressed by improving public transport access, diversifying urban functions, and enhancing leisure facilities.

This study highlights the significant role LUS play in shaping daily behavior. The findings show that activity levels vary by time and location, with higher weekend activity than weekdays, though fluctuation patterns remain similar, consistent with previous studies (Fan et al., 2021; Y. Yang et al., 2021). Leisure blocks peak after work hours and on weekends, with the highest crowd flow around 8:00 PM. Weekend activity peaks are later and longer, as observed by Y. Yang et al. (2021). Squares show higher daytime activity, while parks and waterfront spaces have less fluctuation, indicating lower time dependence. This contrasts with Mu et al. (2021), who found more significant weekday-weekend visitor differences in parks. Urban green spaces peak between 1:00 PM and 4:00 PM (Dong et al., 2022). Waterfront spaces attract fewer visitors at night due to limited services, as noted by L. Chen and Ma (2023). This study did not find significant seven-day activity fluctuations by space type or location, suggesting that activity density may be influenced by surrounding environments and internal facilities. Urban planners should account for the activity patterns and spatiotemporal variations of different LUSs to optimize functionality and safety.

In terms of user diversity, this study found that in the Central Urban Area of Nanjing, families and groups of friends show a strong preference for using LUS, with leisure blocks being particularly favored by younger friend groups. This finding is consistent with previous research, as a survey by Zhang et al.(2021) indicated that young people make up more than half of the participants in district activities. Additionally, many individuals prefer engaging in solitary leisure activities in squares, blocks, and parks. Mu et al. (2021) found that the primary visitors to parks are middle-aged and elderly individuals, accounting for more than 60% of total visitors, with most arriving either with family or alone, which aligns with the observations in this study. However, couples and organized groups participate in leisure activities in these spaces at a relatively lower rate, particularly in waterfront spaces, a phenomenon that has not yet been extensively explored in the existing literature. Therefore, it is crucial to tailor the planning and design of different spaces to meet the diverse needs of users.

The findings reveal that photography, culinary experiences, unique architecture, and local characteristics significantly impact users' experiences of LUS, yet are often overlooked in prior research that focuses mainly on park features. Additionally, environmental ambiance, including landscape design (R. Liu & Xiao, 2020; Salih et al., 2023), vegetation (Wan et al., 2021), and water features (Huai et al., 2023). Accessibility and location are also key, with Lai and Deal (2022) highlighting accessibility over aesthetics. This study also underscores the importance of social and recreational activities, linked to the availability of facilities like entertainment, rest areas, and commercial services, aligning with past studies (Huai et al., 2023; R. Liu & Xiao, 2020). These findings provide valuable insights for urban planners to enhance LUS and user experiences.

This study validates the key concepts of the Behaviour Change Theory proposed in Chapter 2, particularly how the built environment influences the occurrence of crowd activities through spatial supportiveness and functional diversity. According to the theory, external environmental factors, such as spatial characteristics and facility configurations, play a more significant role in motivating behaviour, a finding that is reflected in this research. Spatial supportiveness in the Behaviour Change Theory is composed of predisposing Ffactors and enabling factors. Predisposing factors refer to residents' perceptions of space and their willingness to use it, which provide the motivational basis for space utilization. Enabling factors, on the other hand, support and enhance the occurrence of crowd activities by providing the necessary physical conditions. For example, high-density service facilities and well-developed transportation networks can offer the essential infrastructure for crowd activities. Research indicates that service population density and external road network density significantly influence crowd activity density, suggesting that the intensive configuration of transportation and service facilities can effectively promote crowd gathering and enhance spatial vitality. Additionally, many scholars have noted that people tend to engage in leisure activities near their residences, further highlighting the role of spatial supportiveness in facilitating crowd activities (F. Wang et al., 2020; J. Zhu et al., 2020). Moreover, well-designed transportation networks and convenient transportation facilities significantly contribute to the aggregation of crowd activities (Dong et al., 2022; Y. Niu et al., 2021). Functional diversity is regarded as a reinforcing factor in the Behaviour Change Theory. It promotes the persistence and diversity of crowd activities by offering a variety of spatial choices and opportunities. The diversification of spatial functions not only increases the attractiveness of spaces but also fosters social interactions and diverse activities. For instance, studies have shown that functional diversity in commercial and residential areas enhances spatial vitality, particularly by stimulating various social behaviours, thereby increasing the frequency of space usage and its social functions (T. Wang et al., 2022; M. Liu et al., 2021). Therefore, urban planning should emphasize the incorporation of diverse functions in spatial design, especially in high-density areas, to improve their attractiveness and vitality. In summary, this study validates the core proposition of the Behaviour Change Theory: the external built environment, particularly spatial supportiveness and functional diversity, significantly influences the generation, persistence, and diversity of crowd activities through the interplay of predisposing, enabling, and reinforcing factors. Crowd activities are not only an external manifestation of spatial design but also influence space usage and vitality. Spatial supportiveness provides the motivation and conditions for crowd participation through residents' perceptions and physical infrastructure, while functional diversity further promotes the diversification and sustainability of activities. Therefore, future urban planning should focus on optimizing spatial layouts, increasing functional diversity, and enhancing social functions to improve the vitality of LUS.

From a practical perspective, urban planners should strategically design leisure urban spaces based on the population density and functional needs of different areas. In regions with high population density and convenient transportation, the intensive configuration of service facilities and the development of transportation networks should be prioritized to meet the demands of crowd gathering and activities. Simultaneously, increasing functional diversity, especially in commercial and residential areas, should provide diverse activity options for different groups, enhancing the attractiveness and vitality of these spaces. These strategies not only improve the frequency of space usage but also promote social interactions and enhance residents' quality of life.

4.6 Summary

4.6.1 System Level

i. Spatial Distribution and Functionality of LUS in the Old and New Urban Districts

The results show that parks and squares in the central area of Nanjing exhibit strong clustering tendencies, while waterfront spaces show relatively weak clustering and leisure blocks tend to be randomly distributed, reflecting strategic planning for different LUS. Standard deviation ellipse analysis reveals that LUS in CUA of Nanjing are relatively concentrated and exhibit a clear southeast-to-northwest direction of clustering expansion, with parks having the largest spatial distribution and widest service range, centred approximately in the old town area. Kernel density analysis indicates that the spatial distribution pattern of LUS in Nanjing's CUA displays a "one core, multiple points" layout, with the intersection of Gulou, Qinhuai, and Xuanwu districts as the major core, gradually expanding outward. The distribution of different spaces includes parks forming three dense cores, squares concentrated in the city centre and northern new districts, waterfront spaces distributed along major water bodies forming a large central cluster and several smaller clusters, and leisure blocks mainly concentrated in the bustling commercial areas of the old town. This distribution can lead to resource concentration and a lack of facilities in newly developed areas. To counter this, macro-level policies are essential to redistribute activities and develop underutilized zones. Additionally, the Old City Area (OCA), serving primarily residential, public, and commercial functions, faces spatial resource saturation and limited land, impeding sustainable growth. Urban planning must ensure equitable distribution of leisure resources to prevent "core-periphery" disparities in city services, ensuring all residents have equal access to quality leisure and social facilities.

ii. Supply Deficiency of LUS in Specific Districts

Beyond the densely packed spaces in the OCA, other districts exhibit a shortage of leisure urban space. Districts like Qixia, Yuhuatai, and Liuhe in the Jiangnan area, lacking historical backgrounds, are devoid of leisure blocks. Yuhuatai and Liuhe, despite their proximity to natural water systems, lack waterfront spaces. Northeast Jiangning, an underdeveloped area, lacks detailed land use requirements, and due to its low residential density and vast undeveloped plains, it represents a potential focus for future development. Pukou District, noted for its extensive water systems, currently has a sparse density of leisure spaces due to its large area. However, it is identified as a crucial zone for future development. This potential is particularly strong in its waterfront and natural leisure spaces like parks. Within the Jiangbei region, Pukou’s undeveloped southwestern and northeastern areas offer significant opportunities for enhancing its leisure offerings, especially leisure blocks, to enrich cultural and social activities in the district. iii. Distribution Characteristics and Potential Issues of Various Leisure Spaces

iii. Distribution Characteristics and Potential Issues of Various Leisure Spaces

The four types of spaces each have distinct spatial distribution characteristics and potential issues, refer to Table 4.24.

Table 4.24 : Characteristics and Potential Issue of LUS in Nanjing's CUA

Type of Space	Spatial Characteristics	Potential Issues
Parks	High number; smaller within Old City Area, larger on urban edges	Lack of large, comprehensive parks in densely populated northern and southern areas
Squares	'One-core, multiple-points' structure; balanced within Old City Area	Lower attraction and usage outside of Old City Area
Waterfront Spaces	Clustered around natural water bodies, offering unique experiences	Accessibility and connectivity issues limit full utilization
Leisure Blocks	Smaller, focused clusters in central locations	Insufficient number; do not form significant large-scale clusters, impacting cultural and social activities

iv. Correlation between Residents' Activity Distribution and Leisure Spaces

Chapter 4's comparative study reveals that the distribution of LUS and the pattern of crowd activity share a similar characteristic of concentration. This correlation indirectly confirms that a varied array of leisure spaces boosts pedestrian traffic and the frequency of activities within an area. The OCA, characterized by its use of land for parks, squares, and leisure blocks, experiences a significantly higher intensity of resident activities compared to the less vibrant outskirts. Notwithstanding the absence of data during peak seasons, the heightened activity in the OCA implies its leisure spaces are more appealing for residents' everyday and weekend activities. The concentration of leisure activities and hotspots radiating from the Old City into newer districts indicates a dynamic urban landscape where well-integrated leisure spaces promote more frequent and diverse use. These insights highlight the potential of effectively incorporating leisure spaces to foster a livelier and more engaged urban community.

4.6.2 Individual Level

Findings at the individual level are complex; this article uses Figure 4.40 to provide an overview of the structural layout of these findings. The content is divided into four major sections, each containing 1 to 3 specific findings.

i. Evaluation Results Summary

(a) Overall Performance:

The vitality levels of LUS in Nanjing's CUA also reflect the dense distribution in OCA and sparser distribution in peripheral areas, with a higher proportion of spaces exhibiting a "moderate" level of vitality.

Dimension of Crowd Activity: The eleven leisure spaces in Nanjing's central district generally demonstrate commendable temporal persistence performance. However, more than 60% of these spaces exhibit deficiencies in spatial clustering of activities, with nearly half also lacking in diversity of group activities and sufficient positive feedback. Dimension of Built Environment: The mixed-use nature of surrounding functions generally performs exceptionally, with over 60% of spaces exceeding the average. Service population density and public transport convenience also predominantly surpass the average. However, less than half of the spaces reach the average level in external road network density, surrounding function density, and internal facility mixedness. The performance in internal facility density is notably weak, with only a minority of spaces exceeding the average.

(b) Performance Disparities in Different Types of Spaces:

Leisure blocks perform exceptionally well, especially in attracting diverse crowds and maintaining high user satisfaction, though their activity levels fluctuate significantly, and their sustained appeal is weaker. Parks have low spatial clustering but excel in activity stability and persistence; however, their group diversity and user satisfaction are average and need improvement. Squares attract large crowds effectively and have good group diversity, though there is considerable variation between different squares, and they struggle to maintain a continuous presence with average user satisfaction. Waterfront spaces perform poorly overall, with the exception of time persistence, where they provide a stable leisure experience. However, they have the lowest group diversity and require significant improvements in user satisfaction and experience.

(c) Spatial Distribution Characteristics of Indicator Levels:

In Figure 4.40, indicators marked with blue circles show significant spatial distribution characteristics. These include Spatial Clustering, Group Diversity, Service Population Density, and Internal Facility Density, which tend to decrease from the city centre to the periphery. The indicator of Surrounding Function Density is higher in areas away from water bodies or near the city centre. The activity density in leisure urban spaces located in commercial areas fluctuates significantly over time.

ii. The Importance and Correlation of Indicators in Vitality Evaluation

(a) The Weight of Different Indicators in Vitality Evaluation:

In Figure 4.40, the darker the colour of an indicator, the higher its weight, indicating greater importance in the vitality evaluation. The external representation of Crowd Activity carries more weight than the internal mechanism (Built Environment) in the vitality of LUS. The analysis highlights the importance of spatial clustering and internal facility diversity, advocating a focus on the quality and diversity of activities and facilities in the broader urban context to boost LUS' vitality.

(b) The Correlation Between Crowd Activity and Built Environment Indicators:

In Figure 4.40, solid lines represent highly significant positive correlations, while dashed lines represent moderately significant positive correlations. Spatial Clustering, crucially affected by the interplay between internal facilities and external urban function, is particularly notable. The mix of internal facilities directly impacts activity temporal persistence, highlighting the necessity of diverse, multifunctional environments. Factors like population density and facility variety also affect group diversity, emphasizing the need for balanced, accessible leisure spaces. User satisfaction and positive experiences correlate strongly with the diversity of urban functions and the accessibility of public transport, underscoring the importance of a comprehensive approach in enhancing LUS' vitality, which includes considering both space characteristics and the wider urban setting.

iii. Characteristics and Preferences of Crowd Activity

(a) Different types of LUS exhibit distinct activity patterns

During weekdays, parks and squares attract higher foot traffic, while waterfront spaces and leisure blocks draw more weekend crowds. Leisure blocks are popular for social and entertainment activities, particularly after work hours and on weekends. Squares peak in activity around noon, but parks and squares maintain steady visitor volume throughout the day.

(b) User Group Composition of Various Leisure Spaces

The composition of the population in various types of leisure spaces significantly impacts their use. Leisure blocks attract younger friend groups and families due to their rich modern consumption facilities. Parks and squares predominantly cater to family groups, while waterfront spaces balance well among families, friends, and individual groups.

(c) User Preferences for Spatial Environments

Analysis of social media reviews indicates that users value not only material enjoyment like food and shopping in leisure spaces but also place high importance on aesthetic, historical, and cultural aspects, as well as comprehensive social and leisure experiences.

iv. Characteristics of Built Environment Supply

(a) Characteristics of External Function Supply：

Public and commercial services are the most prevalent urban functions surrounding many LUS, with public services dominating most areas. Residential and educational functions are common but less dominant. The distribution of business offices and scenic spots varies significantly based on the location of the space.

(b) Characteristics of Internal Facility Supply:

Parks and squares tend to focus on scenic facilities, while leisure blocks are oriented towards consumption facilities. Cultural facilities are notably lacking in parks, squares, and waterfront spaces. Moreover, the distribution of sports facilities varies greatly depending on the specific type of leisure space.

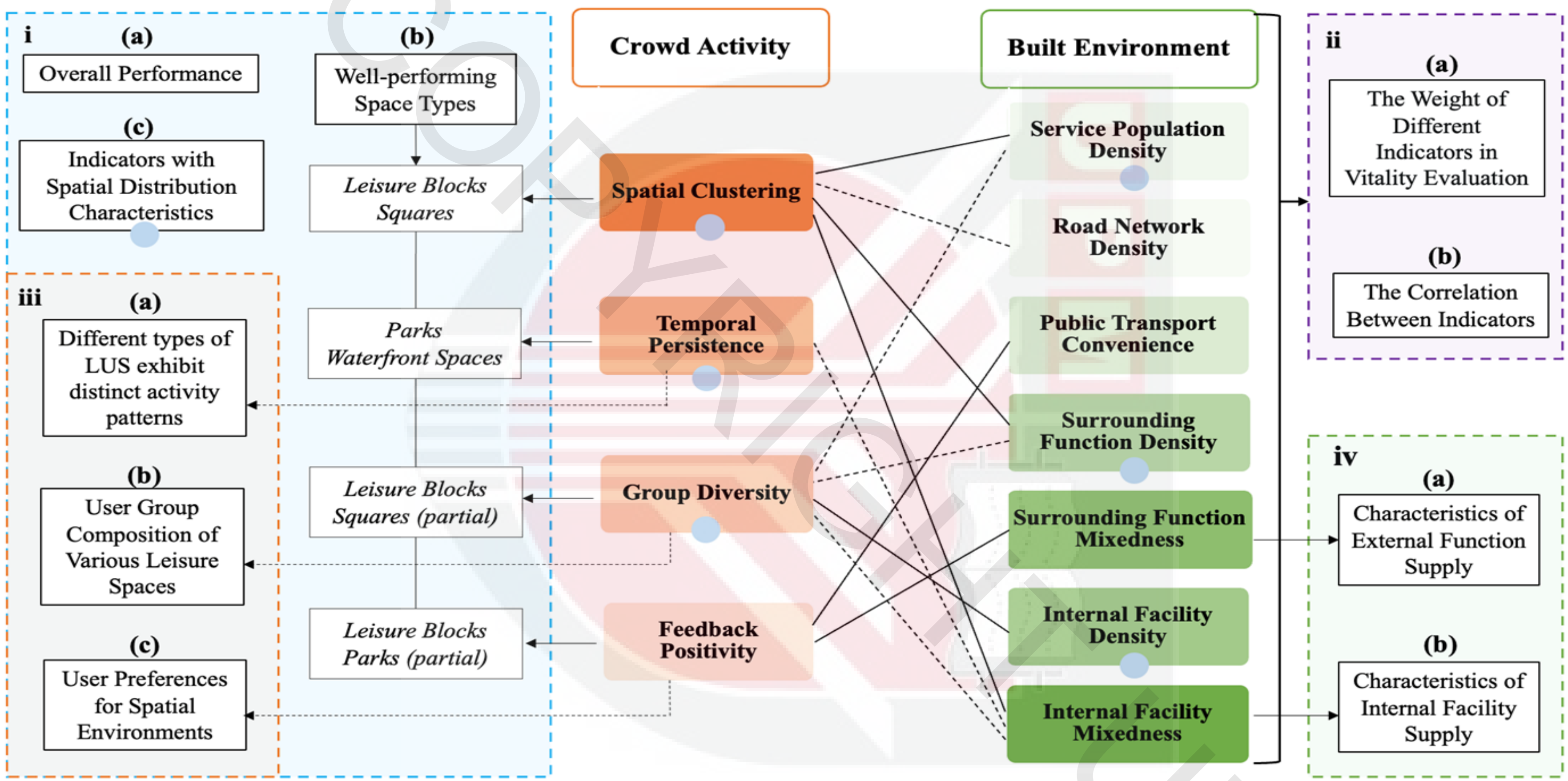

Figure 4.40 : Structural Overview of Individual-Level Findings in Vitality Evaluation
(Source: Author 2024)

CHAPTER 5

STRATEGIC RECOMMENDATIONS FOR ENHANCING THE VITALITY OF LEISURE URBAN SPACES

5.1 Introduction

This chapter conducts an in-depth analysis of the leisure urban space distribution in Nanjing's CUA from both "system-individual" perspectives, accurately identifying the weak links in the distribution and specific issues of insufficient vitality in certain spaces. At the system level, this study combines the overall layout of LUS (including parks, squares, waterfront spaces, and leisure districts) with population density, concentration of people's activities, and service range coverage to reveal the deficiencies in the current spatial arrangement. Based on these findings, a series of principles, goals, and strategies for optimizing the leisure urban system and its spatial layout are proposed, particularly emphasising the importance of "increasing space." At the individual level, the evaluation of crowd activity in the spaces under study not only discerns the reasons for the lack of vitality in various sample spaces but also categorizes the vitality of these LUS into high, medium, and low levels. Lastly, based on the factors of the built environment, targeted recommendations are made to optimize the vitality of LUS in Nanjing, including enhancing accessibility, external functions, and internal facilities. Table 5.1 shows the research framework for enhancing the vitality of LUS.

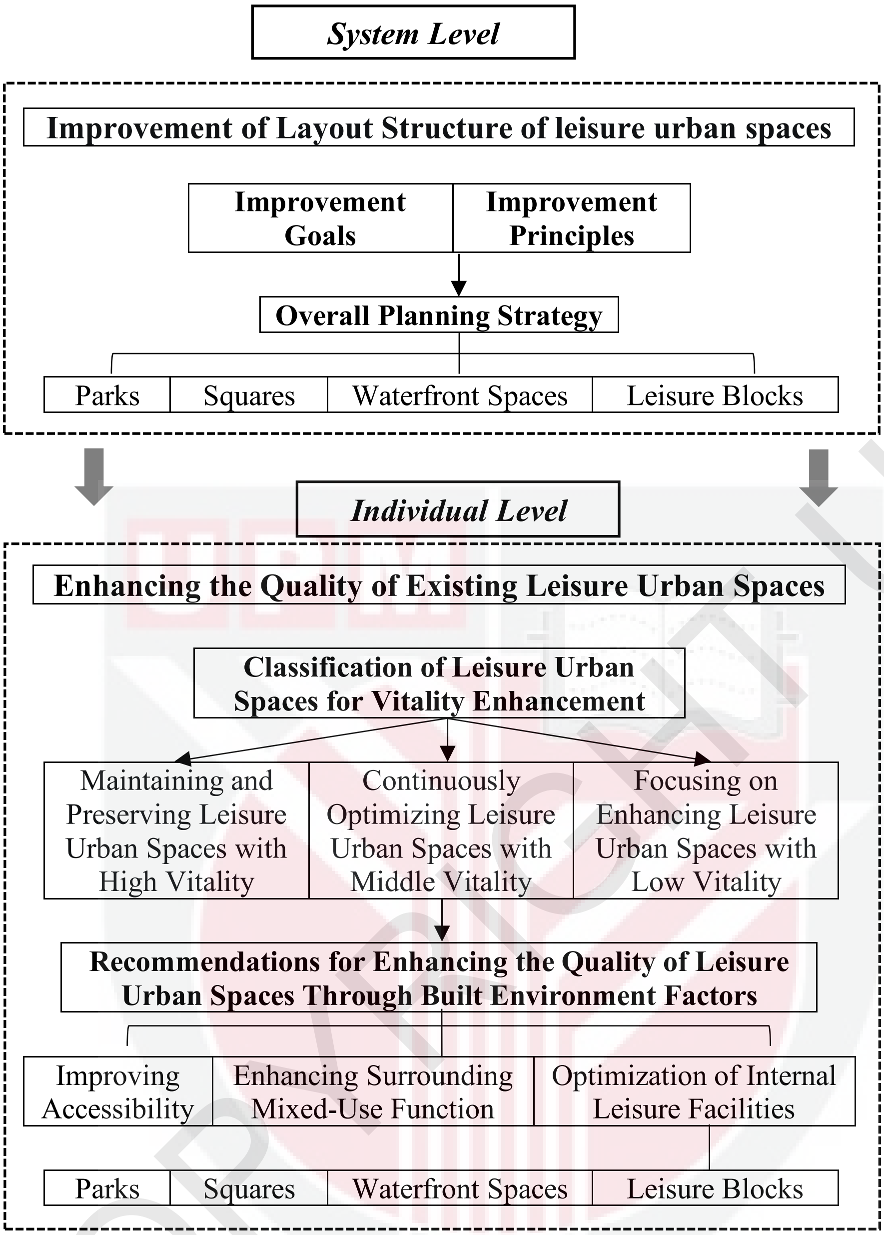

Figure 5.1 : The Research Framework for Enhancing the Vitality of Leisure Urban Spaces
(Source: Author 2024)

5.2 Improvement of Layout Structure of Leisure Urban Spaces

This section will enhance the vitality of LUS from the system level. Based on Nanjing's strategic positioning, planning goals and policy requirements, and the findings of the previous chapter, this section outlines optimization goals and principles to support the detailed strategic recommendations proposed in this paper.

5.2.1 Improvement Goals and Principles for Leisure Urban Space Layout

5.2.1.1 Optimization Goals

i. Network Structure and Regional Equity

With a focus on regional equity, the goal is to develop a balanced network pattern of LUS. Following Nanjing's planning objective, there is a commitment to ensuring that key leisure spaces, particularly parks and squares in the CUA, are within a 5-minute walk for all city residents. This aims to achieve a city-wide balance in the distribution of leisure spaces. By carefully planning these areas' size, spacing, and layout, the goal extends beyond merely enhancing the accessibility of leisure resources for residents. It also involves special attention to areas lacking vitality and leisure options to ensure an equitable allocation of recreational resources.

ii. Openness and Sharing

Derived from an assessment of social fairness, the goal is to construct a leisure system that aligns with the population's needs. Considering the degree of population concentration and distribution, the layout of LUS should be based on population density while enhancing the public accessibility of these spaces. As shared resources among urban dwellers, these spaces should promote an ethos of openness and inclusivity, fully meeting the diverse needs of different resident groups. This means that in planning urban leisure space layouts, openness and sharing should be key considerations to boost usability and attractiveness, ensuring residents in both the old and new city areas can enjoy various leisure services.

iii. Balance and Efficiency

When renewing the layout of LUS in Nanjing, it's important to actively identify and use currently underutilized or inefficient leisure spaces. The goal is to moderately expand the scale of LUS to provide more comprehensive services to the general population. In this process, rational distribution and the incorporation of diverse functions in leisure spaces are emphasized to enhance the coverage and efficiency of services. This strategy will promote the renewal and development of LUS and contribute to the creation of new planning and management models, thereby comprehensively optimizing the city's leisure ecosystem.

5.2.1.2 Improvement Principles

i. People-Centric Principle

Urban planning should prioritize the diverse leisure needs of residents from various social strata and age groups, including the elderly and children, to foster diversity and inclusiveness in leisure space designs. Future planning and management of leisure spaces should invite increased public participation, integrating residents' needs and expectations into the planning process. Continuous adjustments to the layout and amenities of LUS are key to enhancing residents' quality of life and satisfaction. Urban parks and green spaces must be abundant and of high quality, catering to the leisure demands of contemporary urban dwellers.

ii. Adaptation to Local Conditions Principle

The design of LUS should focus on convenience and accessibility, maintaining a strong sense of openness, particularly within the OCA. Increment and improvement of leisure spaces in this area should respect its existing characteristics and historical heritage. With limited land in the Old City, opportunities from recent land vacating and greening initiatives should be capitalized on. For optimal results, macro-level leisure system planning must consider land use in the OCA. Expansion in the OCA could involve revitalizing older neighbourhoods, demolishing unused factories, and integrating fragmented urban spaces, enhancing connectivity and creating a leisure system reflecting regional traits and cultural depth.

iii. Stock Development Principle

Considering the limited available land for development in the high-density OCA of Nanjing and the city's already undergone a large-scale transformation, land resources have become more precious. Therefore, adding leisure spaces faces challenges in the context of new planning. In this background, the current optimization stage should focus on small-scale supplementation and improving service facilities. When optimizing the layout of LUS, priority should be given to areas with poor accessibility. By addressing the accessibility issues in these areas, the efficiency and accessibility range of LUS can be greatly enhanced, achieving maximum benefit improvement within a limited space.

5.2.2 Recommendations for Improvement of the Layout Structure of Leisure Urban Spaces

5.2.2.1 Overall Planning Strategy

Based on the established objectives and principles, three strategies are proposed to optimize the overall layout of LUS in Nanjing's CUA. These strategies aim to respond to the current urban development needs and the leisure activity patterns of residents:

i. Reuse of Urban Fringe Land and Brownfields

This strategy aims to create new leisure spaces in Nanjing by utilizing underused urban areas such as fringe lands and brownfields. Given the small plot sizes yet strong continuity of leisure spaces in the old town, the focus is on transforming these underutilized spaces into new leisure areas, emphasizing the redevelopment and regeneration at a community level. This approach introduces new recreational options and enhances urban quality through environmental improvement.

ii. Development of New Leisure Spaces at Urban Edges

This strategy addresses the OCA's limited and concentrated leisure facilities by planning and constructing larger-scale leisure amenities in the city's outskirts. The size of these new spaces will be tailored to their function and the needs of target user groups. These developments aim to relieve leisure pressure in the city centre, fostering balanced growth between central and peripheral areas.

iii. Enhancement of Leisure Functions and Diversity in Existing Urban Public Spaces

Focusing on the specific needs of densely populated regions lacking comprehensive leisure spaces, this strategy emphasizes diversifying and enhancing the mixed-use of existing leisure areas. By optimizing the layout and functions of parks, waterfront spaces, squares, and pedestrian zones, continuity and accessibility can be improved, creating integrated leisure complexes that combine ecological, cultural, and commercial elements. This strategic approach enriches the leisure experience for residents and tourists and boosts usage efficiency and overall quality of life in the urban environment.

5.2.2.2 Parks

Based on previous research findings, constructing high-quality, evenly distributed urban and community parks can effectively enhance the performance of urban park green space for recreational services. Therefore, considering the current quantity and layout of parks, the strategic development is proposed in Table 5.1.

Table 5.1 : Strategic Development of Parks in Nanjing's CUA

Objective	Target Areas	Strategy	Expected Outcomes
Revitalize Pocket Parks and Micro Green Spaces	OCA-Gulou, Qinhuai, Xuanwu District	Develop small-scale parks in high-density areas with limited space	Improve access to greenery; enhance green space coverage and service efficiency
Expand Community Park Network	Jiangnan Region (excluding the OCA) -Jianye, Qixia District	Build community parks near residential areas, considering urban planning and land use	Provide basic leisure needs; facilitate the evolution into broader leisure nodes
Establish Large-Scale Parks	Jiangbei Region -Pukou, Liuhe, Jiangning District	Create larger parks in less developed areas with ample land	Meet diverse needs; accommodate growing resident demands for leisure space

5.2.2.3 Squares

As analyzed in Chapter 4, the quantity of squares in the CUA of Nanjing is second only to parks, and there are a considerable number of them, so it is not necessary to increase the quantity of squares significantly. Although squares, like parks, provide spaces for everyday leisure activities, they differ in supply and positioning. With their expansive open spaces, Squares are more suitable as gathering places for large crowds and venues for displaying urban culture. However, the current distribution of squares in the CUA of Nanjing is relatively scattered, and the square lands outside the OCA have not fully utilized their attraction potential. Therefore, the spatial layout and functional optimization of squares should focus on the following strategic development in Table 5.2.

Table 5.2 : Strategic Development of Squares in Nanjing's CUA

Objective	Target Areas	Strategy	Expected Outcomes
Enhance Peripheral Squares	Pukou, Qixia Districts	Increase the number of squares in areas with fewer such facilities	Improved distribution and accessibility of leisure spaces
Strengthen Cultural Hubs	OCA	Augment existing squares with cultural programming to highlight urban identity	Squares become focal points for cultural engagement, increased visitor, ship, and community pride
Improve Connectivity within Urban Network	CUA	Upgrade interconnections between squares and other leisure spaces to create an integrated network	A more cohesive urban environment with easier movement

5.2.2.4 Waterfront Spaces

According to the analysis in Chapter 4, waterfront spaces in the CUA of Nanjing are relatively scarce. Therefore, increasing the number of waterfront spaces becomes a primary task in optimizing the leisure layout. While adhering to Nanjing's existing water system layout, it is crucial to consider the overall urban planning comprehensively, effectively addressing the distribution and accessibility issues of waterfront spaces to strengthen the entire city layout. Targeting this objective and in combination with the current quantity and layout features of waterfront spaces, the following strategic developments are proposed in Table 5.3.

Table 5.3 : Strategic Development of Waterfront Spaces in Nanjing's CUA

Objective	Target Areas	Strategy	Expected Outcomes
Open and Expand Waterfront Access	Jiangbei Region-Along Yangtze River	Transform closed waterfront lands into open public spaces, add multiple accessible nodes along the riverfront	Enhanced public access to waterfront spaces, increased recreational space
Restore Historical Water System and Renew Spaces	Jiangnan Region-Along Qin Huai River	Restore historical water systems construct new public cultural facilities along the moat to revitalize the area's heritage	Revitalized cultural heritage, enhanced aesthetic value of waterfronts
Strengthen Connectivity and Accessibility	CUA	Strengthen connections between different waterfront spaces ensure alignment with the urban road network for seamless access	A continuous and accessible waterfront network that promotes ease of movement and recreational activities for residents

5.2.2.5 Leisure Blocks

The analysis in Chapter 4 revealed the spatial distribution and clustering characteristics of leisure blocks in the CUA of Nanjing: although there are not many leisure blocks and they have not formed a large-scale cluster, they are mainly concentrated in three OCA, especially in the Qinhuai District. These blocks, often integrated with residential and commercial areas, become an important component of the urban structure. Considering optimizing the layout of leisure blocks, the following three key strategic developments are proposed in Table 5.4:

Table 5.4 : Strategic Development of Leisure Blocks in Nanjing's CUA

Objective	Target Areas	Strategy	Expected Outcomes
Hierarchical & Regionally Distinctive Distribution	Jiangbei Region-Liuhe, Jiangnan Region-Qixia, Yuhuatai District	Develop new leisure blocks with unique cultural and natural themes to diversify leisure options across the city	Alleviated congestion of leisure resources in the Old City Area, with enhanced regional balance and cultural diversity
Integration of Historical/Cultural Elements & Modern Design	Qinhuai, Liuhe District	Protect and utilize historical heritage in old districts and introduce modern design in new developments	A fusion of tradition and modernity in leisure blocks, with areas becoming cultural landmarks within the city
Enhancing Connectivity with Urban Functions	CUA	Improve the integration of leisure blocks with transportation hubs and other urban amenities for better accessibility	Increased accessibility to leisure areas, promoting a more cohesive and dynamic urban environment

5.3 Enhancing the Quality of Existing Leisure Urban Spaces

This section discusses strategies to enhance the vitality of LUS at an individual level, considering the varying levels of vitality exhibited by different LUS. Specific categorizations and recommendations for optimization will be provided herein.

5.3.1 Classification of Leisure Urban Spaces for Vitality Enhancement

The quantitative evaluation of leisure urban space vitality indicators clearly shows that the vitality levels in Nanjing's CUA can be classified into three categories: high, medium, and low vitality. Additionally, there is a noticeable decline in vitality along the urban-rural gradient. Specifically, a) Spaces with High Vitality: LUS with high or relatively high composite vitality indexes are mainly found at the intersection of the OCA in the Jiangnan region. These areas typically demonstrate robust vitality across various dimensions, although minor deficiencies in one or two indicators may exist, which do not considerably impact the overall vitality. b) Spaces with Medium Vitality: Spaces classified with medium vitality are generally located along the peripheries of the OCA in the Jiangnan region. These spaces often show shortcomings in two to three indicators. c) Spaces with Low Vitality: Most spaces with low vitality levels are situated beyond the Jiangnan region's borders and in its main urban zones. These areas frequently exhibit substantial shortcomings in five to six indicators, leading to an overall diminished vitality, which warrants focused improvement measures (as elaborated in Table 4.19). Therefore, based on their overall vitality levels, specific recommendations for enhancing the vibrancy of LUS can be formulated.

5.3.1.1 Maintaining and Preserving Leisure Urban Spaces with High Vitality

These spaces are mainly located at the junction of the OCA in Jiangnan. It is recommended that high-vitality LUS be maintained and preserved. Among them, two exhibit minor deficiencies in specific dimensions, not significantly affecting their overall vitality; one space is well-developed across all factors and indicators. For spaces with current shortcomings, it's advisable to optimize spatial configuration as outlined in section 5.3.2 selectively, targeting improvements where needed. Well-developed spaces should maintain their high vitality, focusing on sustaining their current environment and continuously improving their operational and management levels to meet evolving urban leisure demands and new lifestyles.

5.3.1.2 Continuously Optimizing Leisure Urban Spaces with Middle Vitality

Spaces with medium vitality are primarily outside the Jiangnan region's borders and in the Jiangbei region. Considering the varying development stages of these areas, it's advised that the construction and development realities of LUS and their respective areas be combined. Continuous observation of vitality characteristics during development is recommended to assess the urgency of vitality enhancement and to implement targeted, progressive measures. Among the five spaces with medium vitality, four have issues with low temporal persistence in activities, and two face problems with low feedback positivity. Most spaces can support urban leisure activities and meet the diverse needs of the population. Spaces with below-average temporal persistence should be a focus for vitality enhancement. Continuous tracking of changes in urban leisure vitality, assessing the need for updating and optimizing the spatial environment, and enhancing the attractiveness and public leisure activity capacity are advised for ongoing vitality enhancement.

5.3.1.3 Focusing on Enhancing Leisure Urban Spaces with Low Vitality

Spaces with low overall vitality comprise a small percentage of the sample in Nanjing's CUA, with most having deficiencies in five or more indicators. To address this, in addition to enhancing the attractiveness and capacity for residents, efforts should be made to attract city centre residents to participate in suburban activities. It is recommended that more resources be allocated to improve the quality of sub-LUS and increase their appeal for diverse activities. Focusing on differentiated thematic positioning, spatial configuration, and renewal design is suggested to optimize themes based on each space's unique characteristics and environment. Enhancing spatial environment quality and attracting diverse populations and activities can meet urban leisure needs and contribute to high-quality public life. Regularly planned festive activities and promotion through Internet platforms can create unique leisure spaces, build cultural symbols and systematically elevate the multidimensional vitality of LUS in the city's peripheral areas.

5.3.2 Recommendations for Enhancing the Quality of Leisure Urban Spaces through Built Environment Factors

5.3.2.1 Improving Accessibility

This section details four key measures to enhance accessibility in LUS. These measures are designed to make leisure spaces more accessible and user-friendly

i. Road Network Enhancement and Expansion

Key to enhancing accessibility is the renovation and upgrading of the existing road network. This involves repairing damaged roads, widening narrow streets, and adding turning lanes for improved traffic flow and safety. Developing secondary roads that link to primary networks and enhancing connectivity between tertiary and secondary networks in constrained areas can ease pressure on main roads. In Nanjing, leisure spaces near denser road networks show higher activity clustering, suggesting that better road utilization can boost leisure activities. Optimizing the road network is thus vital for increasing urban space vitality.

ii. Increasing Entrance Numbers

Field surveys show that many leisure spaces, particularly parks and waterfronts, have limited entry points. In some areas, despite high road density, the number and placement of entrances hinder accessibility and service range. Future planning should focus on increasing entry points to enhance openness and expand service coverage, making these spaces more accessible and user-friendly. Universal access design at entrances is essential, ensuring accessibility for all, including people with disabilities, for a more inclusive experience. These enhancements will allow larger leisure spaces to serve the community better, improving their appeal and functionality.

iii. Optimizing Public Transport Stop Locations

Accessible public transport is critical for extending the reach of leisure spaces, especially those on city outskirts or in poorly connected areas. Expanding the service range can draw distant visitors, contributing to the sustainable vitality of leisure spaces. In Nanjing, spaces surrounded by more public transport stops exhibit higher vitality and positive feedback. However, areas bordering Jiangnan and Jiangbei regions lack adequate public transport compared to central city areas, limiting access to some well-designed leisure spaces. Increasing public transport stops within walking distance of these areas can enhance accessibility, particularly from the city centre.

iv. Developing Diverse Walking Paths

Establishing safe, convenient walking paths encourages green travel and better integration of leisure spaces into the urban fabric. These paths should link residential and commercial zones, offering comfortable and health-promoting routes. Thoughtfully designed, they not only provide easy access to leisure areas but also enhance the urban landscape.

5.3.2.2 Enhancing Surrounding Mixed-Use Function

i. Optimizing Land Utilization near Leisure Spaces

This study advocates for efficient, multifunctional strategies to improve land use around leisure spaces. This involves converting underutilized or low-efficiency areas into multipurpose zones, incorporating retail, dining, cultural, and green elements to enhance functional density and diversity. Chapter 4's correlation analysis demonstrates that these factors significantly influence crowd activity, confirming that enhancing functional richness around leisure spaces is crucial for boosting their vitality. Moreover, this land use optimization elevates the area's economic and social value and provides residents with a broader range of services and leisure options, contributing to community vitality and inclusiveness.

ii. Encouraging Community Engagement and Interaction

This approach emphasizes involving residents in the planning of leisure spaces, creating opportunities for their participation and contribution. Initiatives like community leisure programs, outdoor education, and art exhibitions not only add value to leisure spaces but also foster community bonds. These spaces thus become hubs for community life, enhancing the sense of belonging and engagement among residents.

iii. Integrating Adjacent Work and Residential Areas

Effectively merging office and residential functions with leisure spaces enhances walkability, social interaction, and activity diversity. As shown in Chapter 5, population density near leisure spaces directly affects activity clustering and diversity. Hence, increasing nearby residential density is vital to invigorating these areas. Furthermore, leisure spaces positively influence the well-being of nearby workers and residents. Urban renewal projects should consider adding office and residential elements near leisure areas, creating versatile leisure complexes that boost the area's vitality and appeal. This improves leisure space utilization and enriches residents' living experiences.

iv. Fostering Development of Surrounding Commercial and Leisure Amenities

Developing commercial, dining, and leisure facilities around leisure spaces can increase interaction with the urban environment. Establishing cafes, galleries, and boutique shops offers convenience to leisure space users while facilitating social and economic activities. These facilities can extend leisure spaces into daily urban life, enhancing the area's overall vitality and allure. Thus, the neighbourhoods around these spaces can better cater to residents and tourists, driving economic growth in the wider community.

5.3.2.3 Enhancing of Internal Leisure Facilities

According to the correlation analysis results in Chapter 4, the internal facilities of LUS significantly impact crowd activity. For instance, the density of facilities within a space has a strong positive effect on the diversity of activity groups. The mix of internal facilities positively influences spatial clustering, temporal persistence, and group diversity. Therefore, increasing the number and variety of internal facilities is essential to enhancing LUS's vitality. However, different types of spaces, such as parks, squares, waterfront spaces, and leisure blocks, each have unique spatial characteristics and preferences for types of leisure facilities. Thus, this paper discusses recommendations for optimizing internal leisure facilities based on different space types.

The evaluation results of internal facility density and mix in Chapter 4 show that out of 11 study samples, only 4 exceed the average value for internal facility density, and 5 exceed the average value for internal facility mix. This indicates that more than half of the LUS in Nanjing's CUA are deficient in providing internal facilities. Observations of various space types show:

Regarding internal facility density, Leisure blocks generally have the highest average density, surpassing the overall average, while have the lowest. Some parks also lack a high density of facilities, often favouring expansive greenery over numerous leisure amenities.

Regarding the internal facility mix, parks and waterfront areas usually have higher average values, indicative of diverse facilities. Conversely, squares have the lowest average, possibly due to their open nature limiting facility diversity. Some leisure blocks also lack a varied mix.

These findings suggest a need for improvement across all space types in terms of both facility density and diversity. Waterfront areas and some parks should increase the number of leisure facilities, while squares and certain leisure blocks should focus on diversifying the types of facilities available.

i. Parks

Upon reviewing the analysis, certain parks urgently require enhancements in the quantity and diversity of their recreational facilities. Chapter 4's assessment reveals that three parks fall below the average in terms of internal facility density. For instance, P1 Park, on the fringe of Nanjing's CUA, boasts an array of viewing and sports facilities, with a notable emphasis on the latter. This imbalance highlights the need for P1 to diversify by incorporating more cultural and consumer facilities.

Table 5.5 : Recommendations for the Optimization of Internal Facilities of Parks

Objective	Strategy	Specific Actions	Example
Enriching Sightseeing Facilities	Create immersive experiences that foster exploration and enjoyment through innovative installations and amenities	Introduce features such as interactive sculptures, musical fountains, and botanical mazes that invite discovery and provide amusement	P1
Adding Sports Facilities	For areas with higher population density and moderate park size, develop multi-use sports zones	Including fitness trails and mini sports complexes	P2
	For larger parks, Increase the number and area of activity spaces, improving the ratio of hard surfaces to green spaces	Allocate spaces for flying kites, aerobics, and ball games, balancing hard and soft landscapes	P1
Moderately Introducing Consumer Facilities	Facilitate light dining options and convenient shopping experiences that complement the park setting	Establish a select number of dining options like casual eateries, tea houses, and coffee shops, along with convenience-oriented retail such as souvenir shops and small convenience stores	P3

In contrast, P2 Park, situated in the city centre, has viewing facilities and a decent range of artistic and consumer amenities, yet it lacks sports facilities. P3 Park, peripherally located near the OCA, although equipped with adequate viewing and sports facilities, is deficient in cultural facilities and consumer amenities. Considering the essential functions and characteristics of parks, a balanced enhancement strategy that prioritizes the development of viewing facilities supplemented with sports and consumer amenities is considered reasonable. Typically, parks function predominantly as areas for leisure and entertainment rather than as primary venues for cultural dissemination. Strategic planning for the incorporation of these facilities will more effectively address public needs and elevate both the allure and functionality of the parks. For detailed recommendations, refer to Table 5.5.

ii. Squares

The analysis indicates a clear need for squares to diversify their leisure facilities. As one of the four leisure urban space types, squares boast a substantial number of viewing facilities, which aligns with their intended use and characteristics. However, internal facility assessments from Chapter 4 indicate that all squares assessed fall below the average mix of facilities. Viewing facilities dominate, accounting for over 78% of amenities in these squares. S1 and S3 feature similar facility distributions, with sports amenities comprising about 20%, while S2 offers less than 10% for sports and cultural facilities. This uniformity highlights a deficiency in consumer facilities and a scant offering of cultural facilities across the board.

Table 5.6 : Recommendations for the Optimization of Internal Facilities of Squares

Objective	Strategy	Specific Actions	Example
Enriching Urban Cultural Experience	Install pieces that represent historical and urban culture	Set up historical cultural sculptures, urban cultural display areas, and art performance venues	S1, S3
Moderately Integrating Consumer Facilities	Deploy compact, movable stalls offering diverse local products	Curate a selection of stalls offering drinks, snacks, and cultural and creative products	S1, S3
	Host regular events that blend culture and commerce	Introduce artisan markets and film nights	S1, S2, S3

To address this imbalance, the study recommends bolstering the representation of cultural facilities within squares and judiciously incorporating consumer amenities. Since squares are often intertwined with local history and culture, enhancing their cultural aspects can more effectively communicate their historical and artistic essence. Thus, squares can transcend their traditional roles as places of leisure and gathering to become pivotal venues for the celebration and immersion in urban culture. For a comprehensive list of recommendations, see Table 5.6.

iii. Waterfront Spaces

The analysis suggests that waterfront spaces should expand their repertoire of internal leisure facilities. The assessment in Chapter 5 reveals that the facility density of the two waterfront spaces studied falls below the average. While W2 in the Jiangbei region and W1 in the Jiangnan region both demonstrate a deficiency in facility density, W1 offers a greater variety of facilities compared to W2, which, despite having ample viewing and some sports facilities, is notably scant in cultural amenities.

Table 5.7 : Recommendations for the Optimization of Internal Facilities of Waterfront Spaces

Objective	Strategy	Specific Actions	Example
Creating Water Features	Implement dynamic water installations to elevate the visual experience	Install floating bridges and gardens and incorporate artful water displays like fountains, screens, and kinetic sculptures	W1, W2
Developing Comprehensive Waterfront Activity Areas	Cultivate vibrant waterfront spaces with diverse leisure activities to spur economic growth	Establish waterfront dining that offers culinary delights, creating welcoming spaces for rest and socializing	W2
	Offer seasonal waterfront activities to engage a broad demographic	Host summer aquatic events and festivals for families and youth; in autumn, present outdoor cultural events and film nights for all ages	W1

Considering waterfront areas' distinctive attributes, bolstering viewing facilities and enriching consumer amenities are regarded as reasonable planning moves. Leveraging the natural surroundings of waterfront spaces to augment leisure experiences is essential. Additionally, integrating dining and retail elements not only enriches the visitor experience but also serves to prolong their stay, thereby enhancing the vitality and allure of waterfront spaces. For a detailed list of recommendations, refer to Table 5.7.

iv. Leisure Blocks

The research underlines a clear imperative for leisure blocks to diversify their array of internal recreational facilities. In LUS, leisure blocks are predominantly aligned with consumer facilities, reflecting their role as hubs for commerce and social interaction. Chapter 4's assessment reveals that, although leisure blocks typically have facility densities above the average, there's a notable imbalance in the variety of facilities provided.

Table 5.8 : Recommendations for the Optimization of Internal Facilities of Leisure Blocks

Objective	Strategy	Specific Actions	Example
Adding Culturally Rich Shops	Establish cultural retail spaces to enhance the community's cultural engagement and enrich consumer experience	Set up art galleries featuring local artists, organize exhibitions on the area's history, and support stores selling locally crafted goods and souvenirs	B2
Improving Interconnection of Block Attractions	Design a contiguous scenic route with interactive and visually appealing elements	Add several viewing facilities at various nodes like public art installations, viewing points, and landscaped areas	B1, B2

For instance, B2's facilities are overwhelmingly consumer-focused (87%), with a significant deficiency in viewing and cultural amenities, representing only 6% and 5%, respectively, and sports facilities at a mere 2%. Given that leisure blocks often serve as bastions of a city's historical and cultural identity, it is suggested that an increased presence of cultural and viewing facilities would constitute a strategic enhancement.

These blocks act not only as custodians of urban culture but also as strategic assets within the city's fabric. Augmenting cultural facilities with complementary consumer amenities could amplify the appeal and encourage a more significant influx of visitors, thereby bolstering the vibrancy and ongoing activity within these spaces. For comprehensive suggestions, see Table 5.8.

5.4 Summary

This chapter addresses the current challenges of LUS in Nanjing from both the systemic and individual levels, enhancing the vitality of LUS in the CUA. At the system level, it presents specific strategies for improving the layout structure of LUS, with a focus on enhancing three key aspects. Recommendations are provided for overall planning, regional variations, and various space configurations, offering solutions to the systemic question of 'where to improve.' On the individual level, the chapter provides targeted recommendations to enhance the quality of existing spaces. By categorizing LUS according to their vitality levels, these recommendations are informed by built environment factors, addressing the individual question of 'how to enhance.' In summary, this chapter provides a strategic roadmap for revitalizing LUS in Nanjing's CUA, offering insights and guidance for policymakers, urban planners, and stakeholders involved in enhancing the city's leisure infrastructure.

CHAPTER 6

CONCLUSION AND IMPLICATION

6.1 Introduction

This chapter provides a comprehensive summary of the key findings of this thesis. It comprises the following sections: Firstly, this chapter elaborates on the key findings of the study and how the research objectives were achieved. The second part discusses the contributions of the findings, categorized into theoretical, practical, and social dimensions. The third section outlines suggestions for future studies.

6.2 Key Findings of the Study

This section presents the key findings of the research, organized according to the four sequential research objectives. Table 6.1 summarizes the findings and their corresponding knowledge contributions.

i. Characteristics and Types of LUS

The study identified four primary types of LUS—parks, squares, waterfront spaces, and leisure blocks—each with distinct characteristics and functions. Chapter 2's literature review provided a comprehensive overview of the evolution and global trends in LUS research, highlighting gaps such as the lack of systematic comparative analyses and the need for context-specific studies. Chapter 4's empirical analysis of LUS in Nanjing's CUA revealed significant spatial clustering, with parks and squares concentrated in central areas and waterfront spaces distributed along major water bodies. Leisure blocks, by contrast, were more randomly distributed, reflecting their commercial and cultural functions. The study also identified spatial distribution imbalances, with central areas exhibiting higher vitality due to better accessibility and facility diversity, while peripheral regions showed deficiencies in leisure space supply. These findings underscore the importance of context-specific planning to address spatial imbalances and ensure equitable access to public leisure spaces.

ii. Dimensions and Indicators of LUS Vitality

To address the limitations of traditional research methods, the study developed a multi-source data evaluation framework, combining big data (e.g., Baidu heat maps, social media data, and POIs) with traditional survey data. This framework was applied in Chapter 4 to evaluate LUS in Nanjing's CUA, revealing significant correlations between spatial characteristics (e.g., proximity to transportation hubs, density of facilities) and vitality levels. Key indicators such as spatial clustering, group diversity, activity temporal persistence, and user satisfaction were identified as critical for assessing LUS vitality. The study also highlighted the importance of internal facility diversity and surrounding function density, advocating for a focus on the quality and diversity of activities and facilities to boost LUS vitality.

iii. Development of a Comprehensive Evaluation Framework

As identified in Chapter 2, empirical research on LUS often lacks a systematic comparative analysis, and vitality evaluation is increasingly shifting towards big data analysis methods. Therefore, to ensure accuracy and the multi-indicator nature of the evaluation, the study adopted a multi-source data evaluation method led by big data and supplemented by traditional data, including sources like Baidu heat maps, social media, POIs, and traditional field survey data. A comprehensive evaluation of LUS' vitality at systemic and individual levels was conducted, integrating methods such as

GIS spatial analysis, statistical computation, and text analysis, culminating in constructing a comprehensive evaluation framework. Furthermore, the study in Chapter 4 on the correlation between crowd activity and the built environment attested to the effectiveness of the evaluation framework, with the calculation of indicator weights finalizing the vitality evaluation framework for LUS.

iv. Commonalities, Differences, and Deficiencies in LUS Vitality

Chapter 4's empirical analysis revealed significant spatial distribution imbalances, with central areas exhibiting higher vitality due to better accessibility and facility diversity, while peripheral regions lag behind. Different types of LUS attract distinct user groups and support varied activities. For example, parks and squares are primarily used for recreational and social activities, while leisure blocks cater to cultural and commercial events. The built environment, particularly factors such as service population density, public transport convenience, and internal facility mixedness, plays a critical role in shaping the vitality of LUS. The study also identified specific deficiencies, such as the lack of large, comprehensive parks in densely populated areas and the insufficient number of leisure blocks in peripheral regions. These findings provide actionable insights for addressing spatial imbalances and optimizing the design and management of LUS to enhance their vitality and inclusivity.

Table 6.1 : Linking Research Objectives to Findings and Knowledge Contributions

RO		Findings	Knowledge Contribution	Chapter Reference
1	To understand the characteristics and types of urban spaces from the leisure perspective.	The nature and forms of leisure; Types and characteristics of LUS; Reviewed the global status and trends of LUS	Identified the definition, characteristics, and classification of LUS, along with research gap and trend	Chapters 2; Chapters 4 (supplementary)
2	To explore the primary dimensions and key indicators impacting the vitality of leisure urban spaces	Research object, vitality composition and research methods in vitality evaluation; Correlation between different dimensional indicators.	Defined LUS vitality and its components; Constructed a Theoretical Framework and an Evaluation Indicator Framework for Vitality in LUS.	Chapters 2; Chapters (validation)
3	To develop a comprehensive evaluation framework for the vitality of leisure urban spaces in China using multi-source data analysis methods	Effectiveness and applicability of the evaluation framework; Importance of various indicators in vitality evaluation	Developed a validated comprehensive multi-source data analysis evaluation framework for LUS	Chapter 3; Chapters (validation)
4	To identify the commonalities, differences, and potential deficiencies in the vitality of various leisure urban spaces across Nanjing's Central Urban Areas.	Distribution characteristics and supply differences of different types of LUS in various areas; Performance of LUS vitality across different space types and indicators; Characteristics and preferences of crowd activity; Features of the built environment supply	Identified detailed characteristics and status of LUS； Provided strategic recommendations for enhancing LUS vitality	Chapter 4; Chapters (recommendations)

6.3 The Contribution of the Findings

This study has presented several significant insights in theoretical, practical, and social dimensions.

6.3.1 Theoretical Contribution

This research addresses a critical gap in the study of Chinese LUS by adopting a comprehensive and interdisciplinary approach. Unlike previous studies that often focused on specific types of spaces, this investigation encompasses a wide range of LUS, including parks, squares, waterfront spaces, and leisure blocks. By examining these spaces at both systemic and individual levels, the study provides new theoretical perspectives that diverge from the limitations of earlier research. The study employs an interdisciplinary framework to analyze the dynamic interplay between leisure activities and urban spatial environments, uncovering the internal mechanisms that drive the vitality of LUS. This approach not only enriches the theoretical understanding of how leisure behaviors emerge and evolve in urban contexts but also establishes a novel multidimensional evaluation framework for assessing LUS vitality. This framework integrates spatial layout, planning, design, and leisure behavior, offering a holistic perspective on the dynamic nature of urban leisure activities. Key findings from the study challenge existing theoretical assumptions by revealing the complex interactions between user behaviors, engagement levels, and urban planning decisions. For instance, the research highlights how different demographic groups adapt their spatial usage patterns based on temporal and locational factors, as well as the significant influence of the built environment on attracting participants and enhancing the overall vitality of leisure spaces. These insights contribute to a more nuanced understanding of the socio-spatial dynamics of urban leisure.

Methodologically, the study introduces innovative approaches by leveraging urban big data alongside traditional survey methods. By integrating multi-source data—such as Baidu heat maps, social media data, points of interest (POI), and survey responses—the research overcomes the limitations of single-source data analyses prevalent in traditional studies. This hybrid methodology not only enhances the accuracy and authenticity of the findings but also provides a more balanced and comprehensive understanding of LUS vitality. Furthermore, the study emphasizes the importance of qualitative research in capturing individuals' subjective experiences and perceptions of LUS. By combining qualitative and quantitative methods, the research offers a deeper and more nuanced exploration of the factors influencing leisure space vitality. Empirical surveys and statistical analyses further refine the understanding of how LUS perform across various dimensions and identify critical physical environmental factors that shape leisure activities.

The study's originality lies in its multidimensional evaluation framework, which examines individual spatiotemporal behavior patterns, activity satisfaction, post-activity emotional feedback, and social interactions. It also explores the transition from isolated to integrated behavioral influences within the broader urban context, as well as the impact of the built environment on crowd activity dynamics. These contributions provide fresh theoretical and practical insights for the planning and design of LUS, setting a new benchmark for future research in this field. In summary, this research not only advances theoretical knowledge but also offers innovative methodological tools and frameworks that deepen the understanding of LUS, providing a robust foundation for future studies and practical applications in urban planning and design.

6.3.2 Practical Implications

The value of this study lies in its development of a quantifiable evaluation framework for assessing the vitality of LUS, which facilitates evidence-based decision-making and supports the enhancement of urban planning effectiveness and spatial quality. This framework not only provides a scientific basis for optimizing LUS but also contributes to the long-term sustainable development of cities. The practical implications of this research extend to several professional fields, as outlined below:

i. Government Decision Support

The evaluation framework and strategies proposed in this study serve as critical tools for government decision-making, particularly in formulating vitality strategies for urban centers and emerging areas. By analyzing the distribution and vitality of leisure spaces in the CUA of Nanjing, the study identifies spatial distribution imbalances and vitality deficiencies in specific regions. These findings offer a scientific foundation for policy formulation and resource allocation, enabling governments to address urban development challenges more effectively. For instance, the framework provides concrete guidance for balancing historic preservation with modern leisure needs in OCA and integrating sustainable development principles into leisure space planning. This aligns with China's 14th Five-Year Plan (2021 – 2025) and Urban Design Guidelines, which emphasize the creation of livable, sustainable, and inclusive cities (The Central People's Government of the People's Republic of China, 2021).

However, a key weakness of current policies is their limited focus on data-driven decision-making, particularly in evaluating the effectiveness of public space investments. This study addresses this gap by providing a quantifiable framework that enables governments to prioritize resource allocation based on empirical evidence, thereby enhancing the efficiency and impact of urban development initiatives.

ii. Guidance for Urban Planning and Design

This research equips urban planners and designers with practical tools and frameworks to incorporate diverse vitality factors into the planning and design of LUS, thereby creating more dynamic and attractive urban environments. The study's comprehensive evaluation of leisure spaces in Nanjing's CUA, conducted at both systemic and individual levels, offers specific strategies for optimizing spatial layouts and enhancing the quality of various leisure spaces.

These recommendations support The Territorial Spatial Master Plan of Nanjing (2021-2035) and Green Space System Planning, which advocate for the development of multifunctional public spaces (NMPG, 2020, 2022). However, a notable weakness in current planning practices is the lack of systematic tools to assess the spatial and social impacts of public spaces. This study addresses this limitation by providing a comprehensive evaluation framework that integrates spatial analysis, user behavior data, and environmental factors. For urban managers, these strategies enhance the multifunctionality and attractiveness of public spaces, providing communities with richer leisure, social, and cultural experiences. Planners can leverage the study's findings on leisure space usage patterns to design more flexible and inclusive spaces that cater to the diverse needs of urban populations.

This research equips urban planners and designers with practical tools and frameworks to incorporate diverse vitality factors into the planning and design of LUS, thereby creating more dynamic and attractive urban environments. The study's comprehensive evaluation of leisure spaces in Nanjing's CUA, conducted at both systemic and individual levels, offers specific strategies for optimizing spatial layouts and enhancing the quality of various leisure spaces. These recommendations are particularly valuable for improving the structure and functionality of parks, squares, waterfront areas, and leisure blocks, as well as promoting balanced development between central and peripheral urban areas. For urban managers, these strategies enhance the multifunctionality and attractiveness of public spaces, providing communities with richer leisure, social, and cultural experiences. Planners can leverage the study's findings on leisure space usage patterns to design more flexible and inclusive spaces that cater to the diverse needs of urban populations. For example, the creation of multifunctional public spaces in densely populated areas can accommodate the activity requirements of different demographic groups, fostering greater social interaction and community engagement.

iii. Landscape Design and Architectural Practices

The study's analysis of internal leisure facilities offers innovative insights for landscape designers and architects, enabling them to optimize design elements and enhance the vitality and attractiveness of leisure spaces. For instance, the integration of sightseeing, sports, and consumption facilities in parks, or the incorporation of cultural elements in squares and waterfront areas, can significantly boost the appeal and functionality of these spaces.

These findings align with China's Urban Design Guidelines and Nanjing's Green Space System Planning, which emphasize the importance of creating aesthetically pleasing, functional, and user-friendly public spaces. The Urban Design Guidelines highlight the need for human-centered design (The Central People's Government of the People's Republic of China, 2017), while Nanjing's Green Space System Planning focuses on optimizing the layout and functionality of urban green spaces to enhance residents' quality of life (NMPG, 2020).

However, a weakness in current design practices is the limited consideration of user behavior and activity patterns in the design process. This study addresses this gap by providing data-driven insights into user preferences and spatial usage patterns, enabling designers to create more user-centric and engaging environments. Designers can utilize the study's findings to improve spatial layouts, creating more interactive and user-friendly leisure environments. Additionally, user experience data from the study can inform the optimization of spatial design, such as the addition of interactive elements to increase user engagement and satisfaction.

6.3.3 Social Significance

The vitality of LUS has emerged as a critical dimension in shaping the social fabric of cities, influencing both individual well-being and collective urban life. As essential components of the urban landscape, LUS provide residents with opportunities for social interaction, physical activity, and mental relaxation, all of which are fundamental to enhancing quality of life. Beyond their recreational function, these spaces play a pivotal role in fostering environmental sustainability and ecological health, reflecting the broader socio-economic and cultural development of a city. The quality and accessibility of LUS are thus not only indicators of urban progress but also key determinants of social equity and community resilience.

This study contributes to the social dimension of urban development by offering a systematic framework for evaluating and optimizing LUS. By aligning leisure facilities with the diverse needs of urban residents, the research underscores the potential of these spaces to maximize social engagement, foster community interaction, and create vibrant, inclusive urban environments. The proposed strategies for enhancing LUS utilization emphasize the importance of spatial design and functional diversity, which are critical for promoting social cohesion and reducing psychological stress among city dwellers. These improvements not only enhance individual well-being but also strengthen communal ties, contributing to a more harmonious and socially integrated urban society.

Moreover, the findings highlight the broader societal implications of vibrant LUS, particularly in terms of urban competitiveness and cultural value. By enhancing the economic, social, and cultural appeal of cities, well-designed LUS can attract diverse populations and stimulate community participation. The study's emphasis on equitable access to public leisure spaces supports the development of more inclusive urban areas, where residents from all socio-economic backgrounds can benefit from improved opportunities for leisure and socialization. This, in turn, fosters a sense of belonging and collective identity, which are essential for sustainable urban development and long-term social stability.

In conclusion, the social contribution of this research lies in its ability to bridge the gap between urban planning and community well-being. By providing actionable insights for the optimization of LUS, the study not only enhances the quality of life for urban residents but also promotes social equity, environmental sustainability, and cultural vitality. These outcomes underscore the transformative potential of public leisure spaces in creating more livable, inclusive, and resilient cities, ultimately contributing to the broader goals of sustainable urban development and social cohesion.

6.4 Recommendations for Future Research

Based on the conclusions and findings of this study, several recommendations for future research are proposed:

i. Limitations in Data Collection and Analysis

(a) Insufficient Data Collection Timeframe:

The current study predominantly used Baidu Heatmap data from the summer season to evaluate the vitality of LUS. Previous research indicates seasonal variations in urban space usage. Moreover, the study collected only one week's worth of Baidu Heatmap data, which may lead to errors due to insufficient collection days. If feasible, future studies should expand data collection to multiple seasons and more extended periods to minimize biases caused by seasonal differences and inadequate collection duration.

(b) Precision and Limitations of Spatial Data:

The study employed GIS technology for quantitative analysis of the number and layout of LUS (Points of Interest, POI). However, it did not consider the scale of these spaces. Furthermore, due to the complexity and ambiguous boundaries of urban public leisure spaces, the subjectivity in data cleaning may lead to incomplete data capture and potential errors in the analysis. Additionally, the spatial accuracy of Baidu Heatmap data might cause biases in evaluating activities in small-scale community spaces.

(c) Issues of Data Diversity and Representativeness:

This research found that reviews on squares were limited on the MD website, potentially restricting a comprehensive evaluation of group diversity and feedback positivity in leisure urban space activities. Future studies might consider combining big and small data and employ various methods, such as social media image analysis, to assess the positivity of activities. Additionally, it should be noted that MD reviews may not fully represent all user groups, especially older adults and children.

ii. Expanding and Deepening the Dimensions and Indicators of Vitality Evaluation

While establishing a vitality evaluation index system for LUS in Nanjing City is based on solid theoretical foundations and previous research, factors influencing the vitality of LUS could be more diverse. Future research should include more dimensions, such as vitality differences under social contexts (like political, economic, and cultural backgrounds) and the impact of individual characteristics (such as education, gender, income, and age). Moreover, the current study primarily focuses on external built environments in its evaluation; future research should consider more internal environment assessments, such as safety and convenience indicators and the aesthetic quality of spaces.

iii. Improvements in Vitality Enhancement Strategies

In the current study, strategies for enhancing the vitality of LUS were mostly presented in textual descriptions and tabular formats, which may not provide clear and intuitive discussions. Future research should incorporate analytical diagrams, planning maps, and related design intention effect images to offer clearer and more direct decision-making support for governments and urban planners, thereby enhancing the applicability and impact of research findings.

6.5 Conclusion

The evaluation of Leisure Urban Spaces aims to meticulously analyze the supply and actual usage of various types of urban spaces with leisure functions to understand whether these spaces meet resident needs deeply. This evaluation reveals usage efficiency and issues, providing scientific bases and directions for urban planning and renewal, thereby helping to optimize resource allocation and enhance urban life quality. Consequently, this research has developed a comprehensive evaluation framework for the vitality of LUS that encompasses multiple levels and dimensions. Utilizing emerging big data analysis technologies, it not only enhances the efficiency and applicability of evaluations but also reveals new characteristics and current states of LUS during the evaluation process, offering robust data support for enhancing LUS vitality in future urban planning. Further analysis indicates that the quality of the built environment significantly impacts the performance of crowd activity within LUS. Factors such as residential density, accessibility of transportation, external urban function settings, and the provision of internal leisure facilities all show varying degrees of positive correlation with spatial clustering, temporal persistence, group diversity, and feedback positivity of crowd activity. Based on these findings, this paper proposes strategic recommendations for enhancing LUS vitality, targeting both spatial layout optimization and the improvement of existing space quality to achieve more effective and sustainable vitality promotion in future urban planning practices. Therefore, this research provides a practical method for evaluating LUS, applicable not only in China but also globally. This method supports urban planning, policy-making, and academic research, enhancing the scientific rigour and effectiveness of urban space design. The results are significant for academics, policymakers, urban planners, and researchers in this field, especially those in rapidly urbanizing countries like China, offering important strategies and theoretical support for public space renewal and sustainable urban development.

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APPENDICES

Appendix A

Summary of Characteristics of Studies Included in the Systematic Review

Source	Research Object	Components of Vitality			Research Method	
		Vitality Representation	Potential impact Factors	Significant Indicators	Data Collection	Data Analysis
Banchiero et al., 2020	Park	Crowd activity: The number of users; The diversity of users; The diversity of uses	Generators of Urban Diversity; Qualities of Neighbourhood Parks	/	Observation	Equal Weighted Algorithm
J. Zhu et al., 2020	Park	Crowd activity: Satisfaction; Density	Supply; Demand; Spatial link (9 indicators)	Presence of water in the park; The density of facilities in the park; Population density outside the park	Online check-in data; POI Data	Multiple regression analysis
Mu et al., 2021	Park	Crowd activity: Diversity of age group; Visitor density; Space using intensity; Richness of activity types	/ (5 indicators)	Park location and accessibility; The diversity of sub-spaces and activities; Adequacy of service facilities; High-quality green space; High water quality	Observation; Questionnaire	Expert scoring
Dong et al., 2022	Park	Crowd activity: Average density	External spatial features; External functional characteristics; Accessibility and location; Self-spatial characteristics; Perception of visitors	Distance to nearest traffic stop; Density of surrounding road network; Comprehensive score of green space	Baidu heat map; POI Data; Road network data The building Information data; Observation	Multiple linear regression method
Molavi et al., 2017	Square	Built environment: Use; Plants; Height of buildings; Age of buildings; Closeness	/	Functional factors	Observation; Questionnaire	ANP technology (Questionnaires filled out by experts)
T. Wang et al., 2022	Square	Built environment: The attractiveness of parks and squares; The richness of their surrounding businesses; The road network and population densities; The service levels	/ (4 indicators)	Urban functional mixing; Spatial population distribution; Traffic network density; Attractiveness of space	POI Data; Population data; Road network data	Expert scoring

Chen & Ma, 2023	Waterfront space	Crowd activity: Viewing Stay; Sports Stay; Leisure Stay; Social Stay	Recreation service capacity; Natural environmental quality (7 indicators)	Number of public facilities; Shoreline curvature	Observation (Behavioral notation method) Remote sensing; imagery;	Pearson correlation analysis
F. Wang et al., 2020	Waterfronts	Crowd activity: Dynamic space aggregation features; Dynamic characteristics of time-sharing; Crowd attraction in waterfront space	/ (5 indicators)	The proportion of urban construction land; Unit residence; Facility diversity; Road network density	Mobile phone signalling data; POI Data	Geographical Weighted Analysis
Niu et al., 2021	Waterfronts	Built environment: Functional Mixing Degree; River Attributes; Land Spatial Type; Vision Accessibility; Transportation Accessibility	Crowd activity: Intensity	Functional Mixing Degree; River Attributes; Transportation Accessibility	POI Data; Observation	AHP Expert scoring
S. Liu et al., 2021	Waterfronts	Crowd activity: Density; Stability	Site Design; Traffic Accessibility; Surrounding Population; Service Facility (10 indicators)	Shorelines Open Degree; Public Service Facility Density; Nonmotorized Vehicle Lane Accessibility; Surrounding; Commercial Service Density; Catering Facilities Density	Real-time Tencent user density data; POI Data; Building data; Road network data	Structural Equation Modeling
Fan et al., 2021	Waterfronts	Crowd activity: Average density	Density; Diversity; Accessibility; Vegetation (9 indicators)	Building density; Floor area ratio	Baidu heat map data; POI Data; Building footprint data; Transit stations/stops data; River polygon data; NDVI data	Multiple linear regression GWR model
Ding et al., 2023	Waterfronts	Crowd activity: Density; Stability	Physical environment characteristics; Evaluation of spatial experience (12 indicators)	Functional mixed use; Vegetation coverage index; DianPing/Tourism; DianPing/Entertainment	Baidu heat map data; Land use data; Road network data; Online review data	Multiple linear regression analysis
Sheng, 2013	Residential Block	Built environment: The number of shops (markets, grocery stores, clubs, street vendors, etc.)	/	The topological pattern of the block	Observation	Mixed Space syntax
Yang et al., 2021	Residential Block	Crowd activity: Density	Block accessibility; Block function; Block development intensity;	Road density; Function density	Mobile phone; signaling data; POI Data; Baidu Street View; Block	GWR model

			Block environment perception (9 indicators)		data; road network data; Transportation data; Building data	
Huang et al., 2023	Residential Block	Crowd activity: Intensity; Variation	Diversity; Accessibility (7 indicators)	Functional density; Amenity density; Closeness	Baidu heat map; POI data; Road network data; Building data	Multiple linear regression analysis; GWR model
X. Q. Zhu et al., 2013	Historic Block	Built environment: location characteristic function composition space mode	location characteristic; function composition; space mode	/	Observation; Questionnaires	Mixed
Y. Zhang et al., 2021	Historic Block	Crowd activity: Intensity; Stability; Duration	/ Density; Diversity Design; Accessibility; Distance to Transit	/	Regional scope; Road network; Remote sensing image; Baidu thermal map; Questionnaire	Exploratory factor analysis Analytic hierarchy process
F. Zhang et al., 2022	Historic block	Built environment: Basic characteristics of public space (Accessibility, Comfort, Functionality); Characteristics of History and Culture (Characteristics of material elements, Characteristics of non-material elements)	Material element; Spatial scale; Aesthetic attribute (17indicators)	block location; spatial structure overall layout; block density; greening coverage; block sanitation; architectural features; visual effects	POI data; AMAP(AutoNavi) data; Baidu Street View; Observation	Multiple linear regression analysis; GWR model
Xu et al., 2018	Street	Crowd activity: Average number of visitors	Street form; Street business type; Street accessibility (9 indicators)	/	Observation; Google Street map; Traffic application (My Nanjing)	Multiple linear regression method
M. Liu et al., 2021	Street	Crowd activity: Density	Peripheral; Internal (8 indicators)	Function density; Function mixing degree	Baidu heat map; POI data; Road network; Baidu panoramas	Multiple linear regression method
Yuan & Chen, 2021	Street	Crowd activity: number of visitors	Segment Connectivity; Travel Modes; Building Capacity; Land-Use; Ground-Floor Interface (12 indicators)	Density of entrances and exits of Residential properties; Land-Use Density; types; and degree of mixing	POI data; Road network data; Public transportation data	Pearson correlation analysis
Wangbao, 2022	Street	Crowd activity: Intensity	/ (6 indicators)	Land use mixing degree; Border vacuums	Tencent Location service data; POI data; Building data	Multiple linear regression analysis; GWR model

Appendix B

Example of Crawling Big Data from the Internet

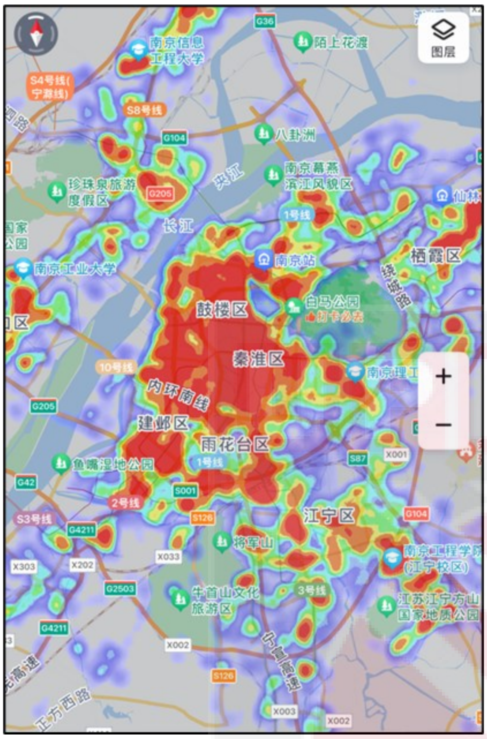


Figure B:1 Interface of Baidu Heat Map at 12:00 Noon in Nanjing

Figure B2: Interface of GeoQuater

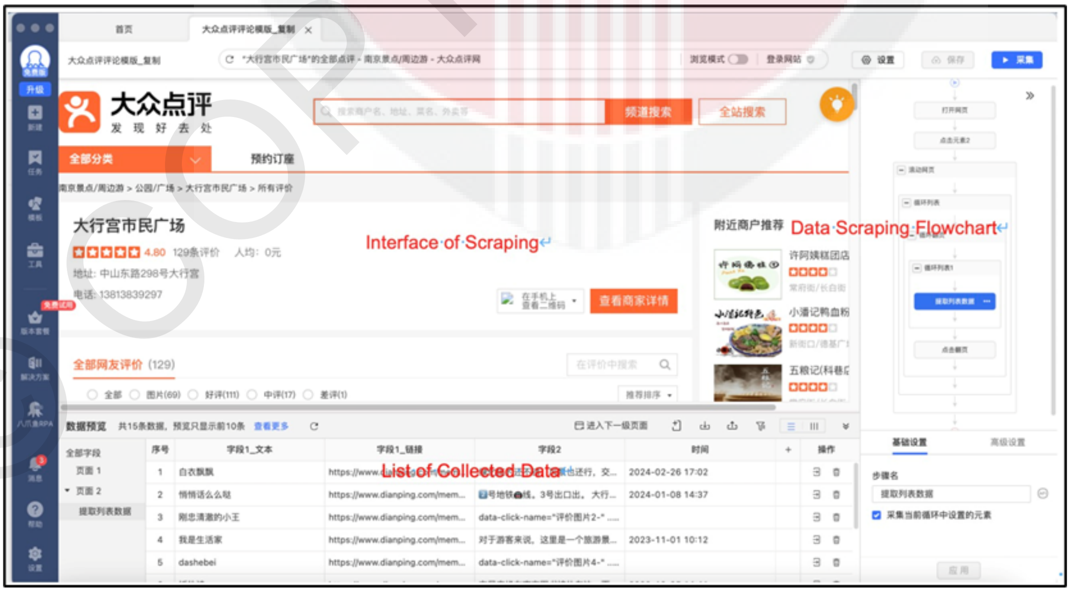


Figure B3: Interface of Octoparse

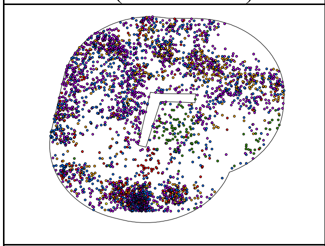
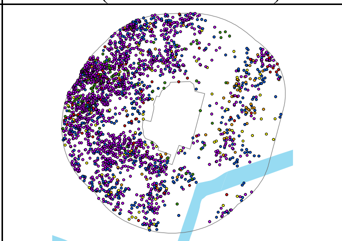
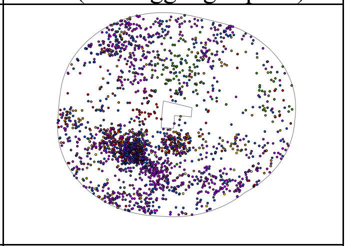
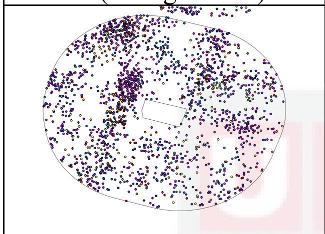
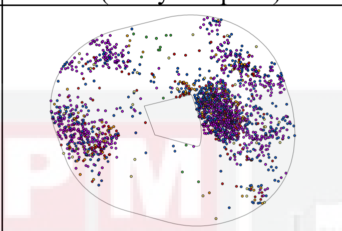
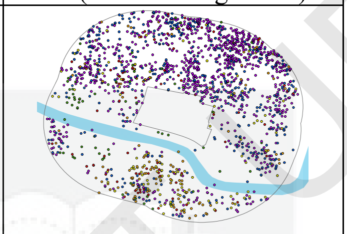
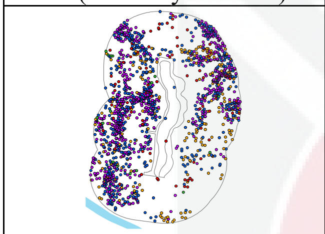
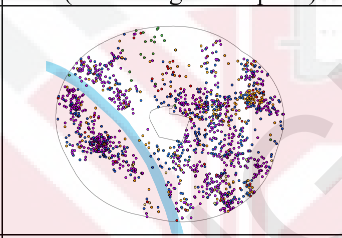
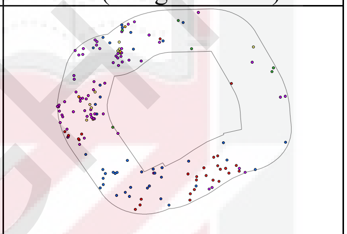
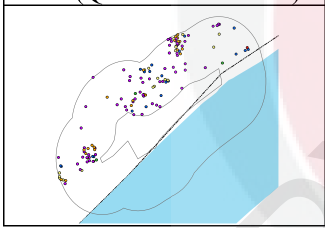
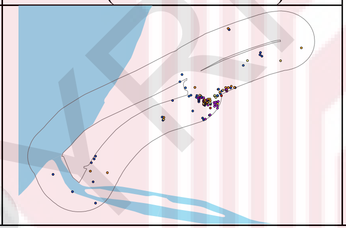
Appendix C

Summarization and Visualization of POI Data in the Research Spaces

Table C1: Statistics of the Number of Various Types of Urban Functional POIs in Each Research Space

Code	Name	Residential community	Commercial service	Business office	Public service	Scenic spot	Education	Total
B2	1912 Block	64	1009	258	1670	481	110	3592
P2	Bailuzhou Park	61	520	81	1520	100	114	2396
S3	Daxinggong Square	32	635	180	1089	198	112	2246
P4	Zhenghe Park	76	591	104	963	180	15	1929
S1	Tianyin Square	26	547	154	990	162	16	1895
B1	Laomendong Block	52	447	77	912	188	68	1744
P3	Xiaotaoyuan Park	95	571	63	708	133	28	1598
S2	Hanzhongmen Square	82	427	54	750	148	25	1486
P1	Yangshan Park	12	64	42	32	5	1	156
W2	Qiaobei Waterfront	4	47	14	59	14	1	139
W1	Yuzui Waterfront	0	35	5	25	30	0	95

Table C2: Visualization of the Distribution of POI of Urban Functions in Research Spaces

B2 (1912 Block)	P2 (Bailuzhou Park)	S3 (Daxinggong Square)
		
P4 (Zhenghe Park)	S1 (Tianyin Square)	B1 (Laomendong Block)
		
P3 (Xiaotaoyuan Park)	S2 (Hanzhongmen Square)	P1 (Yangshan Park)
		
W2 (Qiaobei Waterfront)	W1 (Yuzui Wetland)	POI Residential Community Commercial service Business office Public service Scenic spot Education
		

Appendix D

Summarization of Heat Values for Each Time Point throughout a Week in Research Spaces

Table D1: Statistics of Heat Value for Each Research Space over a Week (from 6:00 AM to 11:00 PM)

	P1	P2	P3	P4	S1	S2	S3	W1	W2	B1	B2
21-6am	5	20	47	16	16	3	2	8	20	28	15
21-7am	22	39	45	17	38	58	13	12	34	45	17
21-8am	77	47	62	19	79	161	24	20	32	49	51
21-9am	54	56	51	25	136	54	37	15	36	80	45
21-10am	55	57	30	26	151	53	97	8	32	132	140
21-11am	44	62	28	27	223	51	71	7	35	144	63
21-12pm	30	38	47	12	189	0	0	14	23	144	33
21-13pm	33	49	38	6	222	48	52	20	18	183	113
21-14pm	31	42	27	26	191	103	54	12	31	162	137
21-15pm	43	53	39	16	218	48	68	10	18	165	69
21-16pm	42	37	47	19	185	58	66	20	29	146	122
21-17pm	39	65	35	22	205	106	36	16	31	233	126
21-18pm	42	60	61	14	204	0	42	30	36	284	115
21-19pm	26	64	39	24	219	0	15	28	42	292	34
21-20pm	23	48	47	22	206	37	7	8	23	270	41
21-21pm	16	55	41	29	123	44	11	7	46	181	33
21-22pm	19	37	23	25	53	0	5	9	26	128	23
21-23pm	17	34	31	44	57	12	6	5	8	94	31
22-6am	14	15	13	14	24	12	3	4	14	31	18
22-7am	17	46	48	38	36	0	11	8	24	35	24
22-8am	0	64	51	35	96	127	28	19	31	17	52
22-9am	37	48	36	21	40	68	62	12	39	71	160
22-10am	38	50	30	30	178	45	110	7	18	81	179
22-11am	26	55	51	17	183	40	175	16	19	94	205
22-12pm	30	52	28	14	209	74	123	12	30	124	207
22-13pm	28	62	35	16	245	93	129	7	23	140	187
22-14pm	39	40	43	25	164	71	176	17	22	170	193
22-15pm	21	63	49	31	265	46	219	9	30	169	129
22-16pm	29	63	48	29	241	113	126	15	23	207	195
22-17pm	69	63	29	32	211	127	71	18	27	228	186
22-18pm	62	60	55	26	307	203	58	25	36	286	152
22-19pm	53	92	52	28	0	0	16	25	0	331	89
22-20pm	26	64	43	17	244	50	13	19	27	347	74
22-21pm	29	79	47	22	0	46	10	0	62	75	24
22-22pm	17	58	32	22	109	0	12	5	38	162	52
22-23pm	11	49	46	15	50	0	6	6	32	101	26
23-6am	14	18	25	10	10	11	0	5	10	46	8
23-7am	34	56	43	15	43	0	10	5	29	44	21
23-8am	38	37	46	20	99	107	39	17	39	68	86
23-9am	44	47	34	19	152	59	106	15	20	78	179
23-10am	42	62	45	24	198	0	127	8	26	119	259
23-11am	26	55	51	21	175	58	121	9	31	141	223
23-12pm	40	67	33	25	241	64	137	6	24	150	201
23-13pm	30	56	28	13	205	0	109	24	24	163	157
23-14pm	8	110	107	70	201	142	292	0	79	358	434
23-15pm	46	57	46	17	184	99	162	8	34	169	207
23-16pm	40	77	43	29	207	67	141	14	28	187	225
23-17pm	46	75	34	20	225	57	76	33	29	219	187
23-18pm	54	54	49	22	221	146	51	38	28	284	149
23-19pm	50	83	55	24	234	0	15	29	41	361	64
23-20pm	23	80	43	21	209	0	17	21	50	333	32

23-21pm	35	72	74	25	150	84	13	14	45	266	30
23-22pm	22	64	49	28	81	41	18	8	25	180	33
23-23pm	12	42	39	27	63	0	8	10	17	96	25
24-6am	z	19	12	17	9	8	5	2	8	32	14
24-7am	19	50	41	14	42	0	22	11	35	43	22
24-8am	43	64	43	24	66	123	65	15	32	54	50
24-9am	35	46	39	46	145	63	113	16	24	94	169
24-10am	31	66	43	28	203	60	146	10	22	114	182
24-11am	38	71	38	23	211	3	275	13	25	115	227
24-12pm	39	58	37	21	222	52	98	11	30	158	215
24-13pm	32	61	40	35	224	0	91	7	13	157	210
24-14pm	35	66	26	24	221	56	137	12	31	176	204
24-15pm	43	71	42	25	234	0	146	6	17	134	211
24-16pm	36	58	40	21	225	88	120	10	20	178	166
24-17pm	49	66	64	50	236	58	83	21	45	256	124
24-18pm	60	55	44	17	212	152	37	35	36	349	117
24-19pm	35	85	58	22	222	101	19	25	54	364	52
24-20pm	27	78	82	30	175	29	24	22	29	305	29
24-21pm	30	75	76	35	157	35	15	14	30	265	39
24-22pm	16	69	52	20	71	43	15	13	19	159	47
24-23pm	17	36	32	18	41	29	5	4	11	104	37
25-6am	6	14	36	29	11	6	6	3	17	33	19
25-7am	20	49	64	17	49	56	10	14	30	46	34
25-8am	46	48	44	20	86	158	48	21	27	56	90
25-9am	30	53	26	20	130	60	95	17	33	79	164
25-10am	32	48	52	30	181	0	177	10	26	94	263
25-11am	32	73	57	25	180	45	140	7	25	125	164
25-12pm	39	60	50	21	221	45	111	8	39	135	137
25-13pm	52	60	36	48	222	50	132	13	27	167	92
25-14pm	36	64	52	19	215	0	150	9	39	162	190
25-15pm	54	47	24	26	221	110	178	18	19	173	223
25-16pm	64	70	45	19	239	0	157	19	36	180	220
25-17pm	59	79	64	34	211	127	58	54	36	246	99
25-18pm	66	109	59	58	219	217	61	59	47	597	235
25-19pm	41	78	34	20	211	62	22	28	40	344	74
25-20pm	34	63	93	17	227	29	13	29	49	364	39
25-21pm	28	51	83	23	160	62	15	19	47	257	65
25-22pm	35	104	0	38	0	58	16	26	0	444	84
25-23pm	15	42	56	18	54	39	4	11	37	98	34
26-6am	7	20	40	9	17	11	6	1	22	23	17
26-7am	29	39	55	17	45	12	50	3	39	39	31
26-8am	32	55	40	23	73	67	124	11	34	60	101
26-9am	49	35	48	25	120	87	196	23	48	102	198
26-10am	60	70	35	23	172	26	181	21	47	152	149
26-11am	42	89	47	25	221	89	142	19	49	206	199
26-12pm	35	65	29	48	245	88	170	18	22	219	211
26-13pm	36	55	43	19	276	81	186	13	27	212	231
26-14pm	51	71	29	24	253	87	186	16	22	223	176
26-15pm	50	42	32	23	263	108	171	21	20	235	214
26-16pm	62	68	41	18	265	37	84	28	44	291	225
26-17pm	52	72	53	28	318	73	56	31	31	339	181
26-18pm	40	79	53	39	224	92	20	41	36	360	106
26-19pm	55	91	52	24	280	73	21	29	40	385	165
26-20pm	35	80	69	19	241	0	20	24	41	411	35
26-21pm	31	80	74	21	168	65	15	12	45	344	83
26-22pm	14	53	53	20	114	0	21	7	27	201	103
26-23pm	18	27	34	27	72	41	6	9	16	121	81
27-6am	9	28	11	21	8	7	18	8	20	20	29
27-7am	17	34	22	18	43	0	73	7	31	43	31
27-8am	28	53	35	43	57	40	138	9	22	65	60
27-9am	31	53	32	20	112	62	166	11	30	123	142
27-10am	50	68	40	30	185	57	210	16	54	143	222
27-11am	42	64	32	34	218	67	132	18	48	181	169

27-12pm	51	72	34	34	252	74	131	13	35	226	187
27-13pm	34	75	38	31	240	65	155	12	21	212	196
27-14pm	57	80	35	34	268	25	184	22	45	250	175
27-15pm	36	72	60	21	285	25	135	23	26	203	191
27-16pm	43	56	46	23	230	24	95	11	35	227	129
27-17pm	42	69	48	26	273	38	21	18	37	223	151
27-18pm	34	79	47	33	237	59	10	25	45	238	66
27-19pm	27	63	46	28	211	22	14	8	37	218	40
27-20pm	39	74	45	20	198	44	8	19	61	215	45
27-21pm	27	62	42	27	151	45	7	10	47	171	42
27-22pm	17	42	40	23	88	11	4	7	36	159	75
27-23pm	7	24	26	31	40	7	58	3	17	76	37

Table D2: Statistics of Heat Value for Each Research Space over a Week (12:00 AM)

Date	P1	P2	P3	P4	S1	S2	S3	W1	W2	B1	B2
21	7	270	301	376	94	242	281	0	7	175	302
22	7	255	261	336	112	222	261	1	7	193	318
23	9	285	324	351	114	224	313	2	9	190	339
24	12	315	311	353	113	230	315	1	12	194	328
25	9	275	312	369	106	214	289	5	9	192	322
26	10	316	272	436	87	239	325	7	10	246	341
27	5	305	291	355	17	224	369	4	5	248	380

Appendix E

Analysis and Summarization of Review Data

```
from collections import Counter
# List of specified keywords
keywords = ["孩子", "小孩", "小朋友", "宝宝", "儿童", "遛娃", "儿子", "女儿", "姑娘", "闺女", "一家人", "家里人",
"孙子", "孙女", "老人", "爸", "妈", "父母", "爷爷", "奶奶", "女朋友", "男朋友", "老公", "老婆", "媳妇", "对象", "情
侣", "爱人", "伴侣", "未婚妻", "未婚夫", "闺蜜", "姐妹", "兄弟", "舍友", "室友", "朋友", "同学", "铁子", "哥们", "
姐们", "bro", "胖友", "伙伴", "同桌", "同伴", "好友", "挚友", "团队", "团建", "旅行团", "团员", "旅游团", "组织", "
社团", "集体", "单位组织", "学校组织", "自己", "独自", "一个人", "自己一个人", "女孩子", "男孩子"]
# Text for analysis
text = "…"
# Split the text into words
words = text.split()
# Count the frequency of each word
word_counts = Counter(words)
# Count how often each keyword appears in the text
keyword_counts = {keyword: word_counts[keyword] for keyword in keywords}
# Filter out keywords that do not appear in the text
keyword_counts = {k: v for k, v in keyword_counts.items() if v > 0}
# Print the counts of each keyword
for keyword, count in keyword_counts.items():
    print(f"{keyword}: {count}")
```

Table E1: Frequency Statistics of Keywords Related to Leisure Companionship in Review Data

Code	Family	Couple	Friends	Organized Collectives	Oneself
P1	352	6	33	4	16
P3	333	5	56	0	62
P3	282	13	82	5	68
P4	26	9	26	2	19
S1	5	0	2	0	0
S2	17	5	19	2	3
S3	15	2	14	0	15
W1	1568	0	257	21	302
W2	188	0	71	0	0
B1	957	223	1196	48	820
B2	213	42	234	4	135

Table E2: The Statistical Data of Sentiment Scoring in Each Research Spaces

Code	Number of reviews	Average Positive Score	Average Negative Score
P3	275	38.50	9.036
P1	389	37.90	12.46
S2	99	31.84	8.56
B1	8622	32.69	10.35
B2	1624	31.07	9.61
S3	39	30.31	10.03
P4	134	27.11	7.98
S1	26	30.87	12.33
W2	286	26.10	8.08
P2	658	28.14	10.23
W1	3206	26.71	9.87

```
# -*- coding: utf-8 -*-
import os
import re
import jieba
import pandas as pd
import numpy as np
import warnings
warnings.filterwarnings("ignore")

class Senti_classify:
    def __init__(self, emotion_dict_path='', mostdict_value=2, verydict_value=1.75,
                 overdict_value=1.5, moredict_value=1.25, ishdict_value=0.5,
insufficientdict_value=0.25):
        self.inversedict = self.open_dict(Dict=emotion_dict_path+'否定词') #否定词
        # 程度副词
        self.mostdict = self.open_dict(Dict=emotion_dict_path+'hownet-程度词语-极其
extreme 最 most')
        self.verydict = self.open_dict(Dict=emotion_dict_path+'hownet-程度词语-很 very')
        self.overdict = self.open_dict(Dict=emotion_dict_path+'hownet-程度词语-超 over')
        self.moredict = self.open_dict(Dict=emotion_dict_path+'hownet-程度词语-较 more')
        self.ishdict = self.open_dict(Dict=emotion_dict_path+'hownet-程度词语-稍-ish')
        self.insufficientdict = self.open_dict(Dict=emotion_dict_path+'hownet-程度词语-欠
insufficiently')
        # 获取每一个程度副词的赋值
        self.degree = {}
        # (Include the remaining part of the __init__ method)
        # ...

    def open_dict(self, Dict='', path=''):
        # (Include the complete implementation of open_dict)
        # ...

    def sentiment(self, reviews):
        # (Include the complete implementation of sentiment)
        # ...
        return review_senti

# ===设置模型
senticlass =
Senti_classify(emotion_dict_path='C:/Users/13656/Desktop/work/20231012boson 情感分析
/emotion_dict/')

def get_senti(x):
    if x > 0:
        return '正面'
    elif x == 0:
        return '中性'
    else:
        return '负面'

# ====开始情感分析
data_path = 'C:/Users/13656/Desktop/work/20231012boson 情感分析/大众点评/'
save_path = 'C:/Users/13656/Desktop/work/20231012boson 情感分析/情感分析结果/'

for filename in os.listdir(data_path):
    data = pd.read_excel(data_path + filename)
    content_senti = data['评价内容'].fillna('').astype(str).map(lambda x:
senticlass.sentiment(x))
    data['正面情感分值'] = content_senti.map(lambda x: x['possenti'])
    data['负面情感分值'] = content_senti.map(lambda x: x['negsenti'])
    data['整体情感分值'] = data['正面情感分值'] - data['负面情感分值']
    data['情感倾向'] = data['整体情感分值'].map(get_senti)
    data.to_excel(save_path + filename, index=0)
```

Figure E2: Python Code for Sentiment Analysis

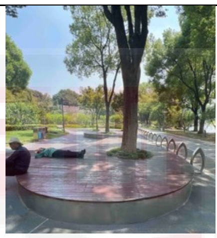
Table E3: Frequency Statistics of High-Frequency Words in the Review Data

Words	English Translation	frequency	Words	English Translation	frequency	Words	English Translation	frequency
拍照	Take photos	1823	晚上	Evening	584	位置	Location	101
美食	Gourmet food	1802	传统	Tradition	569	方便	Convenient	101
建筑	Architecture	1646	气息	Atmosphere	560	下午	Afternoon	100
特色	Characteristics	1224	时间	Time	518	灯光	Lighting	98
逛逛	Stroll around	1140	打卡	Check-in	355	周末	Weekend	78
历史	History	1041	近	Nearby	273	地铁	Subway	77
文化	Culture	968	旁边	Next to	209	体验	Experience	76
朋友	Friends	841	风景	Scenery	109	小吃	Snacks	75
白天	Daytime	781	游玩	Play/Visit	103	免费	Free	58
网红	Internet celebrity	661	孩子	Children	103	自己	Oneself	54

Appendix F

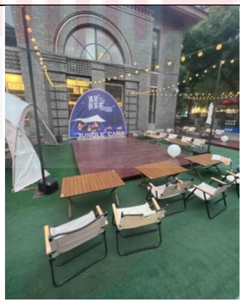
Summarization and Visualization of the Quantity of Filed Survey (Internal Facilities)

Table F1: Examples of Photos from Field Survey of Various Facilities

Sightseeing Facility			
Leisure chair	Rest area	Public art installation	Scenic lookout
			
Pavilion	Bridge	Sculpture	Micro landscape
			
Pond	Sightseeing boat	Camping site	Corridor pavilion
			
Fountain		Sightseeing vehicle	
			

Sport Facility		
Fitness equipment	Movement zone	Children's equipment
		
Ball Park	Running track	Sculpture
		

Culture Facility		
Historic site	Exhibition venue	Art studio
		

Museum	Cultural experience hall	Performing arts venue	library
			

Gallery	Memorial hall	Cultural corridor	Religious venue
			

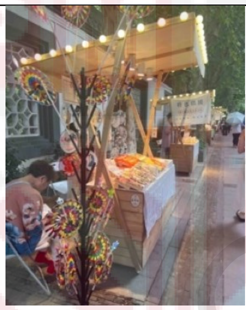
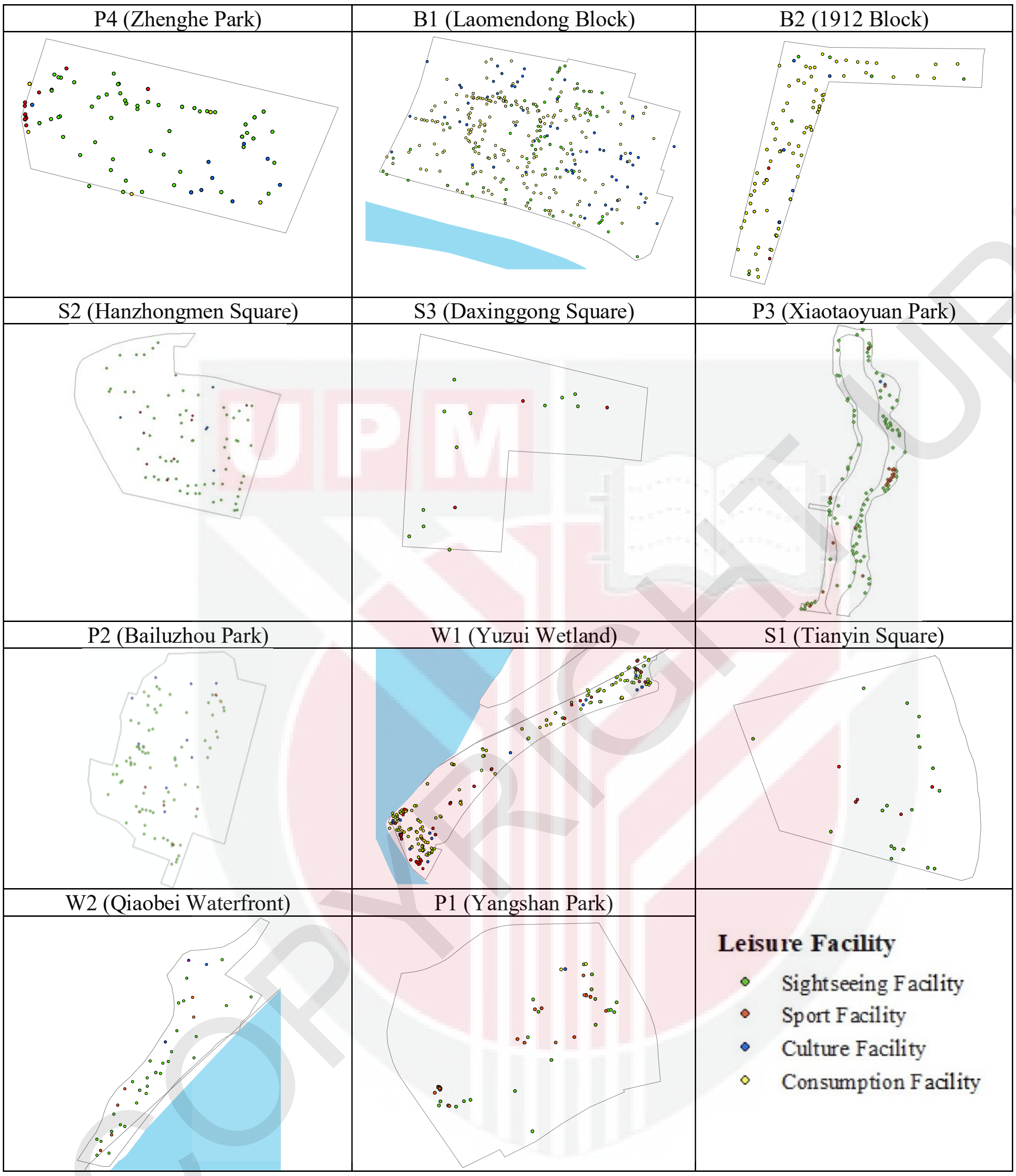
Consumption Facility			
Restaurants	Commodity stand	Snack stall	Beverage shop
			
Shopping store	vending machine	Hotel accommodation	SPA
			
KTV		Photography Service	
			

Table F2: Statistics of the Number of Various Types of Internal Facility in Each Research Space

Facility type/Code	B1	W1	P3	P2	B2	P4	S2	P1	W2	S1	S3	Total
TOTAL												
/	352	255	125	107	103	100	93	48	42	23	15	1263
Sightseeing Facility												
Leisure chair	38	119	65	37		55	79	6	20	6	10	435
Scenic Lookout	1	19	12	7		2		4				45
Public art installation	11	17		1	3			1		5		38
Rest area	4	6	5	1		3		4				23
Pavilion	9	2	2	5	1	3						22
Bridge			2	11		2		3	3			21
Sculpture	7	1			1	1			2	7	1	20
Micro landscape	2		7	2			1	2				14
Pond	4	1	2	3		1		1	1			13
Corridor pavilion	3	2		4								9
Camping site								1	6			7
Sightseeing boat			1	4								5
Fountain			2		1	1					1	5
Sightseeing vehicle		1										1
TOTAL	79	168	98	75	6	68	80	22	32	18	12	658
Sport Facility												
Fitness equipment		3	1					3		3		48
Movement zone		4	2					1	2			37
Children's equipment		3	3	2				5	3			26
Walking trail		19			2	15		11		1		16
Ball Park		10	16									10
Running track		9	3	3		3	8	3	4	1	3	9
TOTAL	0	48	25	5	2	18	8	23	9	5	3	146
Culture Facility												
Historic site	18	6		7		6	5		1			43
Exhibition venue	9	5			2							16
Art studio	13				1							14
Museum	5											5
Cultural experience hall	5	1										6
Performing arts venue	2	1	2		2							7
library	3			1				1				5

Gallery	3			1							4
Memorial hall				1		2					3
Cultural corridor				2		1					3
Religious venue				1							1
TOTAL	58	13	2	13	5	9	5	1	1	0	0	107
Consumption Facility											
Restaurants	74			4	25							103
Commodity stand	54			1	17							70
Snack stall	24	10										54
Beverage shop	25	1		2	9							37
Shopping store	22	2		2	18							32
Vending machine	5	13		3	3	5		2				31
Hotel accommodation	6				2							10
SPA	2			2								8
KTV												4
Photography Service	3				16							3
TOTAL	215	26	0	14	90	5	0	2	0	0	0	352

Table F3: Visualization of the Distribution of Location of Internal Facility in Research Spaces



Appendix G

Summarization of Data Standardization and Calculation Results for Each Indicator

Table G1: Statistics of Calculation Values for Each Indicator

	P1	P2	P3	P4	S1	S2	S3	W1	W2	B1	B2
Y1	0.1876	3.0528	2.7822	7.5342	17.5352	14.4842	55.1181	0.1797	0.6654	11.9052	26.5646
Y2	=Y2-1*0.5+ Y2-2*0.5										
Y2-1	14.8329	18.2798	14.8458	9.4206	80.5328	42.5797	67.6084	9.6931	11.7158	106.5773	79.2347
Y2-2	64	64	57	68	62	55	52	66	62	63	63
Y3	0.5684	0.8079	1.0411	1.4003	0.5983	1.2887	1.2292	0.8049	0.5873	1.3220	1.2781
Y4	=Y4-1*0.5+ Y4-2*0.5										
Y4-1	4.7082	4.1716	4.7400	4.5962	4.2500	4.6591	4.5960	4.2051	4.5373	4.6105	4.6206
Y4-2	22.3400	17.8887	29.4641	20.2452	19.2450	18.5390	25.4391	18.0619	16.8381	21.4605	23.2864
X1	0.2529	2.2170	0.8534	2.4492	0.9078	1.7657	3.4891	0.0829	0.4309	1.6600	1.9758
X2	134.0719	116.9342	65.8988	97.1801	79.9028	100.2195	168.5528	95.3408	90.4297	119.7716	119.8909
X3	13	7	16	13	11	13	11	4	9	13	12
X4	0.3742	10.9205	4.6072	12.5034	10.4533	9.3612	21.4783	0.2964	0.6015	8.5362	18.7608
X5	1.4903	1.1824	1.5069	1.3805	1.2409	1.4648	1.3683	1.2382	1.3386	1.3821	1.4042
X6	0.2578	5.5898	7.8925	30.3098	2.4287	21.2715	10.9448	2.9682	0.8872	23.7163	23.4304
X7	0.9232	0.9144	0.5788	0.9367	0.5236	0.4977	0.5004	0.9702	0.6253	0.9336	0.5045

Table G2: Statistics of Normalized Values for Each Indicator

	P1	P2	P3	P4	S1	S2	S3	W1	W2	B1	B2
Y1	0.0001	0.0523	0.0474	0.1339	0.3159	0.2604	1.0000	0.0000	0.0088	0.2134	0.4803
Y2	0.8471	0.8294	0.6283	1.0000	0.4465	0.4231	0.2005	0.9361	0.8007	0.3438	0.4845
Y2-1	0.9443	0.9088	0.9442	1.0000	0.2681	0.6587	0.4011	0.9972	0.9764	0.0000	0.2814
Y2-2	0.7500	0.7500	0.3125	1.0000	0.6250	0.1875	0.0000	0.8750	0.6250	0.6875	0.6875
Y3	0.0000	0.2879	0.5682	1.0000	0.0359	0.8658	0.7943	0.2843	0.0228	0.9059	0.8532
Y4	0.6899	0.0416	1.0000	0.5084	0.1643	0.4962	0.7139	0.0779	0.3216	0.5692	0.6503
Y4-1	0.9441	0.0000	1.0000	0.7470	0.1379	0.8576	0.7466	0.0589	0.6433	0.7722	0.7898
Y4-2	0.4358	0.0832	1.0000	0.2699	0.1906	0.1347	0.6812	0.0969	0.0000	0.3661	0.5107
X1	0.0499	0.6265	0.2262	0.6947	0.2422	0.4940	1.0000	0.0000	0.1022	0.4630	0.5557
X2	0.6641	0.4972	0.0000	0.3047	0.1364	0.3343	1.0000	0.2868	0.2390	0.5248	0.5260
X3	0.7500	0.2500	1.0000	0.7500	0.5833	0.7500	0.5833	0.0000	0.4167	0.7500	0.6667
X4	0.0042	0.5754	0.2335	0.6611	0.5501	0.4909	1.1472	0.0000	0.0165	0.4463	1.0000
X5	0.9490	0.0000	1.0000	0.6106	0.1803	0.8703	0.5731	0.1719	0.4816	0.6155	0.6835
X6	0.0000	0.2273	0.3255	1.2811	0.0925	0.8958	0.4556	0.1155	0.0268	1.0000	0.9878
X7	0.9005	0.8820	0.1717	0.9292	0.0548	0.0000	0.0057	1.0000	0.2701	0.9225	0.0145

Table G3: Statistics of Weighted Values for Each Indicator

	P1	P2	P3	P4	S1	S2	S3	W1	W2	B1	B2
Value of vitality	6.55	8.03	7.48	11.61	7.64	9.62	15.02	6.28	5.67	10.27	11.84
Y1	0.0198	0.3222	0.2936	0.7951	1.8506	1.5286	5.8169	0.019	0.0702	1.2564	2.8035
Y2	1.0632	0.9507	1.0117	1.4352	0.5619	0.6088	0.51	1.3942	1.2074	0.5423	0.571
Y3	0.5091	0.7236	0.9325	1.2542	0.5359	1.1543	1.101	0.7209	0.5261	1.1841	1.1448
Y4	0.7318	0.617	0.8517	0.6886	0.6454	0.6654	0.7742	0.6225	0.6279	0.7098	0.7406
X1	0.0971	0.8509	0.3275	0.94	0.3484	0.6776	1.3391	0.0318	0.1654	0.6371	0.7583
X2	0.6775	0.5909	0.333	0.4911	0.4038	0.5064	0.8517	0.4818	0.4569	0.6052	0.6058
X3	0.7611	0.4098	0.9367	0.7611	0.644	0.7611	0.644	0.2342	0.5269	0.7611	0.7025
X4	0.0276	0.8065	0.3402	0.9234	0.772	0.6913	1.5862	0.0219	0.0444	0.6304	1.3855
X5	0.9053	0.7183	0.9154	0.8386	0.7538	0.8898	0.8312	0.7522	0.8132	0.8396	0.853
X6	0.0145	0.3154	0.4453	1.7101	0.137	1.2001	0.6175	0.1675	0.0501	1.3381	1.3219
X7	1.7427	1.7262	1.0927	1.7683	0.9884	0.9395	0.9446	1.8314	1.1804	1.7623	0.9524

Appendix H

Questionnaire for Expert

Dear Respondent,

I am a Ph.D. student from the Faculty of Architecture and Design, Department of Urban Planning, at the University Putra Malaysia (UPM). I am conducting a research study titled 'EVALUATION OF THE VITALITY OF LEISURE URBAN SPACES IN CHINA: THE NANJING CONTEXT.' The aim of this study is to construct a comprehensive evaluation framework for the vitality of leisure urban spaces in China, employing quantitative research methods with multi-source big data to assess the vitality of leisure urban spaces in the Central Urban Area of Nanjing at both the systemic and individual levels, and to identify commonalities, differences, and deficiencies among different space types through descriptive analysis. With your participation, I hope to validate the findings of my research. I have designed a simple survey questionnaire to evaluate the significance of each finding. The questionnaire is structured on a five-point Likert scale, please mark the appropriate number according to your evaluation standard. Your help is voluntary, and the response is anonymous and confidential. If you choose to participate, please do not write your name on the survey form. I do not need to know who you are, and nobody will know that you have taken part in this research. Please take a few minutes to complete this questionnaire. The success of the survey largely depends on the reliability of your answers; therefore, please respond to all questions as honestly as possible. I would greatly appreciate your contribution to this research.

Yours sincerely,
PhD Student
Faculty of Design and Architecture
University Putra Malaysia
43400 Serdang,Selangor

To what extent do you agree with the following 7 parts of the analysis findings from the empirical study conducted in the central urban area of Nanjing, China? Please rate your agreement using the scale provided below:

1-Strongly Disagree, 2-Somewhat disagree, 3-Neither agree nor disagree, 4-Somewhat Agree, 5-Strongly Agree

i. Findings on Spatial Distribution Characteristics of Leisure Urban Spaces

This section presents the research findings on the spatial distribution characteristics of leisure urban spaces in the Central Urban Area of Nanjing. Please assess the accuracy of these findings based on your expertise.

<table>
<tr><th></th><th colspan="2">Statement</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>a</td><td colspan="2">System-level analysis of the distribution characteristics of various types of leisure urban spaces is crucial, as it forms the basic conditions for evaluating vitality</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>b</td><td colspan="2">In Nanjing's Central Urban Area, different types of leisure urban spaces display varying clustering tendencies. Parks and squares show significant clustering, while waterfront spaces exhibit less clustering, and leisure blocks are distributed randomly.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>c</td><td colspan="2">Nanjing's Central Urban Area exhibits a "one core, multiple points" distribution pattern of leisure urban spaces, with plenty in the Old City Area but noticeably scarce in the peripheral areas</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>d</td><td colspan="2">While the density of leisure urban spaces across subdistricts generally mirrors population density patterns, variances in specific districts lead to supply-demand imbalance</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>e</td><td colspan="2">The distribution of leisure urban spaces and the pattern of crowd activity share a similar characteristic of concentration, indicating that these spaces' quantity and variety could boost the frequency of activities within the area</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>f</td><td rowspan="4">Various types of leisure urban spaces exhibit unique spatial characteristics and limitations</td><td>Parks: Predominantly located in the Old City Area with a high concentration, but relatively scarce in the densely populated north and south areas</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>g</td><td>Squares: Feature a balanced "one-core, multiple-points" structure primarily in the Old City Area, but have lower attraction and usage outside of this area</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>h</td><td>Waterfront Spaces: Clustered around natural water bodies, they offer unique experiences but are less accessible.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>i</td><td>Leisure Blocks: Concentrated mainly in Old City Area., they exist in small numbers, forming smaller cores without large-scale aggregations</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

ii. Overall Vitality Performance Findings

This section introduces the research findings on the overall vitality performance of leisure urban spaces in the central urban area of Nanjing. Please indicate your agreement or disagreement with these findings.

<table>
<tr><th></th><th colspan="2">Statement</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>a</td><td rowspan="2">Individual-level analysis of the vitality of existing leisure urban spaces through multidimensional evaluation is crucial, serving as a main source of vitality</td><td>Crowd activity as the external representation of the vitality is an important dimension of evaluation</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>b</td><td>Built environment as the internal mechanism of the vitality is an important dimension of evaluation</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

c	In Nanjing's Central Urban Area, the overall vitality of leisure urban spaces is classified into high, medium, and low levels, with spaces of medium vitality comprising the majority					
d	The vitality levels across various space types indicates leisure blocks have the highest vitality, followed by parks, whereas some squares show low vitality, and waterfront spaces uniformly lack vitality					
e	In the dimension of crowd activity, there is strong performance in the indicators of temporal persistence and overall satisfaction, but deficiencies in the indicators of spatial clustering and sentiment feedback					
f	In the dimension of built environment, overall performance in the indicator of surrounding function mixedness is the best, yet there are shortcomings in the density and mix of internal facility					

iii. Key Indicators for Vitality Evaluation Findings

Please assess the importance of the key indicators for evaluating the vitality of leisure urban spaces based on the findings from this study.

	Statement	**1**	**2**	**3**	**4**	**5**
a	The importance of the dimension of crowd activity in the evaluation framework of leisure urban spaces surpasses that of the built environment dimension, yet the built environment remains pivotal for enhancing vitality					
b	The indicators of spatial clustering of activities and diversity of internal facility are the two most important indicators for evaluating the vitality of leisure urban spaces					
c	The multifunctionality and diversity of both internal and external environments of leisure urban spaces are crucial for enhancing their vitality					

iv. Findings on the Correlation between Crowd Activity and Built Environment

This section presents findings based on our research on the correlation between the crowd activity and built environment. Please agree or disagree with these findings.

	Statement		**1**	**2**	**3**	**4**	**5**
	The indicator of crowd activity	**The indicator of build environment**					
a	Spatial Clustering	Surrounding Function Density					
b		Service Population Density					
c		Internal Facility Mixedness					
d		External Road Network Density					
e	Temporal Persistence	Internal Facility Mixedness					
f	Group Diversity	Internal Facility Density					
g		Internal Facility Mixedness					
h		Service Population Density					
i		Surrounding Function Density					
j	Feedback Positivity	Surrounding Function Mixedness					
k		Public Transport Convenience					

v. Findings on Crowd Activity Patterns

The following are the research findings on crowd activity patterns of leisure urban spaces. Please assess these findings based on your knowledge.

	Statement	1	2	3	4	5
a	Parks and squares attract more active on weekdays, while waterfront spaces and leisure blocks are more popular on weekends					
b	Leisure blocks are particularly popular after work hours and on weekends. Squares reach their activity peak during lunchtime on weekdays, but parks and squares maintain a steady flow of visitors					
c	Various types of leisure spaces attract different groups. Leisure blocks draw young friend groups and families, parks and squares primarily serve family groups, and waterfront spaces strike a balance among families, friends, and individual tourists					
d	Users have clear preferences regarding the aesthetic and cultural atmosphere of leisure urban spaces, as well as surrounding conveniences, consumer facilities, and social experiences					

vi. Findings on External Function and Internal Facility Supply

This section presents the research findings on the supply of external functions and internal facilities in leisure urban spaces. Please provide your feedback on these findings.

	Statement		1	2	3	4	5
a	Characteristics of external function supply of leisure urban spaces	Public and Commercial Services as Predominant Urban Functions					
b		Residential and Educational Functions Less Influential					
c		Significant Variation in the Distribution of Business Offices and Scenic Spots Based on Location					
d	Characteristics of internal facility supply of leisure urban spaces	Emphasis on Sightseeing Facilities in Parks and Squares					
e		Leisure Blocks Focused on Consumption Facilities					
f		Lack of Cultural Facilities in Parks, Squares, and Waterfront Spaces					
h		Varied Distribution of Sports Facilities Across Different Leisure Spaces					

VII. Findings on Spatial Distribution of Indicator Levels

In the final section of the questionnaire, please evaluate the research findings on the spatial distribution of indicator levels in leisure spaces

<table>
<tr><th></th><th colspan="2">Statement</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>a</td><td rowspan="4">The levels of some indictors display spatial trend of decreasing from the city center to the periphery</td><td>The overall vitality level of leisure urban spaces</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>b</td><td>The indicator of Spatial Clustering</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>c</td><td>The indicator of Group Diversity</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>d</td><td>The indicator of Service Population Density</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>e</td><td colspan="2">The density of surrounding function is higher in areas away from water bodies or near the city center</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>f</td><td colspan="2">The activity density of leisure urban spaces situated in commercial areas fluctuates more significantly over time</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Summary of Expert Background Information

Expert	Organization	Department / Position
1	University	Associate Professor of urban planning
2	University	Associate Professor of urban planning
3	University	Lecturer of urban planning
4	University	Lecturer of Resource and Environmental Science
5	Urban planning and Design Institute	Land and Spatial Planner
6	Urban planning and Design Institute	Urban planning researcher
7	Government Natural Resources and Planning Bureau	Land Use Planning Department
8	Government Natural Resources and Planning Bureau	Land Use Planning Department

BIODATA OF STUDENT

This student was born in 1995 in Chaoyang City, Liaoning Province, China. She graduated from Dalian Polytechnic University in 2018 with a bachelor's degree in Environmental Design and obtained her master's degree in Urban Planning from the University of Melbourne, Australia, in December 2021. She is a full-time Ph.D. student in Urban Planning and Design at Universiti Putra Malaysia.

LIST OF PUBLICATIONS

Li, X., Kozlowski, M., Salih, S. A., & Ismail, S. B. (2024). Evaluating the vitality of urban public spaces: perspectives on crowd activity and built environment. *Archnet-IJAR: International Journal of Architectural Research*.

Li, X., Kozlowski, M., Ismail, S. B., & Salih, S. A. (2024). Spatial Distribution Characteristics of Leisure Urban Spaces and the Correlation with Population Activity Intensity: A Case Study of Nanjing, China. *Sustainability*, *16*(16), 7160.

Li, X., Kozlowski, M., Ismail, S. B., & Salih, S. A. (2025). Multidimensional Evaluation of Crowd Activity Performance in Leisure Urban Spaces Using Network Big Data: A Case Study from Nanjing, China. *Journal of Urban Planning and Development*, *151*(2), 05025014.