Evaluation methods for waterfront public spaces: insights from different spatial scales in chinese and international cities

ESSAYS AND VIEWPOINT

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Abstract. This research explores the evaluation methods for waterfront public spaces based on different project scales. It categorises the evaluation methods into three levels: large-scale, medium-scale, and small-scale, and proposes the most effective evaluation strategies for each. This study selected waterfront spaces in 38 Chinese cities and 17 international cities as case studies to analyse spatial evaluation methodologies and high-frequency keywords across varying spatial scales. Based on a systematic review of literature published in the past five years, the research employed term frequency analysis to investigate narrative patterns in academic discourse, supplemented by a data-driven analysis of 120 papers for keyword extraction and thematic categorisation. The results indicate that at the macro scale, design evaluation optimises the placement of planning points; at the medium-scale, feedback can be used to adjust spatial layouts and functions; and at the micro scale, dynamic updates of service facilities are possible. This study provides effective methods for more precise analysis of user needs and design optimization strategies.

Keywords: Waterfront public spaces; Evaluation methods; Scale; Design optimisation strategies.

Introduction

Waterfront public spaces play a crucial role in representing the vitality and image of a city, with their spatial design being essential for shaping the city's brand and cultural soft power. As urbanisation progresses, the design of waterfront spaces has become an important element not only in meeting the daily needs of residents but also in showcasing the city's characteristics and attracting tourists. However, current urban waterfront space design faces several prominent issues, particularly in the evaluation system. There is a lack of systematic monitoring and assessment mechanisms, unclear spatial needs in different design scales, and an absence of sustainable evaluation models. Furthermore, there is a shortage of methods that are detectable, traceable, and repairable. Thus, the challenge of establishing a scientific, continuous, and assessable evaluation method based on the varying needs of waterfront spaces at different scales remains a critical issue to address.

In China, approximately 480 cities are situated in major river basins, including the Yangtze, Yellow, and Pearl Rivers, covering over 80% of the total number of cities in the country. As an integral part of these cities, the design and evaluation of waterfront spaces have become particularly important. However, in academic research within China, waterfront space evaluation is often overlooked or undervalued. According to statistics from CNKI (https://www.cnki.net) over the past five years, research on waterfront space design has primarily focused on themes such as waterfront vitality, environmental assessment, and landscape planning. By analysing the abstracts of 120 typical papers, we found that although most studies address spatial design evaluation, keywords in paper titles do not easily lead to relevant evaluation methods, making it difficult to conduct comprehensive searches, and limiting the widespread attention and development of waterfront space evaluation methodologies. Therefore, this paper aims to explore waterfront space evaluation within a larger research framework using keyword analysis. The goal is to help scholars better understand and utilise relevant terms while revealing the deeper challenges behind the fragmentation of research. By placing different keywords, cultural contexts, and academic terms within a specific context, we aim to gain a comprehensive understanding of the connotations of waterfront space evaluation methods. In this process, special attention is given to the representation of waterfront spaces in terms of regional networks and local complexities, as well as to identifying key factors influencing the development of evaluation methods.

Through text data analysis, this study seeks to examine the current status and development of waterfront space evaluation, identify the common challenges and opportunities faced by urban waterfront spaces, and provide theoretical and practical references for academic research and design practice. Ultimately, the aim is to promote the innovation and improvement of waterfront space design evaluation systems, enhance the role of waterfront spaces in sustainable urban development, and elevate the quality and cultural value of cities.

Literature review

Waterfront public spaces are integral components of urban planning and design, offering unique environmental and social functions. The quality of waterfront space design directly influences the city's image, residents' quality of life, and ecological sustainability. Therefore, how to scientifically and effectively evaluate the design and functionality of waterfront spaces has become a key issue in both academic research and practical applications. Existing evaluation methods for waterfront spaces primarily involve three dimensions, namely geographic big data analysis, landscape space aesthetics, and spatial structure. These methods focus on different evaluation goals and approaches, but a systematic, scale-adapted evaluation framework has yet to be established in practical applications.

Geographic big data analysis dimension

In the realm of geographic big data analysis, waterfront space evaluations typically utilise tools like OpenStreetMap, Baidu Maps, ArcGIS, and other spatial information systems to quantify relevant indicators of waterfront areas using road network data and spatial information. The key to this evaluation method is the clear definition of the study area and waterfront types.

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The first step involves a comprehensive analysis of the current state of waterfront spaces, including environmental quality, existing issues, and comfort levels (Liang *et al*., 2023). Subsequently, a scientific indicator system is established, typically following the Analytic Hierarchy Process (AHP), which builds an evaluation structure comprising goal, standard, and indicator layers (Yang *et al*., 2024). The advantage of this method lies in its data-driven and quantitative nature, providing detailed geographic and environmental context, thereby offering theoretical support for comprehensive analysis and optimisation of waterfront spaces (Wang *et al*., 2023).

Landscape space aesthetics dimension

From the perspective of landscape space aesthetics, waterfront space evaluations focus more on human sensory and psychological experiences, emphasising visual perception, tactile experiences, environmental ambiance, and the interaction between humans and nature. Data for these evaluations are primarily collected through field surveys, interviews, and observational photography, assessing aspects such as visual perception, environmental comfort, and spatial atmosphere (Liu, 2022). The construction of evaluation indicator systems considers not only the aesthetic characteristics of the environment but also user demands, behavioural patterns, and psychological responses, especially concerning the differences in the needs of various functional areas and user groups (Jin *et al*., 2024). Moreover, landscape space aesthetics evaluation systems emphasise a comprehensive analysis of ecological environment, local culture, and historical heritage, constructing evaluation frameworks from the dual perspectives of space quality and human behaviour (Liu *et al*., 2023).

Spatial structure dimension

The spatial structure evaluation method primarily focuses on the usability of waterfront spaces, evaluating factors such as accessibility, facility completeness, and activity diversity. In this dimension, the first step is to define the scope of the waterfront space and analyse the environmental quality based on the needs of different functional areas (Xue *et al*., 2024). The evaluation focuses on aspects such as the transportation system around waterfront spaces, including road networks, pedestrian pathways, bicycle lanes, and recreational facilities (e.g., rest areas, restrooms, lighting), as well as safety features. Facility completeness directly impacts the usability and safety of the space, while activity diversity examines whether the space can accommodate various cultural, recreational, and sports activities. This evaluation method is more flexible, emphasising user experience, and has a high degree of subjectivity and adaptability (Cheng, 2018).

Limitations of existing evaluation methods and research needs

Despite progress made in various dimensions of waterfront space evaluation, existing methods still exhibit limitations. Notably, the evaluation methods for waterfront spaces of different scales (such as local waterfront areas versus large-scale waterfront regions) are not clearly distinguished, and the current evaluation frameworks tend to focus on a single dimension, lacking a comprehensive evaluation of different levels of space. Therefore, this study aims to collect literature and analyse data to systematically summarise the factors influencing various evaluation dimensions, exploring methods suited for evaluating waterfront space design at different scales, with the goal of providing more accurate optimisation criteria for waterfront space design.

The main contribution of this research is the integration of geographic big data, landscape aesthetics, and spatial structure into a multi-dimensional evaluation framework suitable for waterfront spaces of different scales. Through the comparison and analysis of various evaluation methods, this study aims to provide theoretical foundations and practical guidance for the optimisation of waterfront space design, promoting the sustainable development of waterfront spaces and the improvement of urban environmental quality.

Methodology

This study conducted a systematic review of 103 Chinese and 17 international case studies published between 2021 and 2024 to evaluate emerging trends and knowledge gaps in waterfront space design and evaluation research. The selected literature was categorised into nine thematic groups based on research focus: 1) spatial vitality analysis, 2) environmental performance assessment, 3) landscape planning frameworks, 4) quality enhancement strategies, 5) safety evaluation systems, 6) ecosystem service valuation, 7) constituent element studies, 8) human well-being impacts, and 9) socio-cultural value exploration.

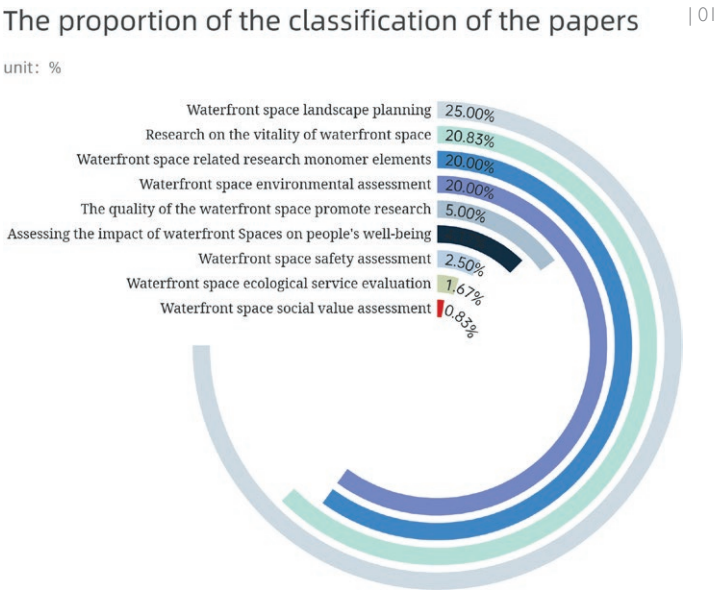
The analysis revealed a predominance of planning and design-oriented studies (68% of total literature), with primary emphasis on landscape aesthetics (42% of design papers), connectivity with adjacent urban fabrics (35%), and user experience metrics (23%). Methodologically, 81% of these investigations employed mixed-method approaches combining field surveys (n=89), in-depth interviews (n=67), and geospatial analysis via GIS platforms like ArcGIS (n=58). Notably, only 12% incorporated longitudinal data tracking, highlighting a critical methodological limitation in temporal dimension analysis.

Although planning and design is the dominant direction, the research on the quality assessment of waterfront space environments is still at a relatively early stage, accounting for only 20% of the 120 papers reviewed in this study. This proportion sug-

01 | The proportion of the classification of research papers

02 | Word cloud referring to waterfront space design

03 | Frequency statistics of hotspot occurrences



Keywords	Frequency	Keywords	Frequency
Waterfront area	475	Waterfront space	139
Planning and design	384	Waterfront environment	114
Urban waterfront space	314	Waterfront public space	112
Landscape design	259	Urban waterfront	76
Urban waterfront	221	Ecological environment	73
Waterfront landscape	219	Water environment	66
Urban design	219	Urban waterfront landscape	55
Strategy research	175	Waterfront environment	55
Public space	162	Ecological restoration	53
Waterfront area	162	Design research	37
Waterfront landscape design	154	Landscape evaluation	14

gests that, while landscape aesthetics and environmental evaluation methods have been applied preliminarily in waterfront space research, the overall quantity remains limited, and there are significant gaps in the systematic theoretical framework and evaluation methods. Therefore, the evaluation system for waterfront spaces in China is still underdeveloped and requires further theoretical refinement and practical expansion.

In the analysis of keyword trends, the most frequently appearing terms in the past five years include "planning design", "landscape design", and "urban waterfront space", reflecting that the primary focus of waterfront space research is still on urban planning and design, particularly in the context of urban waterfront spaces. Research on waterfront space evaluation at different scales (large, medium, small) is relatively scarce, with particularly limited studies on landscape evaluation. By analysing these keywords, we can identify the current hotspots and gaps in waterfront space research, providing important insights for future studies.

Based on literature collection and data analysis, this research offers an in-depth exploration of the current state of waterfront space evaluation, highlights key issues and development trends in waterfront space research, and provides a theoretical foundation for improving the domestic evaluation system for waterfront spaces.

Result

Total search results and proportions

A total of 120 papers related to waterfront space research were collected from CNKI and Google Scholar, covering 55 cities globally, with 38 from China and 17 from abroad. These articles are roughly divided into seven categories, namely waterfront space vitality research, environmental assessment, landscape planning, quality improvement research, safety assessment, ecological service evaluation, research on specific elements within waterfront spaces, human well-being impacts, and social value. Among these, the largest proportion of articles focus on waterfront space planning and design, accounting for approximately 25%, followed by environmental quality assessment, waterfront vitality research, and studies on specific elements like climate and vegetation, each representing around 20%. Other categories make up smaller proportions (see Figs. 1, 2, 3).

Distribution of Studies in Domestic and Foreign Cities

In China, waterfront space research is mainly concentrated in cities such as Shanghai, Beijing, Wuhan, and Suzhou. Shanghai has the highest number of studies, with 13, followed by Beijing, Wuhan, and Suzhou, with 8, 8, and 7 studies, respectively (see Fig. 4). These data indicate that waterfront space research tends to focus on major cities or regions with a significant presence of waterfront areas. Internationally, the distribution is more balanced, with cities like Kyrenia and Seoul, each contributing two studies, and the remaining cities having one study each (see Fig. 5).

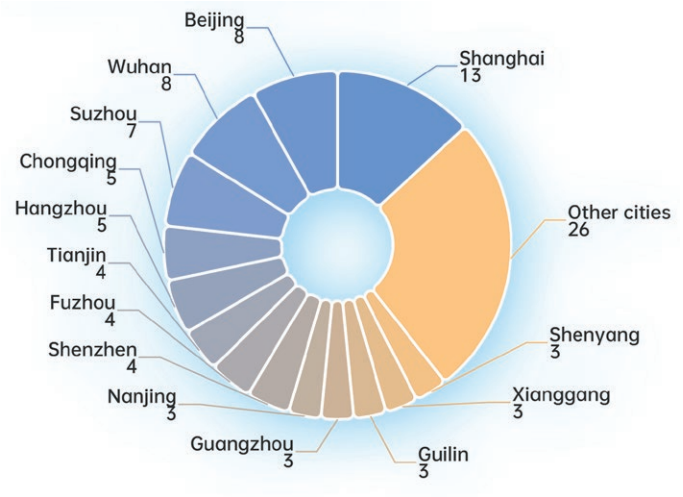
Environmental quality assessment: focus on specific elements and human well-being

Environmental quality assessment is not only concerned with spatial studies but also places significant emphasis on

04 | Scale picture of research key words in Chinese cities

05 | Scale picture of research key words in foreign cites

04 |



| 05

the analysis of individual or specific influencing elements. A comparison of results from CNKI and Google Scholar reveals that Google Scholar contains more studies focusing on individual elements within waterfront spaces, such as the plants, climate, or temperature of these areas. For instance, one article titled *Landscape Aesthetic Value of Waterfront Green Space Based on Space-Psychology-Behavior Dimension: A Case Study along Qiantang River (Hangzhou Section)* uses multi-source data and qualitative and quantitative analysis methods to assess the aesthetic value of waterfront green spaces along 12 representative locations in the Qiantang River region, considering spatial, psychological, and physiological dimensions. Furthermore, international studies tend to explore human well-being more deeply. For example, *The Impact of Attributes of Waterfront Accessibility on Human Well-being: Alexandria Governorate as a Case Study* uses statistical survey methods to compare human well-being (HWB) between two areas with different levels of proximity to the waterfront. The study also surveys respondents' personal characteristics, such as age, education, and health, alongside their psychological perceptions.

Discussion

The research results, derived from China National Knowledge Infrastructure (CNKI) and Google Scholar, encompass 120 papers related to waterfront space research across 55 cities, with 38 domestic and 17 international locations. Among these, studies on waterfront space planning and design account for the largest proportion, approximately 25%. Research on waterfront environmental quality assessment, vitality studies, and specific elements such as climate and vegetation are also prevalent, each representing around 20% of the total. Domestic studies primarily focus on major cities such as Shanghai, Beijing, and Wuhan, while international research shows a more balanced distribution across various locations, with studies concentrated in cities like Kyrenia and Seoul. Notably, foreign studies often delve deeper into the impact of specific elements on human well-being, showcasing a broader focus on the social and psychological dimensions of waterfront spaces. Based on findings from the literature, the optimisation strategies for waterfront space design can be summarised into three main levels, precisely macro-level optimisation, meso-level optimisation, and micro-level optimisation.

Macro-Level optimisation: improving service efficiency of planning layouts

At the macro level, the full-process design evaluation method enables a comprehensive analysis of waterfront spaces through big data platforms, optimising the planning layout. By analysing indicators such as spatial density, accessibility, and service types, we can identify areas with low service efficiency and their potential issues. The key process involves simulating design scenarios and optimising existing service points whether by adding, removing, relocating, or repurposing them. This helps reduce service point vacancy rates, enhancing coverage efficiency and resource utilisation. The optimisation process makes waterfront space planning more rational, effectively improving overall space usage and reducing resource waste.

Meso-Level Optimisation: Enhancing Service Function Adaptability

At the meso level, multi-source data feedback provides insights into the strengths and weaknesses of different service functions at various points. By evaluating the functionality of each service point and incorporating feedback from users, we can ad-

just the spatial layout and functional settings of specific nodes more precisely. These adjustments maximise the strengths of the service points, better meeting the diverse needs of users and improving space utilisation and resident satisfaction. In waterfront space planning and design, there are often differences in usage and functional requirements across different regions. Adjusting the functional layout of specific nodes can enhance spatial flexibility and adaptability, ultimately improving overall service quality.

Micro-Level optimisation: dynamic updates of service facilities
At the micro level, feedback from monitoring data enables effective adjustments to the internal service facilities at public service points. Real-time monitoring of facility usage allows for the timely addition of urgently needed facilities or replacement of those underutilised. This ensures that the service facilities continually meet user needs. This dynamic approach not only makes facility configuration more precise but also embodies a model of dynamic management. As residents' needs evolve, the service facilities must be updated and iterated rather than remaining static. Therefore, the implementation of dynamic management in waterfront spaces enables them to better adapt to changing user demands, enhancing service flexibility and long-term benefits.
Through these three levels of optimisation, the proposed method promotes a more user-centered and efficient design process for urban waterfront spaces. It emphasises a sustainable and adaptive approach, where space functions, layouts, and service facilities are continuously refined to improve the overall user experience and service effectiveness

Limitations and conclusion

This study analyses waterfront spaces in 31 cities across China and proposes evaluation methods tailored to large, medium, and small-scale waterfront spaces. The results highlight the most effective evaluation strategies at each scale:

- macro-Level: The full-process design evaluation optimises waterfront space planning, enhancing overall efficiency. Through analysis of spatial density, accessibility, and service types via big data platforms, areas with low service efficiency are identified, and optimization suggestions are provided;
- meso-Level: Based on feedback from users, the spatial layout and functions of specific nodes can be adjusted accurately, maximising the strengths of service points, increasing utilization rates, and improving user satisfaction;
- micro-Level: Monitoring data feedback allows for the adjustment of service facility configurations at public service points, enabling dynamic management and ensuring timely updates to meet evolving resident needs.

Overall, this study presents a systematic framework for waterfront space design evaluation, helping urban waterfront space designs to respond to user needs more precisely, to optimise design plans, and to enhance space utilisation and satisfaction. Although the proposed methods are limited in practice, they offer significant theoretical insights and practical guidance for future research and evaluation of waterfront spaces.
Despite offering effective strategies for optimising waterfront space design at different scales, this study has several limitations. First, the case cities were limited to 31 cities in China, which, while representative in the context of waterfront space design and evaluation, may not fully reflect the diverse geographical, cultural, and developmental contexts across other global regions. Thus, future research could expand the sample to include cities with varying economic levels, cultural characteristics, and geographic environments to test the applicability and universality of the proposed methods.
Second, the frequency analysis employed in this study, a quantitative research method, effectively identified hot keywords and common evaluation dimensions in the literature but did not delve into the theoretical underpinnings or practical applications behind each evaluation dimension. The depth and complexity of evaluation methods, especially interdisciplinary assessments, require more detailed qualitative analysis to address the limitations of data-driven approaches.
Furthermore, while targeted optimisation strategies were proposed for different scales of spatial evaluation, the diverse and complex nature of urban waterfront space design suggests that more variables – such as economic costs, policy constraints, and community participation – could influence the implementation of evaluation strategies. Future research could integrate case studies to explore how these factors can be systematically incorporated into the design evaluation process to enhance the effectiveness of waterfront space optimisation.

ATTRIBUTION

Conceptualization, X.Wu. C. Gambardella; methodology, X.Wu, C.Gambardella; investigation, J.Zhong; data curation, J.Zhong; writing original draft, J.Zhong, X.Wu. All authors participated and contributed to writing the manuscript.

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