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A Satisfaction Study of Waterfront Public Spaces in Winter Cities from a Demand Perspective: A KANO-IPA Model Analysis Based on Northeastern China

Ping Yu [1,2] and Yu Zhang [1,2,*]

[1] School of Architecture and Design, Harbin Institute of Technology, Harbin 150006, China; 22s034024@stu.hit.edu.cn
[2] Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, Harbin 150006, China
* Correspondence: yu.zhang@hit.edu.cn; Tel.: +86-(0451)-862-81-135

Abstract: Urban waterfront public space is a key infrastructure for enhancing citizens' well-being. However, rapid urbanization squeezes out blue and green spaces in cities, and extreme weather challenges exist in winter cities, resulting in unmet needs and a significant decline in citizens' satisfaction. There is an urgent need to optimize design to bridge the gap between supply and demand. This study proposes a workflow for optimizing the design of waterfront spaces in winter cities based on the KANO-IPA model from the perspective of users' demands. We constructed a systematic and comprehensive set of spatial demand indicators for waterfront public space in winter cities, covering seven demand dimensions and 42 indicators. A satisfaction survey was conducted across 12 sample reaches in northeastern China. We used the KANO model to classify the attributes of spatial demand indicators, then applied IPA analysis to evaluate them, and finally calculated priority indices to quantify their priority sequences. Based on this, we proposed three-phase optimization strategies: near-term priority upgrading, medium-term steady promotion, and far-term charm enhancement, offering recommendations for improving waterfront public spaces in winter cities. This study provides long-term support for urban regeneration, resource management, and waterfront public space design in winter cities.

Keywords: demand; satisfaction; winter city; waterfront public space; KANO-IPA model

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1. Introduction

Waterfront public spaces are rare spaces in cities with both blue and green landscapes, which are important outdoor spaces for promoting public health and well-being [1]. The aftermath of public health events has raised awareness of the important role of urban blue and green spaces in mental health and well-being [2]. People then began to actively explore more opportunities for natural exposure. However, with the acceleration of urbanization, blue and green spaces are gradually being crowded out, and urban residents have fewer opportunities for natural exposure, which is detrimental to their physical and mental health [3]. Modern urban design emphasizes the human-oriented design concept [4]. In the refined development of public space, it is difficult for the traditional 'top-down' design method to fully respond to the actual demands of users [5,6]. In urban regeneration, the 'human-centred' approach prioritizes the well-being of individuals and public interest and emphasizes the active participation of the public [7]. Only by understanding and responding to the actual users' demands can we effectively improve the quality of the public space along the waterfront [8]. Changes in demand may lead to contradictions between supply and demand for waterfront public space, resulting in a 'supply–demand mismatch', which in turn affects the effectiveness of the design. To address this problem, the concepts of adaptive urban design and seasonal urban planning are gradually gaining attention. Adaptive urban design emphasizes the flexibility and adjustability of design solutions [9]. Seasonal urban planning focuses on planning urban spaces according to climatic conditions and seasonal changes in order to optimize resource allocation and meet public needs [10]. Sheng Liu et al. reviewed climate-responsive design strategies to adapt to extreme heat events from an architectural and urban design perspective [11]. Many scholars are actively using adaptive urban planning and design in urban ecosystems to proactively address climate challenges [12,13]. Adaptive urban design and seasonal urban planning can effectively help waterfront public spaces in winter cities cope with extreme climate challenges.

Winter cities are defined as cities with daytime maximum temperatures that do not exceed 0 °C for at least two months each winter, with high snowfall and a cold climate [14], such as Harbin, China, and Edmonton, Canada. At least 30 countries in the world are located in the Northern Hemisphere, and approximately 600 million people live in winter climates [15]. More than half of the territory in China is located in a cold or bitterly cold zone [16]. Seasonal changes have a significant impact on the mental health of the population and are closely associated with symptoms such as depression and anxiety [17]. The global prevalence of winter depression is as high as 10%, of which 70% is recurrent major depressive disorder [18,19]. This condition is particularly common in high northern latitudes [20,21]. Waterfront public spaces are particularly important in winter cities due to their unique ecological landscape and health promotion potential [22,23]. Waterfront public spaces contribute positively to residents' health by enhancing opportunities for physical activity, fostering social interaction, mitigating pollution through processes such as carbon sequestration by vegetation and the natural purification of water bodies, and alleviating stress [24].

The concept of urban waterfront public space in existing studies is broader, and it is mostly integrated with the study of green space. There is a significant difference between blue space and green space, and the presence of water elements needs to be fully considered in the study [25]. Current research is mostly focused on coastal cities [26–28]. Inland rivers and lakes have relatively few research results and need more attention [29]. Design strategies are also mostly limited to landscape or planning systems without an in-depth exploration of specific spatial elements. The design of waterfront public space in winter cities often ignores regional characteristics. There are differences in the renewal design in different urban cultural backgrounds, urban functions, and development levels [30,31]. Therefore, the design of urban waterfronts should take into account the specific context and avoid mechanically applying existing planning models. Ideal waterfront design should be combined with pre-strategic planning [32] and post-use evaluation [33,34] to ensure the rationality and locality of the design.

Under the constraints of climatic conditions, the seasonal changes in user demands for waterfront public spaces in winter cities are obvious [35,36]. Correctly understanding and responding to these changes in demands are the keys to optimizing the use of resources and enhancing the value of the space. Providing accurate supply services from the demand side can effectively avoid a 'supply–demand mismatch' and improve the efficiency of resource allocation. Insufficient supply may lead to social inequity, and residents who are unable to meet their needs will face a decline in their quality of life and well-being. Excess supply, in turn, will lead to wasted resources [37]. Adaptive urban design to cope with climate change under extreme climate challenges is still in the stages of exploration and development. The utilization and development of waterfront public space need further attention.

'Satisfaction' is an effective measure of the relationship between users' demands (psychological expectations) and the reality of the situation [38]. The level of satisfaction with the urban spatial environment will not only affect people's willingness and motivation to use the space [39,40] but also further affect its social and health benefits. Satisfaction was originally used in the business field mainly to measure the level of consumer satisfaction with products or services. Then, satisfaction was introduced in the fields of urban planning, citizen participation, and social sciences to measure the match between people's demand for urban space [41–43], public facilities [44,45], and community services [46,47] and the reality of the situation. Therefore, satisfaction evaluation can effectively guide urban renewal, planning, and design strategy designation [48].

In previous satisfaction studies, the KANO model and the IPA model have been widely used. In 1959, Fredrick Herzberg proposed the famous 'two-factor theory' [49]. Motivated by this theory, Professor Noriaki Kano in Japan proposed the theory of glamour quality and the Kano model [50] to explain how users perceive and evaluate quality attributes. Researchers applied the KANO model to evaluate the quality of environmental services such as riverbanks [51], green parks [52], pedestrianized recreational areas [53], and urban noise [54]. The IPA model proposed by Martilla and James in 1977 is widely used for demand decision analysis [55]. Various industries favour the model for its clarity, ease of use, and intuitive results. In recent years, IPA has been widely used in landscape and architecture to characterize user demands and experience situations [56,57]. Although the IPA model and KANO model are widely used, both have certain limitations. First, the KANO questionnaire design and data processing techniques are relatively basic, which may lead to bias in analyzing users' psychological perceptions. Second, the KANO model is somewhat subjective in the classification and priority setting of demands without sufficiently considering the differences in the importance of demands. To improve the accuracy of the KANO model and IPA model, scholars have constructed integrated models by combining them with other methods, such as fuzzy theory [58], AHP [59], SERVQUAL [60], etc., to match the demands of different industries better. The KANO model and IPA analyses have their focuses, which can theoretically be complementary to each other [61–63]. This study will integrate the KANO model and IPA model to combine the advantages of both to make the classification and prioritization of spatial demand more accurate and scientific.

Based on the interaction between environment and behavioral demand, we propose a path to optimize the public space on the waterfront in winter cities from the demand side (Figure 1). When users' satisfaction is low, an in-depth user demand analysis is first needed, which is the basis of scientific service provision. Through a systematic survey and feedback mechanism, the demands and preferences of different age groups and communities are comprehensively collected to ensure the comprehensiveness and inclusiveness of the design. Subsequently, the areas of mismatch between supply and demand are analyzed to identify problems further. Finally, the physical environment is corrected through feedback to improve the match between demand and perceived quality, achieving resource allocation and service optimization.

Typical winter cities in Northeast China were selected as the study area for conducting field research and satisfaction questionnaire surveys. This study aims to reduce the mismatch between the actual use feelings and demand expectations among users for waterfront public space in winter cities from the demand side to optimize the allocation of resources and to improve the utilization rate of resources. The specific research objectives are as follows: (1) Construct a set of demand evaluation indexes for urban waterfront public space in winter cities to establish the basis for the optimization of waterfront public space in cold regions from the perspective of users' demand. (2) Integrate the KANO-IPA model to classify the spatial demand indicators of urban waterfront public space in cold regions and identify the key optimization indicators. (3) Quantify the priority of the spatial indicators and propose the optimization strategy of waterfront public space in winter cities with differentiated priorities.

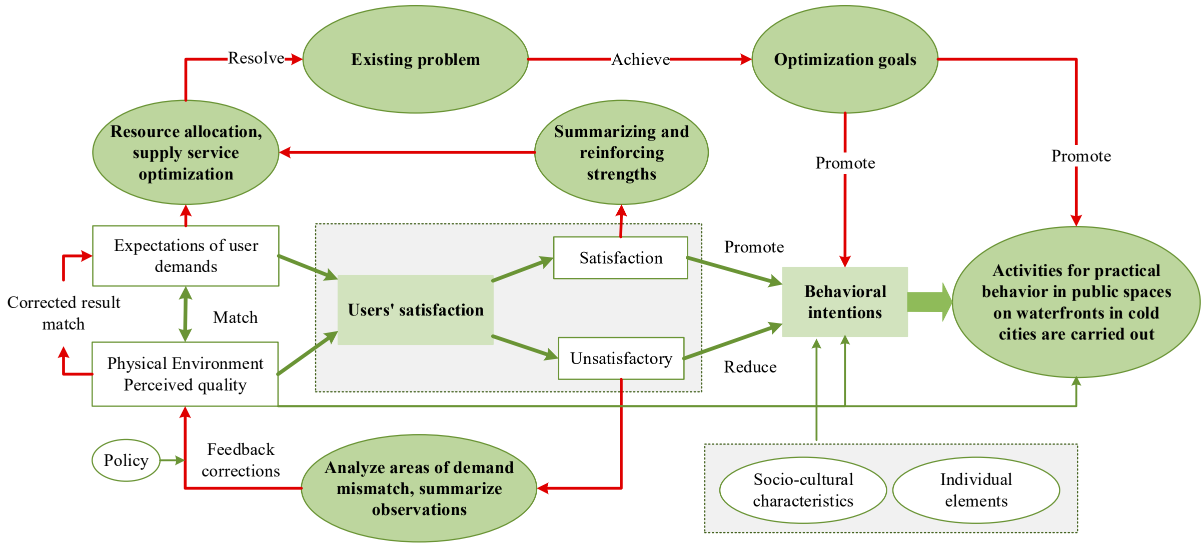

Figure 1. Optimization paths for waterfront public space design in winter cities.

2. Materials and Methods

2.1. Study Area

Waterfront public space is the area in the city that is open to the public, bounded by the bank line and the first urban road adjacent to the waterfront. The waterfront public space environment in winter cities is a multi-layered and complex system consisting of natural, social, and spatial elements closely related to water bodies. In this study, the waterfront public spaces of the Songhua River in Harbin, the Yitong River in Changchun, and the Hun River in Shenyang are selected as the study areas, which are typical winter cities. In the sample selection of river sections, it is ensured that the samples have the feasibility of field research and that the spaces have urban attributes. Finally, 12 typical waterfront public spaces in winter cities were selected as the study samples (Figure 2). These samples have a variety of space types and functions, covering different types of waterfront public spaces in cold regions. They are typical and universal, making them ideal for this study.

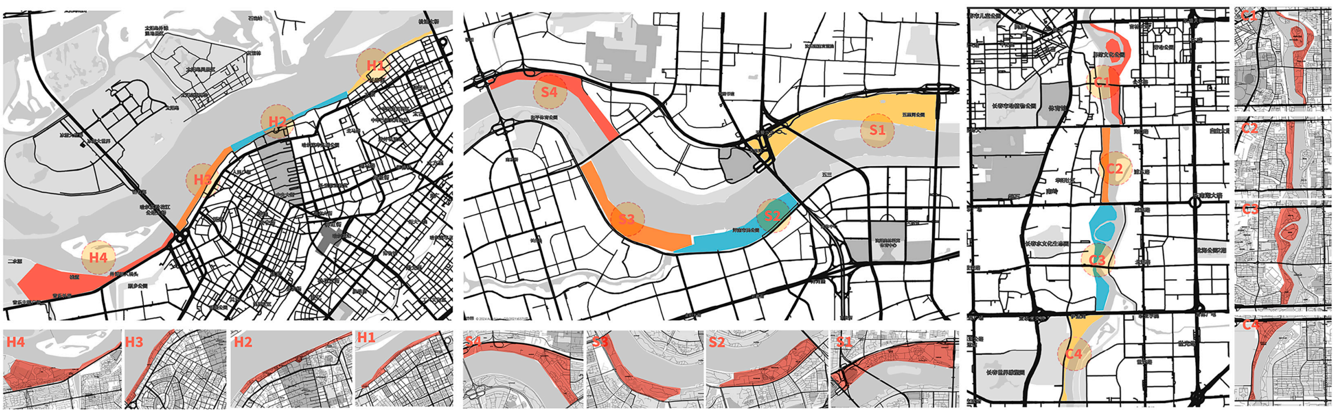

Figure 2. Study area. (**a**) The Songhua River in Harbin; (**b**) The Hun River in Shenyang; (**c**) The Yitong River in Changchun.

2.2. Study Framework

Based on the existing relevant studies, a spatial demand indicator system for the satisfaction evaluation of waterfront public space in winter cities is constructed. Based on the KANO-IPA analysis method, a satisfaction evaluation questionnaire was designed, and data collection was carried out in selected sample river sections. The KANO model classified the attribute categories of spatial demand indicators. The priority decision of spatial demand indicators is first made qualitatively using the IPA model. Then, the final quantitative decision judgement is made according to the priority index calculation. Finally, the evaluation results obtained from the KANO-IPA model analysis are used to guide the optimal design of waterfront public spaces in winter cities. The research framework is shown in Figure 3.

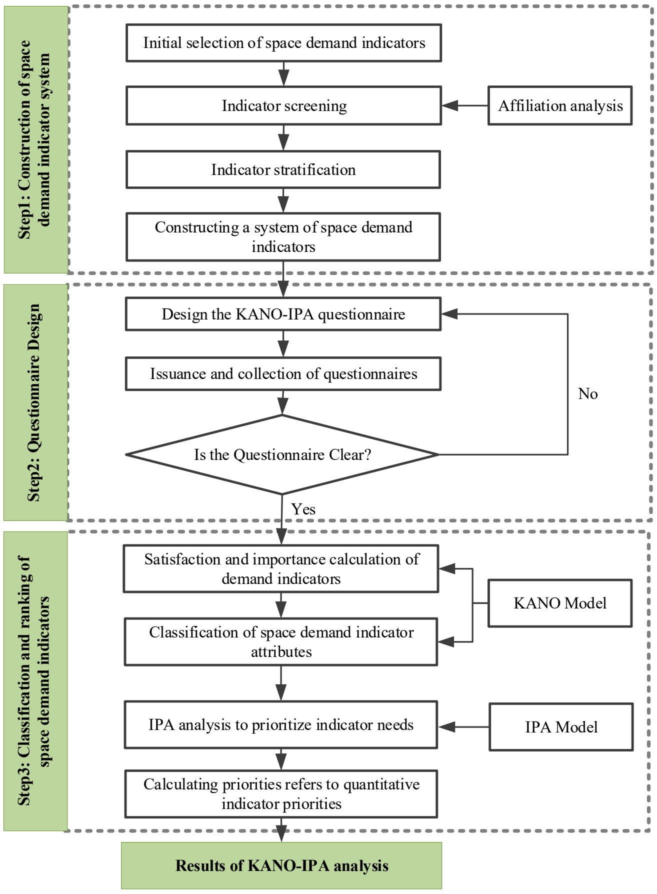

Figure 3. Study framework.

2.3. Establishment of Demand Indicator Sets

2.3.1. Construction of Descriptive Framework for Spatial Demand Indicators

Maslow defines demand as motivations triggered by a sense of lack, i.e., behavioral intentions driven by a sense of dissatisfaction [64]. Barker describes demand as motivations driven by a state of tension or dissatisfaction and oriented toward the achievement of a satisfying goal [65]. These two perspectives suggest that there are two main cores of needs: the first is the 'feeling of dissatisfaction' or 'state of scarcity'; the second is the goal-acquisition motivation driven by the feeling of unfulfillment, i.e., the basic driving force of an individual's behavior. In this study, 'demand' refers to the demands that users have when carrying out a series of activities in waterfront public spaces in winter cities. Demand is not only an intrinsic motivation but also a result of the interaction between people and the waterfront environment. It includes the 'physical demand' that supports the activities and the 'spiritual demand' that arises during the activities.

The hierarchy of basic needs theory identifies five prevalent categories of human needs: physiological, safety, belongingness, respect, and self-actualization [66]. These needs are not satisfied sequentially in a hierarchy but may exist simultaneously. A particular need may dominate at a given time and become the main driver of action. In addition, demands are constantly adjusted with changes in time, place, and external environment, showing dynamism and progressivity. Based on previous research results, this study classifies the spatial demands of users in waterfront public spaces in winter cities into three main categories and seven levels (Figure 4). The demands are categorized into basic demands, enhancement demands, and quality connotation demands. Basic needs focus on the fundamental demands of users, such as accessibility, safety and resource provision, to ensure that the space provides a safe and convenient environment. Enhancement demands focus on optimizing the user experience, providing a comfortable atmosphere and space for social interaction. The quality connotation emphasizes the cultural value of space design, incorporating regional characteristics to enhance spiritual and cultural content.

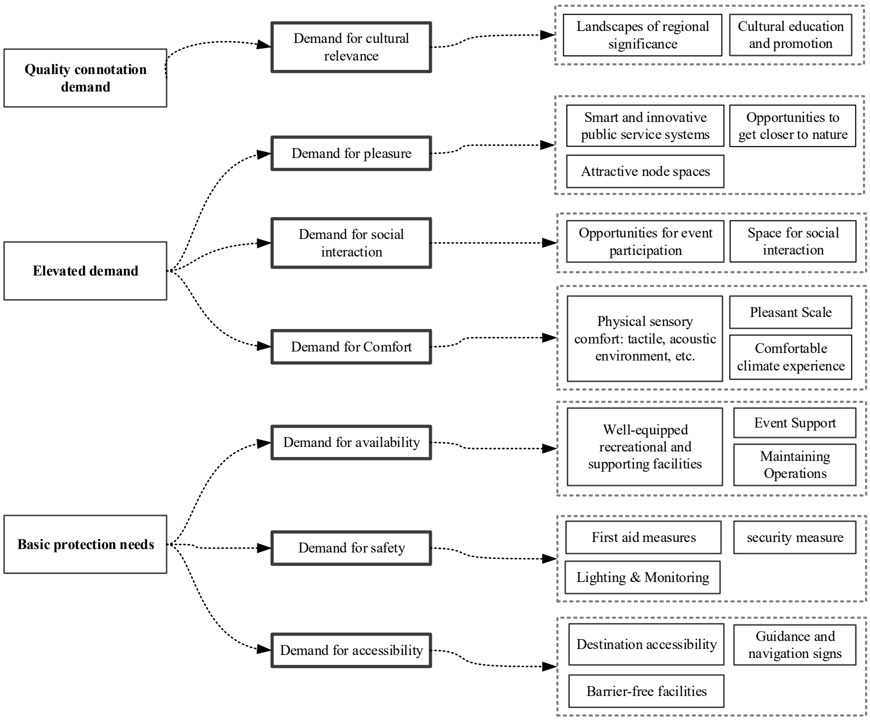

Figure 4. Descriptive framework for spatial demand indicators based on the hierarchy of needs theory.

2.3.2. Selection of Evaluation Indicators

Waterfront public space in winter cities is a complex multi-element integrated system, which is affected by urban location, waterfront water features, and cold climate, which shows four distinctive features: spatial layout along the water body, spatial resources taking into account natural and human elements [67], spatial service provision taking into account the needs of people and nature at the same time [68,69], and significant changes in spatial landscapes and morphology with the seasons [70–72]. The dominant factors faced by waterfront public spaces in different regions are different. Therefore, the selected spatial demand evaluation indicators should be comprehensive and avoid repetition while considering the uniqueness of the cold regions and not missing the key indicators.

To this end, this study preliminarily selects objective evaluation indicators through literature combing, design cases of urban waterfront areas in cold regions, and relevant design guidelines at home and abroad. Meanwhile, combined with expert consultation and field research on the sample river section, the preset indicator set was supplemented and amended to form a preliminary indicator set. Subsequently, the indicator set was secondarily screened through expert questionnaires using affiliation analysis. Finally, the indicators were divided into different levels to construct a complete demand indicator set (Figure 5). It provides the basis for the subsequent satisfaction evaluation using the KANO-IPA model.

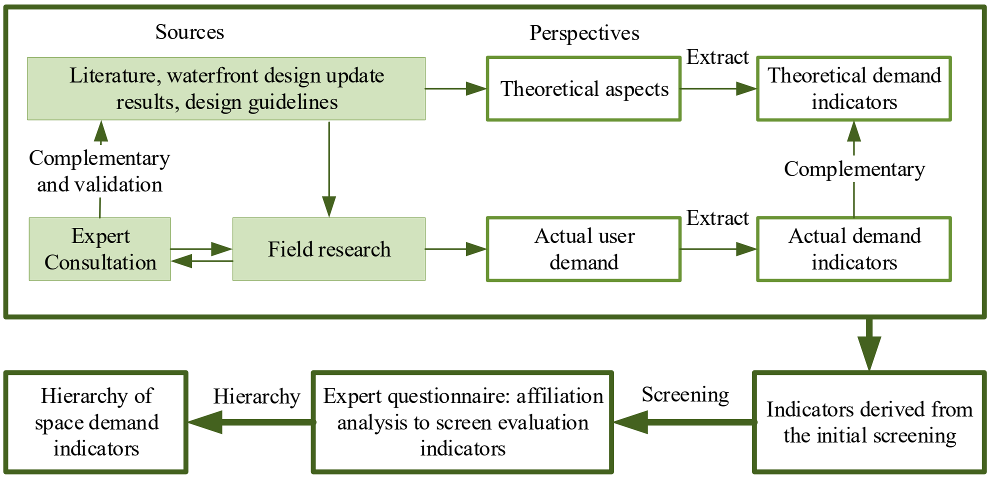

Figure 5. Process for the selection of spatial demand indicators.

The selection of preset indicators in this study is based on the characteristics of waterfront public spaces in winter cities. The spatial demand indicators are mainly derived from three sources: (1) domestic and international waterfront design guidelines, especially waterfront design guidelines for cities in the cold region of northeastern China; (2) the literature and cases related to the renewal design of waterfronts in cold cities; (3) interviews related to the behavioral needs of users in the sampled river sections. The study aims to extract the elements of public space in cold urban waterfronts that users are concerned about, transform them into assessable indicators, and incorporate them into a satisfaction evaluation system of spatial demand indicators. By filtering the high-frequency terms in sources (1) and (2), extracting the common environmental elements, and combining them with the supplementary indicators in source (3), a final set of 58 predefined indicators was identified (Table 1).

Table 1. A predefined set of indicators.

No.	Indicators of Space Demand	No.	Indicators of Space Demand
F1	External accessibility	F30	Climate shelter
F2	Entrance and exit recognition	F31	Heating facilities
F3	Internal path accessibility	F32	Thermal recharge facilities
F4	Vertical waterfront corridor	F33	The colour scheme of the site
F5	Cross-river accessibility	F34	City skyline
F6	Signage and signposting	F35	Tactility of materials
F7	Accessible facilities	F36	Ground cover
F8	Safety monitoring system	F37	Acoustic environment
F9	Night lighting	F38	Street-level building interface permeability
F10	Safety anti-skid facilities	F39	Slow lane width
F11	Levelling of sites	F40	The openness of view to the opposite shore
F12	First aid facilities	F41	Size and scale of activity space
F13	Green landscape quality	F42	All ages of activities
F14	Greening coverage	F43	Abundance of activity types

Table 1. *Cont.*

No.	Indicators of Space Demand	No.	Indicators of Space Demand
F15	Configuration of landscape ornaments	F44	Openness of activity space
F16	Adequacy of activity sites	F45	Attractive nodal space
F17	Accessibility of walking along the waterfront	F46	Design theme features
F18	Quality of water bodies	F47	Shoreline esthetics and hydrophilicity
F19	Public toilet	F48	Abundance of water-friendly activities
F20	Leisure seating	F49	Water-friendly facilities
F21	Shared service facilities	F50	Accessible lawn
F22	Storage facilities	F51	Intelligent service facilities
F23	Commercial facilities	F52	Cultural awareness-raising device
F24	Sanitation facilities	F53	Cultural promotion venues
F25	Recreation and fitness facilities	F54	Ice and snow landscape resources
F26	Car parks	F55	Geographical characteristics of street frontage Building facades
F27	Recreational facilities	F56	Bridge style coordination
F28	Landscape maintenance	F57	Overall landscape coordination
F29	Maintenance of active site facilities	F58	Characteristic cultural symbol setting

Considering the number of questions in the questionnaire and the efficiency of the research in the later stage, affiliation analysis is used to screen these indicators initially and eliminate the indicators with low affiliation. The affiliation degree refers to the degree of the relationship of an element to the set composed of all elements. Considering the initial spatial demand indicators of waterfront public space in winter cities as a set and each indicator as an element, the degree of affiliation of each indicator = the number of times the indicator has been selected/the total number of people who participated in the survey. The affiliation questionnaire was directed to scholars and experts in related fields as well as architects who have had experience in practical engineering projects. A total of 30 questionnaires were obtained, of which 27 respondents provided valid questionnaires, with a validity rate of 90%, and the basic information statistics of respondents providing valid questionnaires are shown in Table 2.

Table 2. Basic statistical characteristics of respondents providing valid questionnaires.

Characteristics	Category	Percentage
Academic discipline	Architectural Design	40.7%
	Landscape Architecture	22.2%
	Urban and Rural Planning	22.2%
	Other Design-Related Disciplines	14.9%
Genders	Male	55.5%
	Female	44.5%
Educational background	Undergraduate	14.9%
	Master's Degree	48.1%
	Ph.D. Candidate	37.0%

The screening of spatial demand indicators with >70% affiliation is based on questionnaire feedback. The other indicators involved were added and amended according to the open-ended comments. Finally, a total of 12 indicators were eliminated, and 8 indicators were merged. According to the experts' opinions, storage facilities (F21) and shared service facilities (F22), the width of a walkway (F40), the area and scale of activity space (F42), the abundance of activity types (F44) and the abundance of water-friendly activities (F49), and the cultural promotion devices (F53) and the cultural promotion sites (F54) were combined.

Finally, the accessibility demand (A), safety demand (B), availability demand (C), comfort demand (D), social interaction demand (E), pleasure demand (F), and cultural demand (G) were used as the first-level criterion layer, and the 42 spatial demand indicators were used as the second-level evaluation indicator layer to obtain the waterfront public space demand indicator set for the winter cities (Figure 6).

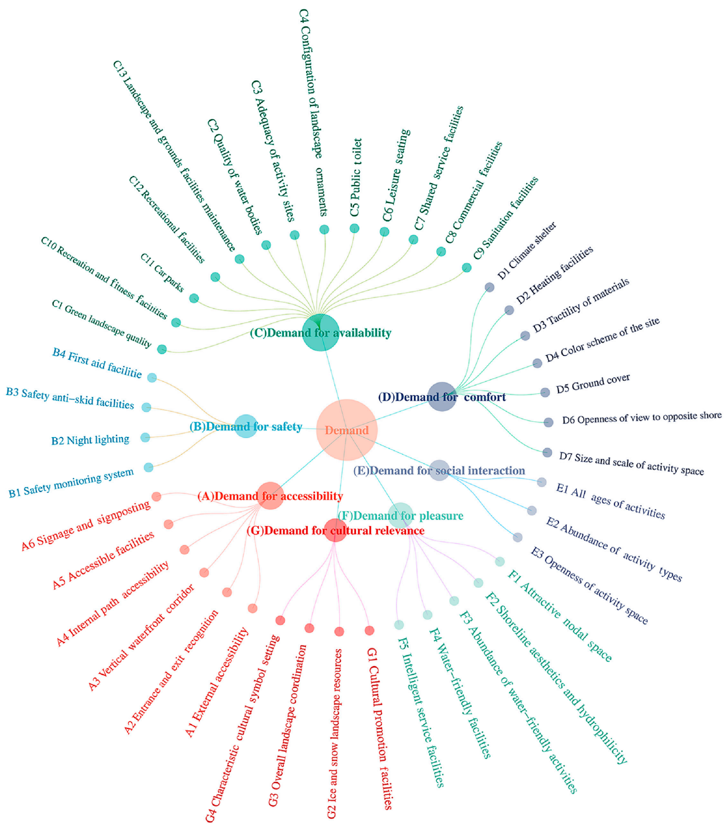

Figure 6. Indicator set of waterfront public space needs in winter cities.

2.4. Evaluation Model and Questionnaire Design

2.4.1. KANO Model

The Kano model statistically measures the satisfaction of each demand indicator through the Kano questionnaire, which can effectively categorize user demand and help us understand the non-linear nature of demand [73]. The model provides a more resource-efficient and effective tool for capturing the indicators that need to be improved for the urban renewal of waterfront public spaces in winter cities. According to the glamour quality theory, not all demand fulfilments directly improve satisfaction. Different categories of demands also have inconsistent effects on satisfaction. The KANO model classifies requirements into five categories, including the must-be requirement (M), one-dimensional requirement (O), attractive requirement (A), indifference requirement (I), and reverse requirement (R). The explanation of the five categories for quality attributes is shown in Table 3.

Table 3. Explanation of the five categories for service quality attributes in the Kano model.

Attribute Category	Explanation
Must-Be Requirement (M)	A basic service element should be required. When it is met, customer satisfaction does not increase significantly, but if it is not met, customer satisfaction decreases significantly.
One-Dimensional Requirement (O)	Increasing the availability of this service element will lead to greater user satisfaction, while failure to fulfil this category of needs will lead to a decrease in satisfaction.

Table 3. *Cont.*

Attribute Category	Explanation
Attractive Requirement (A)	This service element exceeds the user's expectations after they have been met, providing additional value and attraction to the user. Satisfaction does not decrease when it cannot be met, and it is an understanding of the user's latent demands. Enhancing the level of availability of this type of need will surprise the user.
Indifference Requirement (I)	The effect of this service element on user satisfaction is not significant. The presence or absence of the elements of this category of needs does not elicit a particular response from users. Users are not concerned about this type of element.
Reverse Requirement (R)	Adding or improving this service element will result in greater user dissatisfaction. They are attributes that deviate from user expectations. Such features or services are to be avoided.

2.4.2. IPA Model

The IPA model is a comprehensive analytical approach consisting of two dimensions, Importance and Performance [55], which is generally measured on the horizontal axis by the level of customer-perceived importance and on the vertical axis by the level of customer-perceived satisfaction. The IPA is divided into four quadrants (Figure 7). Based on its distribution, a judgement can be made on the treatment strategy for spatial requirements.

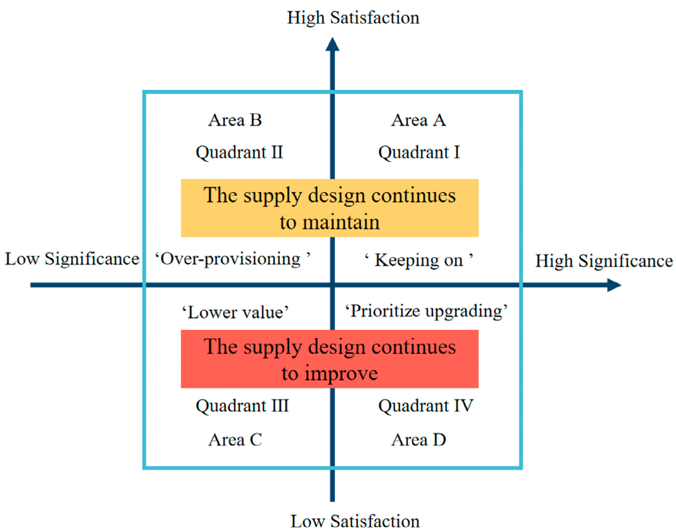

Figure 7. Schematic diagram of IPA analysis.

Requirements located in Quadrant I have a high level of customer satisfaction and importance, and those located in Quadrant II have a high level of customer satisfaction. Still, their importance is not high enough to indicate that this type of requirement is over-concerned. The decision determination type for both quadrants' spatial demand indicators continues to be maintained. Requirements located in Quadrant III have a low level of customer satisfaction and importance. Requirements located in Quadrant IV have a low level of customer satisfaction but a high level of importance, indicating that this type of requirement is something that customers value more but are not satisfied with. The decision determination type for both quadrants' spatial demand indicators continues to improve.

2.4.3. KANO-IPA Questionnaire Design

In the traditional KANO model, users can only assign two fixed values to the demand attributes, failing to express the fuzzy ideas in the psyche fully. With the advancement of academic research and practice, the traditional KANO model has been gradually optimized with the analytical KANO model [58,74]. The analytical KANO model can describe the uncertainty of the user's psychological state and incorporate quantitative analysis, which further enhances the accuracy of the model to effectively identify the user's preferences and achieve the optimal trade-off between the user's satisfaction and the provision of resources. Based on the analytical KANO model, this study assesses the importance of spatial demand in making up for the shortcomings of the traditional KANO model. This study was conducted using the KANO-IPA model.

There are 42 spatial demand indicators in this study. Suppose each demand needs to be evaluated from both positive and negative sides. In that case, it may significantly increase the difficulty of completing the questionnaire, which in turn affects the quality of the survey and reduces the respondents' willingness to participate. Therefore, the questionnaire design requires focusing on simplicity to improve the research efficiency. According to the experience of previous research [58], the assignment interval of the perceived importance of user demands is usually set to [0, 1], and a categorical assignment is used. The questionnaire is designed in combination with the spatial demand indicators, and the specific form and assignment are shown in Table 4 (taking the spatial demand indicator of 'barrier-free facilities' as an example).

Table 4. KANO-IPA questionnaire (using 'accessibility' as an example of a spatial demand indicator).

KANO Questionnaire					
	Very Satisfied	**More than Satisfied**	**Indifferent**	**More Dissatisfied**	**Very Dissatisfied**
Positive question: How do you feel when traveling in waterfront public spaces in cold cities with adequate accessibility?	1 O	0.5 O	0 O	−0.25 O	−0.5 O
Reverse question: How would you feel if accessibility was not adequate when you were traveling in a waterfront public space in a cold city?	−0.5 O	−0.25 O	0 O	0.5 O	1 O
IPA Questionnaire					
	Very important	Important	General Importance	Some Importance	Unimportant
Importance of adequate accessibility		[0.6,0.8)	[0.4,0.6)	[0.2,0.4)	[0,0.2)

The KANO-IPA questionnaire of the present study was distributed in the sample reach during February–March and July 2024 to collect data. A total of 380 questionnaires were distributed. By eliminating invalid questionnaires such as incomplete and irregular filling, 355 valid questionnaires were obtained. The validity rate of questionnaire recovery was 93.42%. The proportion of the survey participants of different age groups, genders, and activity types was matched to real-life situations to ensure more accurate conclusions about attitudes and demands regarding the use of urban waterfront public spaces in the cold region. Statistical results were collected with basic information about the sample reaches (Figure 8).

Different types of groups may have unique needs. For example, there is a need for adequate business amenities and weather-shielded business space for self-employed people, especially in the winter months. It is worth noting that nearly one-fifth of the active population are retired workers. During the field study, it was found that they preferred low-intensity physical activities such as walking and educational activities in the waterfront public space. Due to the lack of work–study time constraints, the retired elderly group is more willing to arrive at their destinations at 10:00 a.m. to 12:00 p.m. and 14:00 a.m. to 16:00 p.m. to carry out activities. Most of the activities are carried out by middle-aged and elderly people, and there is a lack of children and youth groups. This suggests that we need to pay more attention to the suitability of the space for the elderly and the young and also increase the fun of the space to attract the younger groups.

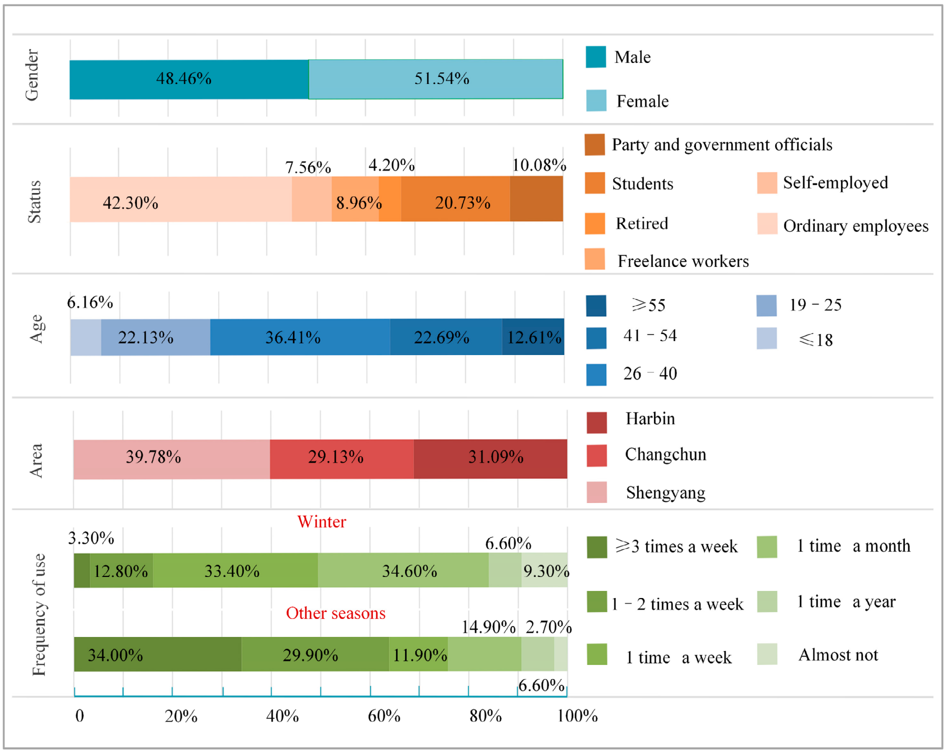

Figure 8. Basic information about the respondents.

2.5. Data Analysis

2.5.1. Attribute Classification and Screening of Indicators

Based on the analytical KANO-IPA questionnaire, the forward per capita weighted satisfaction ($\overline{x}_i$) and the reverse question per capita weighted satisfaction ($\overline{y}_i$) are calculated as follows:

$$\overline{x}_i = \frac{1}{J}\sum_{j=1}^{J} x_{ij} b_{ij} \tag{1}$$

$$\overline{y}_i = \frac{1}{J}\sum_{j=1}^{\overline{J}} y_{ij} b_{ij} \tag{2}$$

Among them, x_{ij} is user j's rating of the reverse satisfaction problem for the waterfront public spatial demand indicator f_i in winter cities (after this, referred to as spatial demand indicator f_i), and y_{ij} represents the rating of the positive satisfaction problem. b_{ij} is user j's rating of the spatial demand indicator's 'importance'. The combined rating of user j on the demand indicator is expressed as $w_{ij} = (x_{ij}, y_{ij}, b_{ij})$.

This study follows the guidelines for establishing an analytical KANO model to plot the KANO coordinates. The composite attributes of the spatial demand indicator f_i are transformed into a vector method $\overline{\gamma}_i$, i.e., $f_i(\overline{x}_i, \overline{y}_i) \to f_i(r_i, \alpha_i)$, as shown in Figure 9.

The importance index r_i and satisfaction index α_i are calculated as follows:

$$r_i = \sqrt{\overline{x}_i^2 + \overline{y}_i^2} \tag{3}$$

$$\alpha_i = \arctan(\overline{y}_i / \overline{x}_i) \tag{4}$$

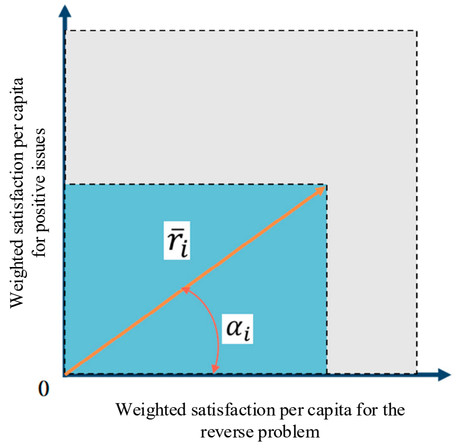

Figure 9. Vector $\overline{r}_i$ for the combined attributes of the demand indicator f_i of waterfront public space in winter cities.

The end position of the vector represents the spatial demand category to which the spatial demand indicator f_i belongs. Setting the threshold value of the category determination of the spatial demand indicator is $k = (r_0, a_L, a_H)$, then the attribute determination category for the spatial demand indicator f_i at this time is shown in Figure 10.

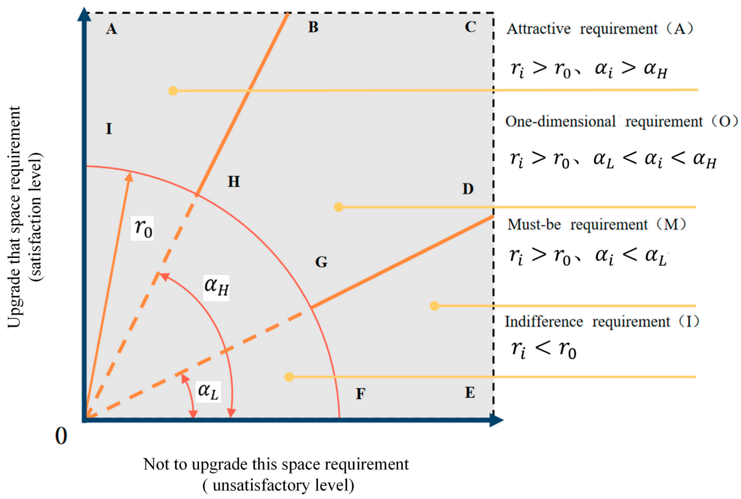

Figure 10. Graphical representation of the classification of spatial demand indicators for the analytical KANO model.

2.5.2. Evaluation of Decision-Making on Spatial Demand Indicator

Average importance $\overline{r}$ and average satisfaction $\overline{\alpha}$ are calculated as follows:

$$\overline{r} = \frac{1}{I}\sum\nolimits_{i=1}^{I} r_i \tag{5}$$

$$\overline{\alpha} = \frac{1}{I}\sum\nolimits_{i=1}^{I} \alpha_i \tag{6}$$

The IPA model also uses the axes of the KANO model above, setting the horizontal axis as the importance index $r_i\left(0 \le r_i \le \sqrt{2}\right)$, and the vertical axis is the satisfaction index $\alpha_i(0 \le \alpha_i \le \pi/2)$. Two special straight lines of average importance $\overline{r}$ and average satisfaction $\overline{\alpha}$ were selected as the basis of division to divide the IPA model into four regions (Figure 11).

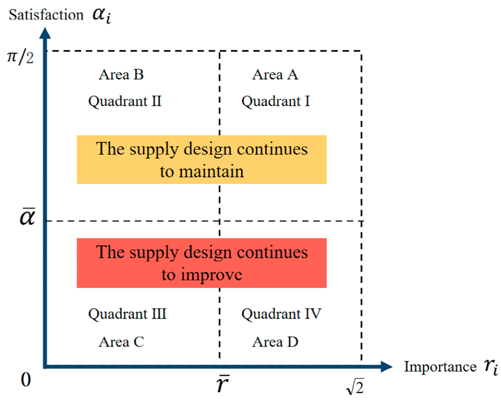

Figure 11. IPA model quadrant diagram.

2.5.3. Quantification of Indicator Priorities

Since the four quadrant diagrams of the IPA analysis can only make initial qualitative decisions about spatial demand indicators, quantitative prioritization is not possible. A prioritization index is introduced as a decision criterion for ranking, which allows for more accurate prioritization of the spatial demand indicators. The priority index ρ_i of the demand index is calculated as follows:

$$\rho_i = \frac{2\sqrt{2}}{3}\left(1 - \frac{\alpha_i}{\pi}\right) r_i \tag{7}$$

Among them, α_i is the satisfaction index and r_i is the importance. When the value of the priority index ρ_i is higher, this means that the ranking priority of the space demand indicator is higher. Therefore, this formula can be used to quantitatively rank all spatial demand indicators, providing a more accurate basis for ranking decisions on spatial demand indicators.

3. Results

3.1. Reliability Analysis and Validity Test

The reliability of the questionnaire scale was tested in this study using SPSS 27.0 software. The findings showed that the reliability coefficients of the forward, reverse, and importance questions were 0.941, 0.943, and 0.893, respectively, which were over 0.8, and two of them were over 0.9, which indicated that the KANO-IPA questionnaire designed in this study had a high degree of reliability and ensured the validity and applicability of the collected data [75].

KMO and Bartlett's sphericity test was used in this paper to assess the validity of the questionnaire. The results showed that the KMO values for the forward, reverse, and importance questions were 0.926, 0.935, and 0.866, respectively, which were greater than 0.8, and the p-value was less than 0.05, indicating that the questionnaire data had a high level of reliability and were suitable for further analysis.

3.2. Calculation of Significant Indexes

The results of calculating the importance index r_i and satisfaction index α_i based on the data are shown in Figure 12.

According to the feedback from the research on the sample reaches, most of the spatial demand indicators have small differences in the importance index. Still, the configuration of landscape ornaments (C4) and characteristic cultural symbol setting (G4) have been given high importance. In contrast, vertical waterfront corridor (A3), quality of water bodies (C2), commercial facilities (C8), tactility of materials (D3), and intelligent service facilities (F5) are considered relatively unimportant. In the waterfront public spaces of cold regions, users' demands are more focused on safety, water-friendly facilities, recreational facilities, etc. Vertical river corridors do not directly enhance accessibility and the visual experience, and commercial amenities experience reduced winter demand and shift to indoor or enclosed spaces, likely contributing to their lower importance. In cold climates, surface materials such as metal and stone tend to freeze or become uncomfortable to touch, affecting the user experience [76]. Therefore, although certain facilities are designed to have a good material feel, such details are often overlooked in cold climates, which may also explain the low importance of material tactility.

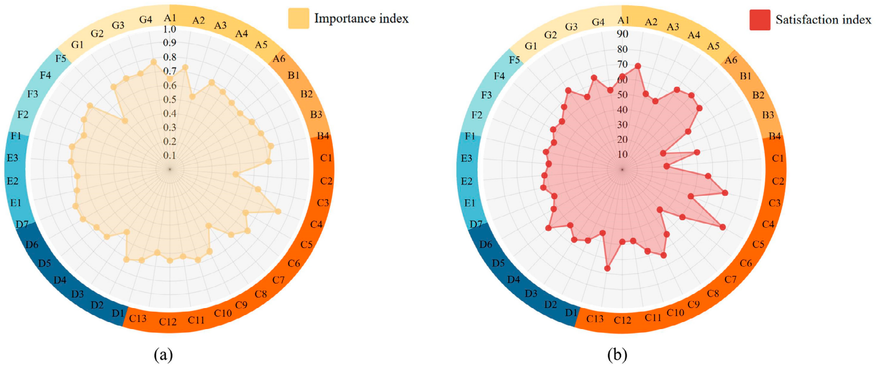

Figure 12. Visualization of the results of the calculation of the important indices of spatial demand indicators. (**a**) Important index; (**b**) satisfaction index.

In terms of satisfaction, there are some differences in the satisfaction indexes of the indicators within the categories of demand, except for demand for pleasure and demand for social interaction. Among them, public toilets (C5), adequacy of activity sites (C3), and entrance and exit recognition (A2) are the indicators with the highest level of satisfaction. On the contrary, safety anti-skid facilities (B3), green landscape quality (C1), and shared service facilities (C7) had lower satisfaction levels. During the field research, it was found that there were few safety warning signs in the sample of the research river section, some roads were dimly lit or not illuminated, and the road surface was not smooth enough, which would significantly increase the risk of users' activities in the waterfront concerning meeting the actual demands. The vegetation level of the sample space was not rich enough. Plaza space and other nodes were relatively lacking in green embellishment. Only the Yitong River sample C2 waterfront green space had a relatively high green space rate and was richer in species. However, there was a general lack of vegetation species adapted to the cold winter climate in the sample reaches, leading to the loss of natural vitality in the waterfront area in winter. As society progresses and people's lifestyles change, there may be new points of demand for shared service facilities on the waterfront that are overlooked and may not have been adequately met in the current waterfront.

3.3. Attribute Classification Based on the KANO Model

Based on the improved KANO model, the spatial demand metrics were divided into four demand categories (Figure 13), with two must-be requirements (M), twenty-four one-dimensional requirements (O), twelve attractive requirements (A), and three indifference requirements (I).

Safety anti-skid facilities (B3) and green landscape quality (C1) are two essential spatial requirements that are currently 'pain points' in the design of the waterfront public space in winter cities. If not improved and changed, they may greatly affect the overall satisfaction of the users of waterfront public spaces in winter cities. These two demands are key indicators for improving overall satisfaction.

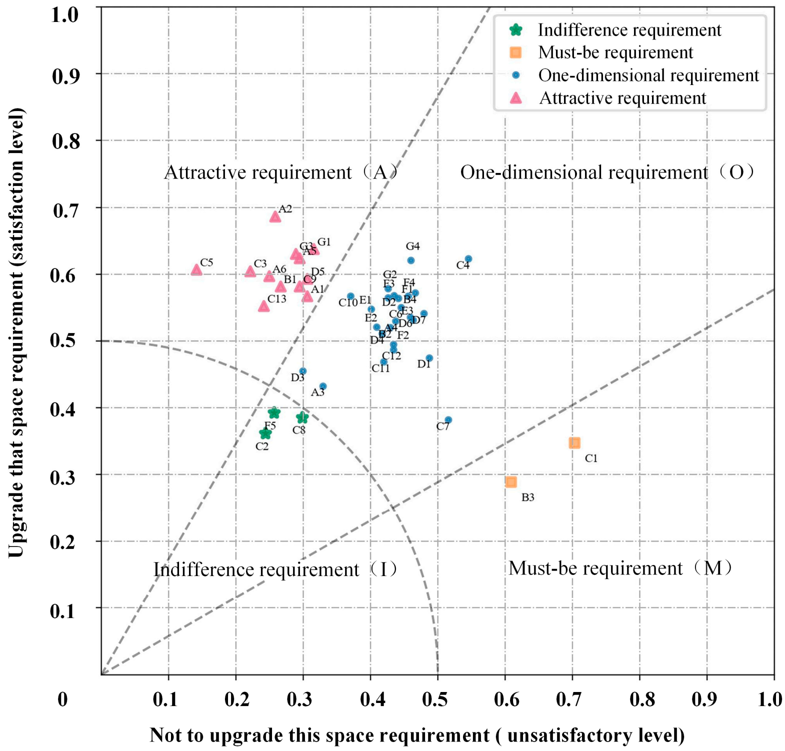

Figure 13. Attribute classification results for spatial demand indicators.

Users have high expectations for one-dimensional requirements, which are called 'itch points'. Enhancement of these aspects will have a positive relationship with satisfaction and should be given priority attention. The basic security needs include vertical waterfront corridor (A3), internal path accessibility (A4), night lighting (B2), first aid facilities (B4), activity space adequacy (C4), leisure seating (C6), shared service facilities (C7), recreation and fitness facilities (C10), car parks (C11), and recreation and entertainment facilities (C12). These indicators are directly related to the accessibility of the site and the availability of site resources and are key to ensuring the proper functioning of the public space. Although these are basic indicators, there are still many problems requiring solutions at this stage.

Most spatial indicators of elevated demand are attractive requirements (A). They are intended to optimize the spatial experience of users, and their classification as attractive requirement is in line with the expectations of the survey. It also indicates the users' demands for improving the quality of waterfront public spaces in winter cities. Twelve attractive requirements (A) have shown a high level of satisfaction and have not expressed more expectations. In the situation of budgetary constraints or resource limitations, improvements to these spatial demands are not necessary. Rather, maintaining the status quo is sufficient. On the other hand, this suggests that these space demands are 'points of preference' for users. With adequate resources, user satisfaction and spatial attractiveness can be further enhanced by providing innovative designs for waterfront public spaces in winter cities.

The quality of water bodies (C2), commercial facilities (C8), and intelligent service facilities (F5) are indifference requirements (I). Current users pay less attention to these demands, so too much investment may not significantly improve satisfaction. In this case, resources should be prioritized in the most impactful areas. This demand type is not involved in the discussion in the subsequent analytical decisions of the IPA model. However, this is not to say that these 'pain points' should be completely ignored in practice. The spatial demands of users are dynamic and may change to become more important spatial demand indicators in the future.

3.4. Evaluation of Decision-Making on the IPA Model

The respective distributions of the must-be requirement (M), one-dimensional requirement (O), attractive requirement (A), and indifference requirement (I) in the four quadrants are shown in Figure 14. The mean value of the importance index is 0.665, and the mean value of the satisfaction index is 54.380.

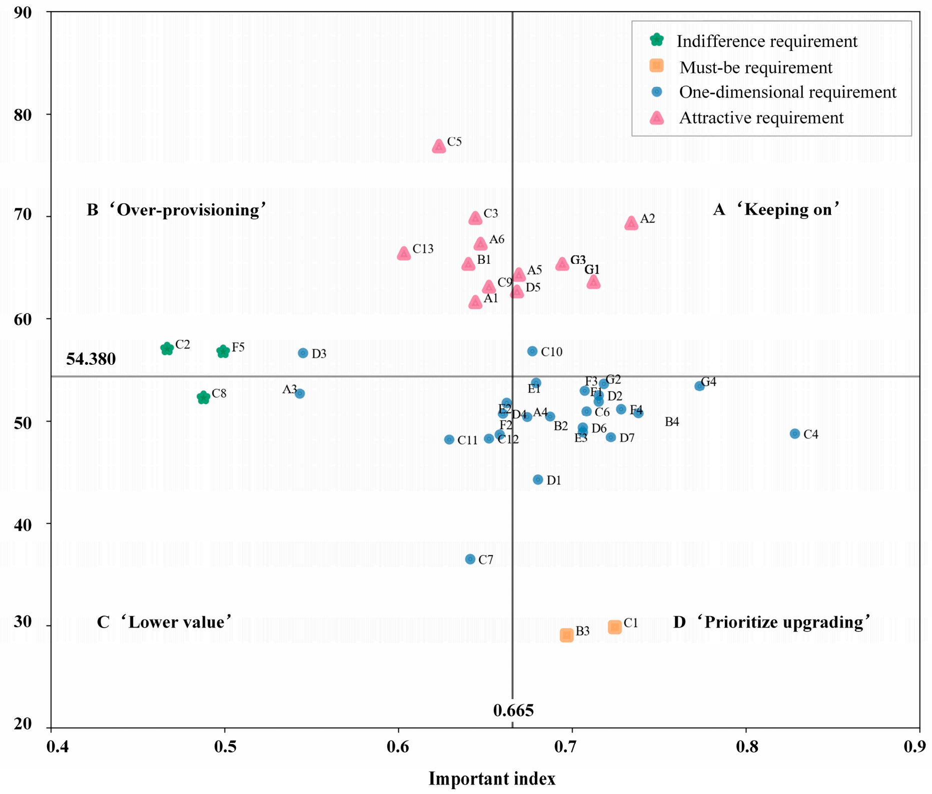

Figure 14. IPA analysis diagram.

In the IPA quadrant diagram, the decision outcome for the spatial demand indicators in quadrants I and II is a continuation, with quadrant I having a higher priority than quadrant II, collectively referred to as the ‘keeping on’ spatial demand indicators. Quadrant III and IV spatial demand indicators result in an optimization decision, where quadrant IV has priority over quadrant III. Those in quadrant IV are ‘priority upgrading’ spatial demand indicators, while those in quadrant III are ‘partial refinement’ spatial demand indicators. It is worth noting that both attractive requirements and indifferent requirements are located in the holding strategy area, indicating that the IPA model matches the results of the Kano model. Since indifferent demand (I) is not involved in decision-making, 18 spatial demand indicators were finally identified for priority enhancement, namely B3, C1, A4, B2, B4, C4, C6, G2, D1, D2, D6, F1, F3, F4, D7, G4, E1, and E3. In addition, seven spatial demand indicators need partial refinement, namely A3, C11, C12, C7, F2, E2, and D4. The importance and performance gaps of these demands are relatively small, indicating that progressive refinement is still needed, although not a priority for improvement. Finally, the 14 spatial demand indicators that need to be contained are C10, D3, A5, D5, G1, G3, A2, C3, C5, A6, B1, C9, A1, and C13. These demands have reached a high level, and they are sufficient to maintain the status quo.

3.5. Prioritization of Spatial Demand Indicators

Prioritizing can help supply entities select the most important spatial demand indicators that can maximize user satisfaction in the context of limited resources. Calculate the priority index of each demand indicator to achieve the quantitative results of the priority ranking of 'priority upgrading' spatial demand indicators (Table 5), 'partial refinement' spatial demand indicators (Table 6), and 'keeping on' spatial demand indicators (Table 7).

Table 5. Prioritization of 'priority updating' spatial demand indicators.

Spatial Demand Indicators	ρ_i	Classifications	Prioritization
C4 Configuration of landscape ornaments	0.569	O	1
C1 Green landscape quality	0.556	M	2
B3 Safety anti-skid facilities	0.551	M	3
G4 Characteristic cultural symbol setting	0.512	O	4
B4 First aid facilities	0.499	O	5
D7 Size and scale of activity space	0.497	O	6
F4 Water-friendly facilities	0.491	O	7
E3 Openness of activity space	0.485	O	8
D1 Climate shelter	0.483	O	9
F1 Attractive nodal space	0.479	O	10
C6 Leisure seating	0.478	O	11
D2 Heating facilities	0.477	O	12
D6 Openness of view to the opposite shore	0.477	O	13
G2 Ice and snow landscape resources	0.475	O	14
F3 Abundance of water-friendly activities	0.470	O	15
A4 Internal path accessibility	0.466	O	16
B2 Night lighting	0.457	O	17
E1 All ages of activities	0.449	O	18

Table 6. Prioritization of 'partial refinement' spatial demand indicators.

Spatial Demand Indicators	ρ_i	Classifications	Prioritization
C7 Shared service facilities	0.482	O	1
F2 Shoreline esthetics and hydrophilicity	0.452	O	2
C12 Recreational facilities	0.450	O	3
D4 Color scheme of the site	0.447	O	4
E2 Abundance of activity types	0.444	O	5
C11 Car parks	0.434	O	6
A3 Vertical waterfront corridor	0.362	O	7

Table 7. Prioritization of 'keeping on' spatial demand indicators.

Spatial Demand Indicators	ρ_i	Classifications	Prioritization
C10 Recreation and Fitness Facilities	0.437	O	1
G1 Cultural Promotion Facilities	0.434	A	2
G3 Overall Landscape Coordination	0.434	A	3
A2 Entrance and Exit Recognition	0.425	A	4
D5 Ground Cover	0.410	A	5
A5 Accessible Facilities	0.404	A	6
A1 External Accessibility	0.399	A	7
C9 Sanitation Facilities	0.399	A	8
B1 Safety Monitoring System	0.384	A	9
A6 Signage and Signposting	0.382	A	10
C3 Adequacy of Activity Sites	0.371	A	11
C13 Landscape and Grounds Facilities Maintenance	0.359	A	12
D3 Tactility of Materials	0.352	O	13
C5 Public Toilet	0.336	A	14

The average priority index values for the three categories of demands, 'priority updating', 'partial refinement', and 'keeping on', are gradually decreasing, indicating that the impact or urgency of demands from 'priority updating' to 'keeping on' on waterfront public spaces is diminishing in order. This result aligns with decision-making logic and validates the accuracy of the spatial demand priority ranking. At the same time, the priority index of spatial demand indicators within each category shows significant differentiation, indicating that there are clear differences in the importance of these demands. Therefore, during the optimization process, attention should be focused on the most critical needs. In the type "priority updating", the priority of the configuration of landscape ornaments (C4) is significantly higher than that of other indicators, indicating that this demand should be prioritized in the optimization of waterfront public spaces in winter cities. In the type 'partial refinement', there is a clear gap between the vertical waterfront corridor (A3) and the rest of the indicators in this category, with very low satisfaction and importance indices. In the type 'priority updating', attractive nodal space (F1), leisure seating (C6), heating facilities (D2), and openness of view to opposite shore (D6), along with the type 'keeping on', accessible facilities (A5), external accessibility (A1), and sanitation facilities (C9) have similar priority indices, which indicates that the urgency for optimizing these spatial demand indicators can be regarded as approximately the same.

4. Discussion

This study organized a set of spatial demand indicators that encompass seven dimensions of demand and 42 specific spatial demand indicators—an evaluation of the satisfaction with spatial demand in 12 samples from three winter cities in Northeast China. Using the KANO model to classify spatial demand indicators, we identified two must-be requirements (M), twenty-four one-dimensional requirements (O), twelve attractive requirements (A), and three indifference requirements (I). Through IPA decision analysis, we further obtained eighteen spatial demand indicators for "priority updating", seven spatial demand indicators for "partial refinement", and fourteen spatial demand indicators for "keeping on". Finally, the specific indicators were ranked according to their priority index, clarifying the order of different spatial demand indicators in various types of demands for resource allocation and design improvement. These results provide a clear theoretical basis and decision-making guidance for the design improvement and resource allocation of waterfront public spaces in winter cities.

Compared to cities in other climate types, the climatic characteristics of winter cities, such as severe cold, snow, and ice, pose special challenges to the use of public spaces and the durability of facilities. The results of this study indicate that safety features and warming equipment are particularly important during the cold season. A study conducted in Salt Lake City, U.S.A., reported that safety issues in winter are positively correlated with ice, snow, and cold [77]. The demand for water-friendly activities and open spaces was equally significant in summer. Other relevant studies conducted in Hokkaido, Japan, similarly found that people's healthy activity levels are significantly lower in winter than in non-winter months and that outdoor activity levels are lower in cold places than in non-cold places [78]. Therefore, the behavioral demands of the waterfront in winter are significantly different from those in non-winter. The seasonal fluctuations in behavioral demand are even more important to focus on in areas under the influence of cold climates. Therefore, the design of waterfront public spaces needs to be 'seasonally resilient' to provide functions under different climatic conditions. This categorization of demand is consistent with previous research in Khabarovsk, Russia [79], which further validates the applicability of the KANO-IPA model in winter cities and provides a unique perspective for the optimal design of waterfront public spaces.

An orderly and hierarchical approach to optimal design is adopted to ensure that each step and resource input are as effective as possible to maximize efficiency. Winter cities experience significant seasonal variations and face resource constraints, so design optimization must consider both the time span and cost-effectiveness. Based on the spatial demand indicators in the types 'priority upgrading', 'partial enhancement', and 'keeping on' identified in this study, time-spanning optimization strategies are proposed. They are the near-term priority updating design strategy, the medium-term steady promotion design strategy, and the far-term glamour enhancement design strategy. In the case of conflicting resource allocations, the design tools corresponding to each spatial demand indicator are based on a combination of prioritization and practical considerations.

(1) The near-term priority updating design strategy emphasizes rapid response and problem-solving to enhance attractiveness and meet the urgent demands of users. In this sample river reach, the indicators of priority upgrading mainly focus on the improvement of functional facilities and landscape creation, especially safety anti-skid facilities (B3) and first aid facilities (B4), which are, respectively, ranked third and fifth. These two items are the basic security for waterfront public space activities in winter cities. Several studies showed that the layout and improvement of safety and emergency facilities significantly affect the willingness of urban residents to use waterfront public space [80,81]. Cold temperatures and icy conditions in winter make it more dangerous to go out at night. Paukaeva et al. reported that in winter cities such as Khabarovsk, Russia, the probability of people being out and about at night drops dramatically [79]. Therefore, the addition of security monitoring and night lighting can reduce the safety risks caused by water and vegetation cover, enhance the safety of users, and increase the rate of nighttime use. Appropriate lighting design not only creates a warm atmosphere but also visually relieves the sense of cold [82] and stimulates outdoor activities. Also, lighting can effectively respond to the reduction in sunlight and alleviate seasonal affective disorder [83]. In addition, safety tips for winter ice sports should be added in winter cities. Climate shelter (D1) and heating facilities (D2) are in high demand during winter in winter cities [84]. Outdoor activity spaces should provide cold buffer units, such as heat recharge and rest and shelter facilities, to enhance the activity experience of residents in winter. Studies have shown that cold weather significantly reduces residents' willingness to engage in outdoor activities when the temperature is lower than 4.4 °C. In comparison, the number of outdoor activity participants gradually increases when the temperature rises above 4.4 °C [85]. In terms of ground-based landscape design, the ice and snow resources of winter cities can be transformed into advantages by adding regional cultural symbols, shaping unique ice and snow landscapes, and creating weather-appropriate natural landscapes. The construction of ice and snow facilities such as igloos and snow houses is not only environmentally friendly and innovative but also encourages people to stay outdoors for a longer time. Iceland's ice hotels and winter events highlight Viking traditions through ice sculptures of longships and shields, celebrating the region's history and adding cultural richness to the landscape. Similarly, the Harbin Ice and Snow Sculpture Festival in China recreates landmarks such as the Great Wall and the Pagoda in ice. The sculptures also showcase traditional Chinese architecture, calligraphy, and symbols, linking art to local culture. In the meantime, the potential for multi-group, multi-temporal coexistence should be explored to create public spaces that are shared by all ages. Several studies have shown that increasing social support in urban public spaces in cold regions can attract more participants [86–88]. Enhancing the site's public facilities to be age friendly [78] and child friendly [89]. Smoothing area boundaries promotes mixed use by multiple groups to enhance mobility and accessibility between areas, stimulating the diverse behavioral coexistence of multiple groups. The information transfer pathway should be increased between spaces to enhance implicit communication. For example, the slow walkway fitness rating system platform in the Hunhe area of Shenyang makes it possible for the public to perceive the activities of other people through the platform while

they are working out and entertaining themselves, thus enhancing spatial interactivity and connectivity.

(2) The medium-term steady promotion design strategy focuses on the long-term planning and continuous optimization of waterfront public spaces in winter cities, aiming at solving bottlenecks in the development of the spaces through phased implementation, enhancing multi-dimensional shared services and increasing the playability and comfort. These strategies include optimizing resource allocation, increasing diversified activities, and enhancing visual comfort to lay the foundation for the long-term development of the space. The installation of shared lockers can facilitate users' storage of personal belongings, such as luggage, rain gear, and bicycles. For example, providing outdoor lockers makes it easier for cyclists to engage in other activities after cycling while protecting the equipment from the elements. In addition, car parks should be designed to reduce pedestrian and vehicular interference with each other, with additional planted areas for snow storage and snowmelt absorption. Snowfall may reduce visibility [90]. Landmark elements should be installed at the main entrances, using LED lighting and reflective materials to enhance visibility at night and in snowy weather so that they are still recognizable in winter when they are covered in snow. Additional seasonal variable spaces should be created to ensure year-round activity, and the waterfront public spaces should be fully developed for seasonal activities. For example, frozen water surfaces in winter can be transformed into snow and ice recreation sites, adding temporary designs to meet seasonal demands [79]. The resilience measures can help enhance the resilience of waterfront public space and promote its sustainable development.

(3) The far-term glamour enhancement design strategy focuses on long-term planning and strategic layout to develop spatial glamour and features to enhance the soft power of waterfront public spaces in winter cities. This type of strategy focuses on spatial demand indicators that, although less urgent, require higher resource inputs and costs to improve satisfaction significantly. These strategies focus on the following areas: improving accessibility through the enhanced maintenance of facilities, increasing the detailing and refinement of design, guiding public participation, and enhancing cultural infiltration and educational outreach. The ultimate goal is to improve the operational stability, safety, and convenience of the space, enrich the content of public activities, and highlight the city's image. In the sample area, there is a mismatch between the slow-moving transport facilities and the demand, especially in the cold climate, and it is especially necessary to improve the slow-moving transport. Slow-moving transport is the preferred choice of citizens for short trips, such as walking, jogging, and cycling [91]. Therefore, it is important to protect the right of way for slow-moving traffic. Drawing on the experience of Copenhagen, the gradual reduction in on-street parking, the increase in bicycle lanes, and the use of physical separation measures have effectively improved the protection of the right of way and the safety of traveling. In terms of design details, the demands of different user groups need to be taken into account. For example, height-adjustable equipment is installed to accommodate users of different heights and sizes. Natural materials, such as wood, are used to provide a warm touch in areas of frequent contact, compensating for metal materials that are too cold in winter. The freezing and thawing phenomenon in winter cities creates unique natural landscapes and activity experiences. Winter festivals, winter sports, and snow-related outdoor activities can make cities in cold regions more attractive [92]. The ice and snow resources in the public space along the waterfront can be used to develop winter ice and snow education programs, such as ice fishing, ice and snow sports training, ice sculpture making, and snow survival skills, to enrich the winter cultural life and educational experience of the residents.

In the actual optimization and updating process, the three types of optimization and design strategies are carried out simultaneously. However, in the case of resource constraints, in principle, the updating can be carried out in the priority updating in the near term, steady promotion in the medium term, and glamorous enhancement in the long term. The updating of spatial demand indicators included in different categories of optimization and design strategies can also be carried out in the order of priority index. Overall, optimization design strategies should be flexible to respond to the dynamic changes in the supply of waterfront public spaces and the demands of citizens in winter cities. The design should not only address current issues but also consider the potential for future development. As cold climate changes intensify, spatial design strategies must continuously adapt. Therefore, the optimization of spatial design should be a dynamic process that requires continuous assessment and adjustment in line with urban development and climate change to ensure that spatial design consistently meets the demands of residents and possesses long-term sustainability.

Although this paper has achieved certain results, there are still shortcomings, and the following three aspects need to be further explored in depth in subsequent studies. First, the number and scope of data acquisition should be further expanded to improve the comprehensiveness and representativeness of the sample. In the future, more waterfront public spaces in small- and medium-sized cities should be included in the study to collect multi-source and extensive data. Additionally, a more targeted approach focusing on specific populations, such as the elderly and children, could provide more refined insights into their needs and preferences. Second, the satisfaction evaluation of the spatial demand indicators is based on current data, which reflects the needs of waterfront public space users in winter cities at this stage. However, demand changes over time, especially in cold regions, and physical conditions, user expectations, and perceptions of space may change due to technological advances, policy changes, and other factors. Therefore, the practice should consider the time gap between the research results and the actual application to ensure that the measures are feasible. Future research should introduce a temporal dimension to explore cyclical and cross-cyclical changes in satisfaction. By analyzing satisfaction across different seasons or even over multiple years, researchers can identify seasonal or annual trends and adapt recommendations accordingly. This would enable the development of more precise optimization strategies that can provide better theoretical support for the practical application of waterfront public spaces in winter cities. Third, although preliminary optimization strategies have been proposed in this study, these strategies are currently based on preliminary experimental results only and have not been subjected to in-depth feasibility and cost–benefit analyses. This deficiency can be remedied in the future, and the practicality and impact of the study can be further enhanced. Collaboration with researchers in related fields, such as management and finance, can be carried out in future studies to conduct exhaustive feasibility and cost–benefit analyses of the optimization strategies to make the renewal of waterfront public spaces in winter cites more economical, green, and sustainable [93]. In addition, small-scale experiments can be implemented in the local areas of waterfront public spaces in winter cities to verify the practical effects of the strategies and provide empirical support for future strategy adjustment and optimization.

5. Conclusions

This study proposes a process for optimizing the design of waterfront public spaces in winter cities based on the KANO and IPA models from the perspective of users' demands, aiming at solving the problem of insufficient satisfaction due to the mismatch between supply and demand. Through this optimization mechanism, resource allocation can be effectively optimized to reduce user dissatisfaction and enhance user participation. Even when satisfaction is high, summary analyses should be conducted to consolidate areas of high performance. Optimizing the design of urban waterfront public spaces in cold regions is a dynamic process that requires continuous evaluation and adjustment. Over time, the same spatial configuration may bring different levels of satisfaction at different times, so it is important to dynamically monitor changes in demand and adjust supply on time to achieve balance and dynamic equilibrium in the long term.

This study constructs a systematic and comprehensive demand indicator set for waterfront public space in winter cities, covering seven demand dimensions and a total of 42 indicators. The attributes of spatial demand indicators are classified by the KANO model and combined with the IPA analysis method for decision category determination. Calculating the priority refers to quantitative demand priority, which provides a scientific basis for supply design. This study proposes that the near-term priority updating design strategy, the medium-term steady promotion design strategy, and the far-term glamour enhancement design strategy be implemented in phases to meet different levels of demand and enhance satisfaction.

This study not only provides a systematic evaluation tool and process for the optimization of waterfront public space in winter cities but also provides a scientific basis and practical guidance for future regeneration design by accurately identifying the gap between supply and demand and rationally allocating resources. It also improves the accuracy of the optimization strategy based on the prioritization of demand. We provide long-term support and reference for the optimization of waterfront spatial design in current winter cities and even for future urban renewal and resource management, which has a wide range of application prospects.

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