

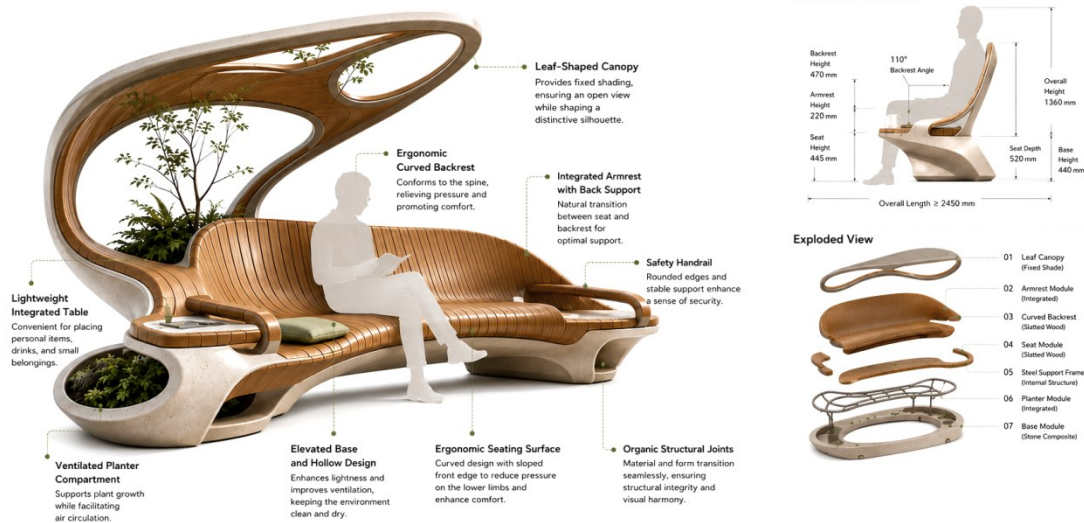
User-Demand-Oriented Design of Restorative Seating in Urban Parks: Using a GT–Kano–AHP–QFD–TOPSIS Hybrid Model

Suli Ti ^a, Ting Yu,^{a,b,*} Qitao Wu,^a and Qing Zhang^a

* Corresponding author: ty5020422@gmail.com

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GRAPHICAL ABSTRACT



User-Demand-Oriented Design of Restorative Seating in Urban Parks: Using a GT–Kano–AHP–QFD–TOPSIS Hybrid Model

Suli Ti ^a, Ting Yu,^{a,b,*} Qitao Wu,^a and Qing Zhang^a

Urban parks are increasingly expected to support rest, relaxation, and restorative perception under accelerating urbanization and everyday stress. However, studies on park seating still lack a systematic pathway for translating user demands into design elements and selecting design alternatives. Taking restorative-oriented wooden seating in urban parks as the object, this study developed a GT–Kano–AHP–QFD–TOPSIS hybrid model. Semi-structured interviews with 30 park users were analyzed using grounded theory. Kano classification was then conducted using 91 valid questionnaires. Twelve experts applied AHP to weight 13 user demand items, which were translated into design elements through QFD. Finally, 17 evaluators rated three design alternatives on a seven-point scale, and TOPSIS was used for ranking. The results showed that seating comfort, ergonomic dimensional optimization, and aesthetic form had the highest weights, at 0.1614, 0.1404, and 0.1321, respectively. Ergonomic dimensions, backrest design, lumbar support, multi-user adaptability, and aesthetic form were identified as priority design elements. Alternative 3 achieved the highest relative closeness coefficient (0.8007), indicating the best overall performance. This study provides a traceable user-oriented decision pathway for wooden park seating design, while its findings reflect perceived preferences rather than clinically or physiologically verified outcomes.

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Keywords: User demands; Urban park; Restorative seating; GT–Kano–AHP–QFD–TOPSIS hybrid model; Restorative design

Contact information: a: Department of Convergence and Art, School of Design, Silla University, Busan 46958, South Korea; b: Department of Interior Design, School of Creative Design, Zhejiang University of Security Technology, Wenzhou, Zhejiang Province, 325000 China;

* Corresponding author: ty5020422@gmail.com

INTRODUCTION

In the post-pandemic period, public mental health pressures and the demand for everyday restorative environments have remained prominent concerns. The World Health Organization reported that, during the first year of the COVID-19 pandemic, the global prevalence of anxiety and depression increased by 25% relative to pre-pandemic levels, indicating the sustained psychosocial burden imposed by public health emergencies (World Health Organization 2022). With rapid urbanization, urban parks have become among the green open spaces most frequently used in residents' daily lives. They provide essential environmental conditions for rest, short-term stay, social interaction, and relaxation. Previous studies have shown that the quality and accessibility of urban green spaces, together with built-environment characteristics, are closely associated with residents'

mental health and perceived well-being (Fang *et al.* 2024). Accordingly, improving users' comfort, relaxation, and perceived restoration through specific facilities in urban parks has become an important topic in healthy-city and public-space design research.

Among the various public facilities in urban parks, seating is a key micro-scale element that links bodily support, duration of stay, and place experience. It provides basic functions such as rest, observation, waiting, and social interaction. Its spatial arrangement, dimensional proportions, material tactility, formal characteristics, color relationships, and integration with the surrounding landscape also shape users' comfort, perceived safety, sense of affinity, and overall satisfaction. Previous studies have shown that the form, materials, patterns, and spatial order of public seating significantly influence users' aesthetic evaluations and use experiences (Mohamed 2024). Identifying renewal strategies for public seating based on residents' needs can further improve the specificity and practical applicability of urban park facility design (Zhang and Sun 2024). Therefore, seating should not be regarded merely as a general resting facility. Rather, it can be understood as a micro-scale medium in urban parks that supports bodily comfort, environmental perception, and restorative experience.

Wooden seating in urban parks warrants focused research attention. Compared with public facilities made of metal, concrete, or plastic, wood offers natural texture, warm tactility, strong environmental compatibility, and biophilic qualities. These characteristics allow wooden seating to integrate more effectively into the green landscape context of urban parks (Jasińska *et al.* 2024; Lin *et al.* 2024). As a renewable material, wood also has potential advantages in low-carbon performance, repairability, and recyclability when supported by appropriate material selection, structural design, preservative treatment, and maintenance strategies. These properties are consistent with the sustainable development of outdoor public furniture (Hitka *et al.* 2022). However, existing studies on urban park seating have largely focused on the renewal of general public facilities, aesthetic satisfaction, and spatial arrangement optimization. Less attention has been paid to how the material characteristics of wood contribute to the formation of user demands, the translation of design elements, and the selection of design alternatives. In park seating design oriented toward restorative experience, the tactile, visual, ecological, and maintenance-related properties of wood have not yet been adequately incorporated into a systematic design evaluation framework.

In this study, the term “restorative seating” does not refer to seating with medical or clinical treatment functions. Instead, it denotes wooden seating in urban parks designed to support perceived restoration, psychological comfort, emotional relief, and relaxation. The aim is not to demonstrate that seating directly reduces anxiety or produces clinically verified psychological or physiological outcomes. Rather, the study examines how users perceive seating in terms of safety, comfort, naturalness, affinity, and contextual fit. Research on restorative environments has shown that natural environmental features, perceived spatial safety, and environmental experience can influence individuals' perceived restoration (Grave *et al.* 2024). However, a clear translation gap remains between theoretical concepts of restorative environments and furniture-scale design language. Further research is therefore needed to determine how users' subjective demands for comfort, relaxation, safety, naturalness, and aesthetic quality can be translated into evaluable, comparable, and implementable design elements for wooden seating.

User-oriented design research has increasingly adopted methodological approaches that integrate qualitative identification with quantitative translation. Grounded Theory (GT) is well suited to deriving dimensions of user demand from interview data (Charmaz

2014). The Kano model distinguishes must-be, one-dimensional, and attractive demands, thereby revealing the asymmetric effects of different demand attributes on user satisfaction (Kano *et al.* 1984; Berger *et al.* 1993). The Analytic Hierarchy Process (AHP) can be used to determine the relative weights of user demands (Saaty 1980), while Quality Function Deployment (QFD) translates these demands into design elements (Hauser and Clausing 1988; Akao 1990). The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) supports the comprehensive evaluation and ranking of multiple design alternatives (Hwang and Yoon 1981). Previous studies have applied Kano, AHP, and QFD to public facilities, age-friendly environments, and furniture design, demonstrating their effectiveness in complex demand identification and design translation (Liu *et al.* 2024). However, research on wooden restorative seating in urban parks still lacks an integrated methodological chain that connects user demand identification, demand attribute classification, weight determination, design specification mapping, and comprehensive alternative evaluation.

Beyond the absence of an integrated methodological chain, a conceptual gap also remains in explaining how heterogeneous and subjective user demands are progressively transformed into explicit furniture-design decisions. Existing approaches often address demand identification, prioritization, or design translation as separate analytical tasks. This study therefore treats user-centered furniture design as a staged demand-transformation process linking user expression, demand attributes, priority structures, design specifications, and alternative evaluation.

To address these limitations, this study focused on wooden restorative seating in urban parks and developed a GT–Kano–AHP–QFD–TOPSIS hybrid model. User demand dimensions were first identified through preliminary interviews. The Kano model was then used to classify demand attributes, while AHP was applied to determine the relative weights of user demands. These demands were subsequently translated into design elements through QFD. Finally, TOPSIS was used to comprehensively evaluate and rank the design alternatives. This study aimed to establish a user-demand translation pathway for wooden seating design in urban parks and to provide a methodological reference for restorative-experience-oriented wooden public furniture design. Accordingly, this study addressed the following research questions:

RQ1: What are the core dimensions of user demand for wooden restorative seating in urban parks?

RQ2: How are different user demands prioritized based on Kano attribute classification and AHP-derived weight ranking?

RQ3: How can user demands be translated into actionable design elements for wooden seating, and how can different design alternatives be comprehensively evaluated?

EXPERIMENTAL

This study adopted the Double Diamond Model as its overall framework. Through the four stages of “discover, define, develop, and deliver,” the design process was organized into two consecutive diamond structures: problem exploration and demand definition, followed by design development and outcome delivery (Design Council 2005). The first diamond focuses on exploring and defining the problem space. It uses divergent research to comprehensively identify relevant issues, followed by convergent analysis to clarify key user demands. The second diamond focuses on generating and implementing

solutions. It involves screening, prioritizing, and translating multiple design possibilities into an implementable design alternative. The model emphasizes the continuity and systematic logic of design research, from “identifying the right problem” to “developing an appropriate solution.” It therefore aligns well with the user-demand-oriented objective of restorative seating design in urban parks.

The methodological sequence was determined by the progressive transformation of information required in user-centered furniture design rather than by simply combining multiple analytical techniques. GT was positioned first because the relevant user-demand criteria were not assumed in advance and therefore needed to be inductively derived from users’ situated experiences. Once the demand set had been established, the Kano model was used to distinguish the asymmetric effects of different demand attributes on satisfaction, thereby providing a structured basis for screening and organizing the demands before weighting. AHP was then applied because Kano classification identifies demand types but does not determine their relative priority within the design decision process. The resulting weights were subsequently introduced into QFD, which translated prioritized user demands into actionable design elements and technical characteristics. Finally, TOPSIS was applied after the design criteria, their weights, and the design alternatives had been established, allowing the alternatives to be compared according to their overall proximity to the weighted ideal solution. Thus, each method addresses a limitation left by the preceding stage and provides the necessary input for the next stage.

Compared with single-stage decision-making approaches that begin with predefined evaluation criteria or focus primarily on weighting or alternative ranking, the present sequence is more suitable for this study because the initial user-demand structure itself was unknown and required qualitative exploration before quantitative decision analysis. No single method used in the framework independently covers demand elicitation, satisfaction-attribute classification, priority weighting, design translation, and alternative selection. The integrated sequence was therefore selected to preserve traceability from raw user expressions to final scheme evaluation, rather than to claim universal superiority over other decision-making methods. Importantly, the integration is operational rather than merely procedural: the Kano-screened demand set forms the basis of the AHP hierarchy, the AHP-derived weights enter the QFD relationship matrix and subsequent alternative evaluation, and the QFD-prioritized design elements guide the generation and refinement of the design alternatives evaluated by TOPSIS.

Building on the logic of the Double Diamond Model, this study developed a GT–Kano–AHP–QFD–TOPSIS hybrid research pathway by integrating Grounded Theory, the Kano model, the Analytic Hierarchy Process, Quality Function Deployment, and TOPSIS. The pathway establishes a sequential information-transfer process in which the output of each analytical stage serves as the input to the next, progressing from demand discovery and classification to prioritization, design translation, and alternative evaluation. As shown in Fig. 1, the research framework comprises four interconnected stages.

In the Discover stage, GT is used to identify user demands from qualitative data. In the Define stage, the Kano model classifies demand attributes and AHP establishes their relative priorities. In the Develop stage, QFD translates prioritized user demands into actionable design elements and supports the development of design alternatives. In the Deliver stage, TOPSIS evaluates and ranks the alternatives. Thus, the output of each stage serves as the input to the next, forming a traceable pathway from user-demand identification to design translation and alternative selection.

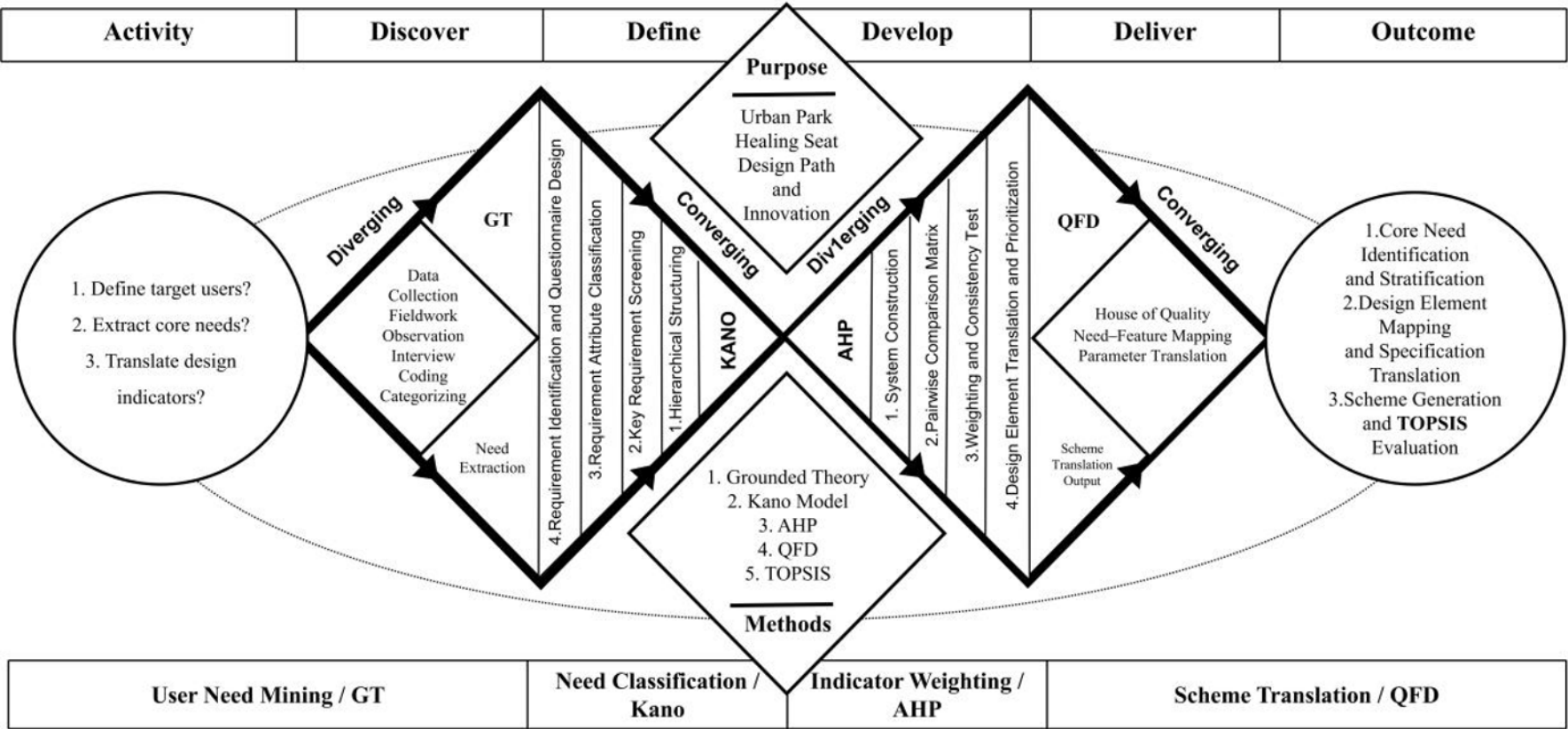


Fig. 1. Overview of the research workflow

User Demand Acquisition Based on Grounded Theory

Expert workshops: Semi-structured interview framework

GT emphasizes the iterative integration of data collection and analysis. Once the research direction has been clearly defined, the interview guide should remain open, flexible, and revisable, rather than being fully fixed before the study begins (Charmaz 2014; Foley *et al.* 2021). Before conducting formal interviews with park users, this study reviewed relevant literature on restorative environments, urban public spaces, public seating design, and user demand translation. The review results were used to identify preliminary issues related to restorative seating in urban parks. Two rounds of interdisciplinary expert workshops were then organized. Experts in landscape design, environmental design, industrial design, environmental psychology, and public facility design participated in the discussions. The workshops focused on three main issues: the key problems of urban park seating in real-use contexts; the core characteristics that distinguish restorative seating from general park seating; and the ways in which users' subjective experiences, including relaxation, perceived safety, privacy, sense of belonging, and perceived closeness to nature, could be transformed into research dimensions suitable for interviewing, coding, and design translation. This process did not replace user interviews. Instead, it helped clarify the scope of the interviews, refine the wording of the questions, and reduce the risk that the interview guide would be too broad or misaligned with the research objectives.

Table 1. Semi-Structured Interview Guide

Respondent Group	No.	Interview Question
Park users	1	When and under what circumstances do you usually visit urban parks? What activities do you typically engage in, and in what situations do you use park seating?
	2	Which locations and types of park seating do you usually prefer? Please explain the reasons for your preferences.
	3	Which aspects of park seating are most important to you? What existing problems most strongly affect your use experience?
	4	When you feel tired, irritated, or in need of relaxation, what types of seating and surrounding environments are more likely to make you feel comfortable, calm, and relaxed?
	5	How would you describe an ideal restorative-oriented seat in an urban park? What functions, design features, or environmental conditions would you expect it to provide?

After expert discussion and multiple rounds of revision, this study developed a semi-structured interview framework for restorative seating in urban parks (Kalender *et al.* 2023). The framework comprises five dimensions. The first dimension addresses use contexts and behavioral characteristics, including the time, location, activity state, and mode of stay associated with park visits and seating use. The second dimension concerns functional needs and spatial adaptation, including requirements for comfort, safety, shading, dimensional suitability, accessibility, and ease of use. The third dimension focuses on perceived restoration and emotional experience, including users' perceptions of relaxation, safety, privacy, companionship, and emotional relief while using the seating. The fourth dimension examines environmental perception and landscape relationships, including the relationship between seating and tree shade, waterscapes, pathways, quiet areas, and the surrounding natural environment. The fifth dimension concerns design

preferences and expectations for improvement, including preferences regarding materials, colors, forms, sense of enclosure, and additional functions. This interview framework provided the basis for subsequent open coding, axial coding, Kano demand classification, AHP-based weight calculation, and QFD-based design translation. The detailed interview questions are presented in Table 1.

User interviews: Identifying explicit and latent demands for restorative seating in urban parks

Field investigations were conducted in representative urban parks in China, with two parks in Wenzhou, Zhejiang Province, selected as primary study sites: Sanyang Wetland Urban Park in Ouhai District and Ma'anchi Urban Park in Lucheng District. Respondents were recruited through a combination of on-site random interception and purposive sampling. The inclusion criteria were as follows: participants had visited urban parks within the past year, had actual experience using park seating, and were able to clearly describe their perceptions of seating use contexts, satisfaction, pain points, and expectations for restorative experience. To improve the relevance of the data, priority was given to users who visited parks frequently and regularly used park seating. The interviews continued until no new substantive concepts emerged during open coding, indicating that theoretical saturation had been reached. In total, 30 park users were interviewed. Their demographic characteristics are presented in Table 2. The interview transcripts were analyzed through open coding, axial coding, and selective coding to identify the core user demands for restorative seating in urban parks. These findings provided the basis for subsequent Kano classification, AHP-based weighting, and QFD-based design translation.

Data collection and organization

Formal interviews were conducted with 30 participants between January 10 and March 12, 2026. This sample size was considered adequate to capture users' experiences with urban park seating across different use scenarios. Semi-structured interviews were conducted using both online and offline methods. Each interview lasted 7 to 16 min, with an average duration of approximately 13 min. All interviews were audio-recorded and fully transcribed, providing the primary dataset for subsequent GT coding and analysis.

Participation in the interviews, questionnaires, AHP expert evaluations, and design-alternative evaluations was entirely voluntary. All participants received a Participant Information Sheet and provided informed consent before participation. Participants involved in the semi-structured interviews additionally consented to audio recording and transcription. Interview recordings, transcripts, questionnaire responses, expert judgments, and design-evaluation data were handled confidentially. Personally identifying information was removed during data processing, and anonymized data were used for analysis and reporting. Access to the research data was restricted to the research team.

Semantic coding

Open coding is the initial stage of GT analysis. Its purpose is to conceptualize raw textual data, identify analytically meaningful semantic units from participants' responses, and extract initial concepts. In this study, NVivo 15.0 was used to conduct sentence-by-sentence review and open coding of the semi-structured interview transcripts. To improve the objectivity and reliability of the coding results, three researchers independently completed the initial coding.

Table 2. Demographic Characteristics of Semi-structured Interview Respondents

Participant	Gender	Age	Occupation/ Role	Educational Level	Park Visit Frequency	Seating Use Frequency	Main Activities	Interview Location
P1	Male	41	University teacher	Master's degree	Five times per week	Frequent	Accompanying family members; relaxation	Yanghu Wetland Park, Changsha, China
P2	Male	22	Undergraduate student	Bachelor's degree	Twice per week	Frequent	Walking; solitary activity	Binhe Park, Linfen, China
P3	Female	38	Designer	Master's degree	Three times per week	Frequent	Accompanying children; walking	Hunan Martyrs' Park, Changsha, China
P4	Female	66	Physician	Bachelor's degree	Six times per week	Frequent	Exercise; walking	Sanyang Wetland Park, Wenzhou, China
P5	Female	35	Lawyer	Doctoral degree	Four times per week	Frequent	Accompanying children; walking	Xuanwu Lake Park, Nanjing, China
P6	Female	22	Undergraduate student	Undergraduate study in progress	≥3 times per week	Frequent	Viewing scenery; resting	Chaoyang Park, Beijing, China
P7	Male	28	Doctoral student	Doctoral study in progress	Twice per week	Frequent	Walking; solitary activity	Sanyang Wetland Park, Wenzhou, China
P8	Female	27	Company employee	Bachelor's degree	Twice per week	Frequent	Resting; using a mobile phone	Xianghu Lake Park, Hangzhou, China
P9	Male	29	Designer	Bachelor's degree	≥3 times per week	Frequent	Viewing scenery; solitary activity	Ma'anchi Park, Wenzhou, China
P10	Female	31	Teacher	Master's degree	Twice per week	Frequent	Accompanying family members; resting	Yuexiu Park, Guangzhou, China
P11	Male	33	Civil servant	Bachelor's degree	Three times per month	Occasional	Walking; short-term stay	Baita Park, Hangzhou, China
P12	Female	35	Full-time mother	Bachelor's degree	>4 times per week	Frequent	Accompanying children; resting	Binhe Park, Linfen, China
P13	Male	36	University	Doctoral degree	≥3 times per	Frequent	Viewing scenery;	Lianhuashan

			teacher		week		quiet stay	Park, Shenzhen, China
P14	Female	38	Company employee	Junior college degree	1–2 times per week	Frequent	Resting; chatting	Xuanwu Lake Park, Nanjing, China
P15	Male	40	Self-employed worker	Senior high school	1–3 times per month	Occasional	Waiting; resting	Xuanwu Lake Park, Nanjing, China
P16	Female	41	Researcher	Doctoral degree	1–2 times per week	Frequent	Resting after walking; observing the landscape	East Lake Scenic Area, Wuhan, China
P17	Male	45	Engineer	Bachelor's degree	1–2 times per week	Frequent	Resting after exercise	East Lake Scenic Area, Wuhan, China
P18	Female	47	Homemaker	Senior high school	≥3 times per week	Frequent	Accompanying family members; chatting	Hunan Martyrs' Park, Changsha, China
P19	Male	43	University teacher	Doctoral degree	1–2 times per week	Frequent	Viewing scenery; solitary activity; relaxation	Hunan Martyrs' Park, Changsha, China
P20	Female	52	Public institution employee	Bachelor's degree	1–2 times per week	Frequent	Resting; socializing	Yanghu Wetland Park, Changsha, China
P21	Male	55	Manager	Bachelor's degree	Seven times per month	Frequent	Walking; short-term stay	Yanghu Wetland Park, Changsha, China
P22	Female	58	Retired teacher	Bachelor's degree	≥3 times per week	Frequent	Resting; chatting	Yangfushan Park, Wenzhou, China
P23	Male	60	Retired public official	Junior college degree	≥3 times per week	Frequent	Playing chess; social interaction	Olympic Forest Park, Beijing, China
P24	Female	62	Retired employee	Senior high school	≥3 times per week	Frequent	Sunbathing; chatting	Yuexiu Park, Guangzhou, China
P25	Male	64	Retired worker	Junior high	≥3 times per	Frequent	Resting; viewing	Xuanwu Lake

				school	week		scenery	Park, Nanjing, China
P26	Female	66	Retired employee	Senior high school	≥3 times per week	Frequent	Resting; accompanying grandchildren	East Lake Scenic Area, Wuhan, China
P27	Male	68	Retired teacher	Bachelor's degree	≥3 times per week	Frequent	Viewing scenery; solitary activity	Century Park, Shanghai, China
P28	Female	70	Retired person	Junior high school	≥3 times per week	Frequent	Resting; sunbathing	Hunan Martyrs' Park, Changsha, China
P29	Male	72	Retired person	Senior high school	≥3 times per week	Frequent	Chatting; resting	Jiushan Park, Wenzhou, China
P30	Female	74	Retired person	Primary school	≥3 times per week	Frequent	Resting; accompanying family members	Sanyang Wetland Park, Wenzhou, China

Table 3. Open Coding Results Based on Grounded Theory

Main Category	Subcategory	Initial Concepts	Number of Codes	Reference Points
B1. Scenario and User-Group Adaptation	A1. All-Day Use	a1. Health and wellness; a5. Age; a6. Number of users; a7. Style	11	28
	A2. Multi-User Adaptation	a2. Solitary use; a3. Social interaction; a4. Companionship	12	30
	A3. Landscape Adaptation	a8. Quiet and semi-private setting; a9. Landscape view; a10. Spatial scale	18	91
	A4. Pet Friendliness	a11. Pet accommodation	1	1
B2. Safety and Maintenance Assurance	A5. Facility Safety	a12. Load-bearing stability; a13. Shaking and tilting; a14. Environmental safety	9	24
	A6. Cleaning and Maintenance	a15. Easy-to-clean materials; a16. Easy-to-maintain environment; a17. Easy-to-maintain structure	18	33
	A7. Accessibility	a18. Wheelchair accessibility	1	1
B3. Ergonomic Comfort and Support	A8. Ergonomic Dimensional Optimization	a19. Seat height; a20. Seat width; a21. Seat depth	11	25
	A9. Armrest Support for Body Posture	a22. Relaxed sitting posture; a23. Assistance with standing	6	15
	A10. Lumbar Curve Support	a24. Support intensity; a25. Curve conformity	15	44
	A11. Backrest Optimization	a26. Backrest curvature; a27. Backrest angle	4	11
B4. Multifunctional Expansion	A12. Enhanced Multifunctionality	a29. Proximity to toilets; a31. Sunshade and rain protection; a32. Working and reading	2	8
	A13. Auxiliary Functional Modules	a30. Storage; a28. Mobile phone charging; a33. Heating	9	15
	A14. Seasonal Adaptability	a34. Warmth in winter and coolness in summer	1	1
B5. Formal Perception and Expression	A15. Appearance and Form	a35. Harmony; a36. Form; a37. Simplicity; a38. Color	5	8
	A16. Seating Experience	a39. Thermal perception; a40. Naturalness; a41. Softness and firmness	12	30

Concept labels and category assignments were then standardized through comparison, discussion, and cross-checking, resulting in a relatively stable initial conceptual system.

A total of 41 initial concepts, labeled a1–a41, and 16 categories, labeled A1–A16, were identified. During axial coding, these categories were further integrated into five main categories, labeled B1–B5. During selective coding, two core categories were ultimately extracted: C1, sensory interaction experience, and C2, environmental symbiotic efficacy. Based on these results, a theoretical model of user demands for urban park seating was constructed, as shown in Table 3.

Theoretical saturation test

GT is an iterative process in which concepts are generated from raw data through theoretical sampling, constant comparison, and repeated category integration. By continuously comparing and analyzing each data source, researchers identify emerging concepts and categories and use them to refine the theoretical framework. Theoretical saturation is reached when subsequent data no longer generate new concepts, categories, or relationships (Hennink and Kaiser 2022).

In this study, three-level coding of the interview data from 30 respondents yielded 41 initial concepts. By the time coding reached the 25th respondent, all newly added statements could be incorporated into the existing category system, and no new concepts or categories emerged. This indicated that the basic conditions for theoretical saturation had been met. To enhance the completeness and rigor of the analysis, the research team continued coding the remaining five interviews. As no additional concepts or categories were identified, the theoretical analysis was confirmed to have reached a high level of saturation.

User Demand Classification Based on the Kano Model

Scale and questionnaire design

Based on the Kano model of user demand analysis, this study developed a questionnaire to classify the user-demand attributes of restorative seating in urban parks (Cavacece *et al.* 2025). The questionnaire adopted the classical paired functional–dysfunctional question format of the Kano model. A total of 16 user-demand attributes were evaluated. For each attribute, respondents answered one functional question concerning their reaction when the feature was present and one dysfunctional question concerning their reaction when the feature was absent (Kano *et al.* 1984; Berger *et al.* 1993).

For both the functional and dysfunctional questions, respondents selected one of five categorical Kano response options: (1) “I dislike it that way,” (2) “I can live with it that way,” (3) “I am neutral,” (4) “It must be that way,” and (5) “I like it that way.” The numerical values from 1 to 5 were used only as category codes for data entry and did not represent a five-point Likert scale. Each pair of functional and dysfunctional responses was classified according to the standard Kano evaluation matrix into Attractive (A), One-dimensional (O), Must-be (M), Indifferent (I), Reverse (R), or Questionable (Q). For each user-demand attribute, the frequencies of the six Kano categories were calculated across the 91 valid questionnaires, and the category with the highest response frequency was used as the final Kano classification.

The final questionnaire comprised 16 paired Kano items across five major user-demand dimensions, forming the demand-classification system for restorative seating in

urban parks. A schematic representation of the paired functional and dysfunctional Kano questionnaire is shown in Fig. 2.

Functional Requirements of Healing Seating in Urban Parks					
	I dislike it that way (1)	I can live with it that way (2)	I am neutral (3)	It must be that way (4)	I like it that way (5)
Feature Present	☐	☐	☐	☐	☐
Feature Absent	☐	☐	☐	☐	☐

Fig. 2. Schematic representation of the paired functional and dysfunctional Kano questionnaire

Data collection

To broaden the range of perspectives included in the Kano survey, data were collected through both online and offline channels. The offline survey was conducted from March 13 to April 19, 2026, in selected urban park spaces. With on-site guidance from the research team, structured questionnaires were distributed to actual park users, including family groups, leisure visitors, and individual visitors. A total of 50 offline questionnaires were distributed, of which 27 valid responses were obtained.

The online survey primarily targeted design-related practitioners and researchers, including landscape designers, product designers, and scholars in related fields. A total of 100 online questionnaires were distributed, and 64 valid responses were obtained. In total, the combined online and offline survey yielded 91 valid responses. The use of the two recruitment channels enabled the study to incorporate both park-user and professional perspectives, thereby broadening the range of viewpoints considered in the Kano demand classification. The combined sampling strategy was intended to broaden the range of perspectives rather than to achieve statistical representativeness of the broader urban park user population.

Reliability and validity tests

Reliability and validity analyses were conducted in SPSS 27.0 using the collected questionnaire data to assess the measurement quality and structural adequacy of the scale. Internal consistency was first evaluated using Cronbach's α coefficient. The overall scale yielded a Cronbach's α value of 0.903, exceeding the commonly accepted threshold of 0.90 (Hair *et al.* 2014). This result indicates excellent internal consistency and supports the suitability of the data for further analysis.

The Kaiser–Meyer–Olkin (KMO) test and Bartlett's test of sphericity were then used to assess sampling adequacy and the appropriateness of the data for factor analysis. The KMO value was 0.773, exceeding the recommended threshold of 0.70 (Hair *et al.* 2014). Bartlett's test of sphericity was statistically significant ($p < 0.05$), indicating sufficient correlations among the variables.

These results confirm that the user demand scale for restorative seating in urban parks has good reliability and validity. The dataset therefore provides a reliable empirical basis for subsequent Kano classification and multidimensional demand structure analysis.

Table 4. Analysis of Kano Results

Code	(%)						Type	SI	DSI
	A	O	M	I	R	Q		(%)	(%)
A1. All-Day Use	5.49	76.92	12.09	5.49	0.00	0.00	O	82.42	-89.02
A2. Multi-User Adaptation	4.40	75.82	8.79	10.99	0.00	0.00	O	80.22	-84.61
A3. Landscape Adaptation	70.33	13.19	6.59	9.89	0.00	0.00	A	83.52	-19.78
A4. Pet Friendliness	5.49	8.79	10.99	73.63	1.10	0.00	I	14.44	-20.00
A5. Facility Safety	2.20	18.68	71.43	7.69	0.00	0.00	M	20.88	-90.11
A6. Cleaning and Maintenance	5.49	18.68	65.93	9.89	0.00	0.00	M	24.17	-84.62
A7. Accessibility	3.30	13.19	13.19	70.33	0.00	0.00	I	16.49	-26.38
A8. Ergonomic Dimensional Optimization	5.49	78.02	7.69	8.79	0.00	0.00	O	83.52	-85.72
A9. Armrest Support for Body Posture	7.69	76.92	12.09	3.30	0.00	0.00	O	84.61	-89.01
A10. Lumbar Curve Support	8.79	75.82	8.79	6.59	0.00	0.00	O	84.62	-84.62
A11. Backrest Optimization	7.69	76.92	7.69	7.69	0.00	0.00	O	84.62	-84.62
A12. Enhanced Multifunctionality	70.33	13.19	8.79	7.69	0.00	0.00	A	83.52	-21.98
A13. Auxiliary Functional Modules	69.23	13.19	10.99	6.59	0.00	0.00	A	82.42	-24.18
A14. Seasonal Adaptability	7.69	14.29	5.49	72.53	0.00	0.00	I	21.98	-19.78
A15. Appearance and Form	71.43	13.19	7.69	6.59	0.00	1.10	A	85.55	-21.11
A16. Seating Experience	5.49	79.12	8.79	5.49	0.00	1.10	O	85.55	-88.88

Note: A, O, M, I, R, and Q represent Attractive Requirement, One-dimensional Requirement, Must-be Requirement, Indifferent Requirement, Reverse Requirement, and Questionable Requirement, respectively; SI and DSI represent Satisfaction Impact Coefficient and Dissatisfaction Impact Coefficient, respectively.

To quantify the effects of different functional attributes on user satisfaction, this study calculated the satisfaction impact coefficient (SI) and dissatisfaction impact coefficient (DSI) for each indicator based on the Kano classification matrix. SI measures the extent to which the presence of a given function enhances user satisfaction, whereas DSI reflects the degree of user dissatisfaction caused by the absence of that function (Berger *et al.* 1993). The calculation formulas are as follows,

$$SI = \frac{A+O}{A+O+M+I} \quad (1)$$

$$DSI = -\frac{O+M}{A+O+M+I} \quad (2)$$

where A denotes attractive demand, O denotes one-dimensional demand, M denotes must-be demand, and I denotes indifferent demand.

As shown in Table 4, different restorative demand attributes varied substantially in their contributions to satisfaction and dissatisfaction. A higher SI value indicates that the presence of a function more strongly enhances users' restorative experience and spatial satisfaction. A lower, more negative DSI value indicates that the absence of the function is more likely to generate dissatisfaction and weaken the spatial experience. For example, seating experience, ergonomic comfort support, and appearance and form contribute strongly to satisfaction enhancement. In contrast, facility safety, cleaning, and maintenance are more closely associated with must-be demands, and their absence would substantially reduce the user experience. As shown in Fig. 3, A4, A7, and A14 are classified as indifferent demands. Overall, the Kano model effectively identifies differences among demand levels for restorative seating in urban parks. These findings provide an important basis for subsequent functional prioritization, design optimization, and refined public space renewal. Therefore, the three indifferent demand items were excluded from the subsequent AHP analysis.



Fig. 3. Better-worse analysis results

AHP-Based Calculation and Ranking of User Demand Weights

Construction of the hierarchical structure model

Before calculating AHP weights, this study decomposed user demands for restorative seating in urban parks into a hierarchical structure based on the preceding Kano classification results. A three-level AHP model was constructed, comprising the goal layer, criterion layer, and sub-criterion layer. The goal layer was defined as “core user demands for restorative seating in urban parks.” The criterion layer included three Kano demand types with clear effects on user satisfaction: must-be demands (M), one-dimensional demands (O), and attractive demands (A). Indifferent demands (I) and reverse demands (R) were excluded from the subsequent weighting analysis because they provide limited support for establishing effective design priorities.

The sub-criterion layer comprised 13 representative functional demands identified through the Kano analysis: facility safety, cleaning and maintenance, all-day use, multi-user adaptation, ergonomic dimensional optimization, armrest support, lumbar support, backrest optimization, seating experience, landscape adaptation, multi-functionality, auxiliary module expansion, and appearance and form, as shown in Fig. 4. This hierarchical structure established a clear correspondence between user demand attributes and specific design evaluation indicators, providing the basis for constructing judgment matrices, calculating weights, and conducting consistency tests.

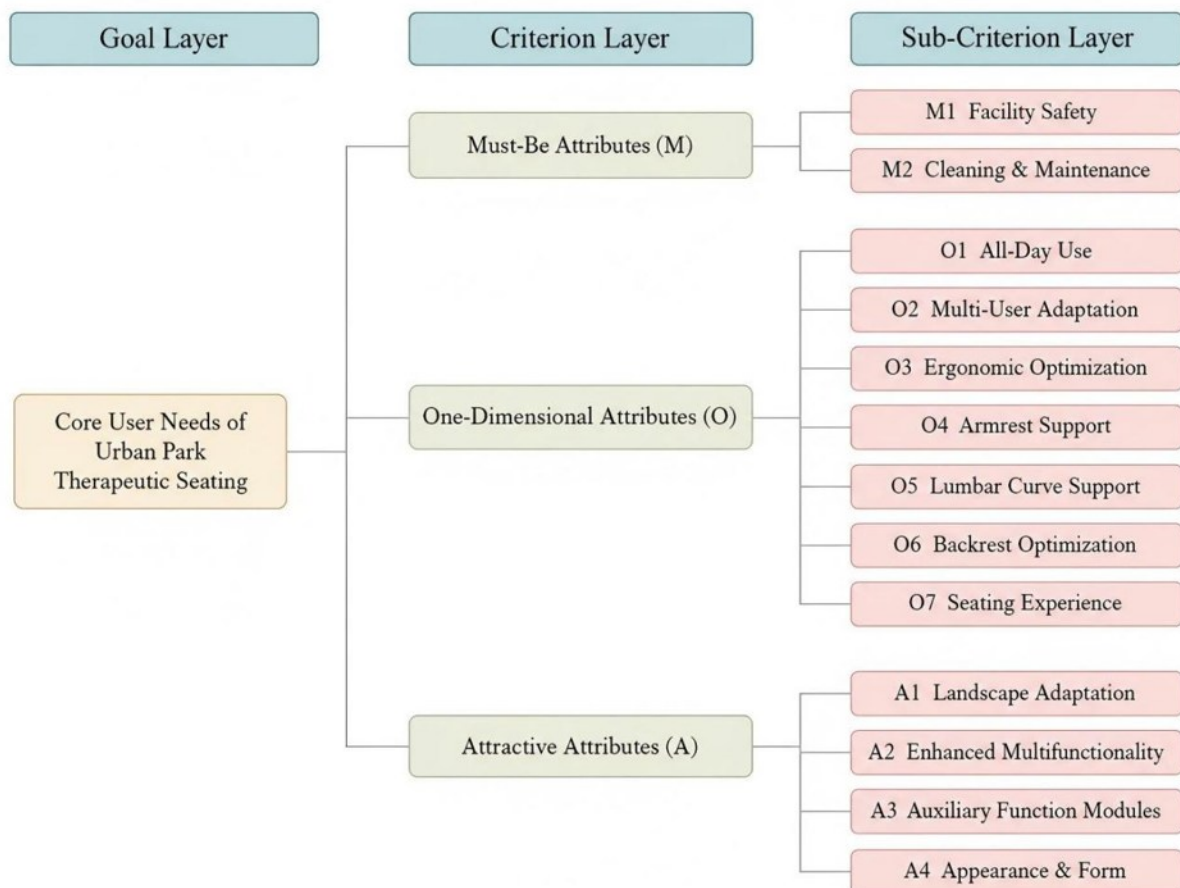


Fig. 4. Hierarchical analysis model of user demands

Construction of the judgment matrix and weight calculation

After establishing the hierarchical structure model, 12 experts were invited to conduct pairwise comparisons of the indicators using the Saaty 1–9 scale (Saaty 1980). The expert panel comprised professionals with backgrounds in landscape design, industrial/product design, and visual/environmental design. Experts were selected based on their professional or academic experience in furniture design, public-facility design, environmental design, ergonomics, or related user-centered design fields, as well as their familiarity with design evaluation and multi-criteria decision-making. Only individuals with relevant professional practice, research, or teaching experience were included to ensure that the judgments reflected both design expertise and the characteristics of urban public seating. (Saaty 1980). Based on this approach, the judgment matrix was defined as follows:

$$A = (a_{ij})_{n \times n} \quad (3)$$

where a_{ij} denotes the relative importance of indicator i with respect to indicator j . The judgment matrix satisfies the following conditions:

$$a_{ij} = \frac{1}{a_{ji}}, (i, j = 1, 2, 3, \dots, n) \quad (4)$$

To derive the weight vector $\mathbf{w}$, a normalization-based method was applied. The specific steps are as follows: First, matrix A is normalized column-wise:

$$b_{ij} = \frac{a_{ij}}{\sum_{k=1}^n a_{kj}}, \quad (5)$$

Second, the row sums of the normalized matrix are computed:

$$c_i = \sum_{j=1}^n b_{ij}, \quad (6)$$

Finally, the weight of each indicator $\mathbf{w}_i$ ($i = 1, 2, 3, \dots, n$) is obtained by normalizing vector

$$\omega_i = \frac{c_i}{\sum_{k=1}^n c_k}, \quad (7)$$

According to Eq. 3, the judgment matrix for the criterion layer of user demands for restorative seating in urban parks was first constructed (Table 5).

Table 5. Judgment Matrix for the Standard Layer

Index	M	O	A	Relative Weight
M	1	1/5	1/3	0.1047
O	5	1	3	0.6370
A	3	1/3	1	0.2583

Using Eqs. 4 through 7, the corresponding relative weights were calculated. Following the same procedure, judgment matrices were constructed for the 13 functional attributes at the sub-criterion level, and their local weights were computed (Table 6). The global weight of each functional attribute was then obtained by multiplying its local weight by the weight of the corresponding criterion, followed by normalization. Based on the resulting weights, all indicators were ranked according to their priority.

Table 6. Sub-Criterion Level Judgment Matrix

Main Indicator	Sub-Indicator	Judgment Matrix							Relative Weight
M	M1 Facility Safety	1	2	/					0.0708
	M2 Cleaning and Maintenance	1/2	1						0.0354
O	O1 All-Day Use	1	1/4	1/5	1/5	1/5	1/6	1/7	0.0181
	O2 Multi-User Adaptation	4	1	1/4	1/5	1/5	1/6	1/7	0.0298
	O3 Ergonomic Dimensional Optimization	5	4	1	3	2	1	1	0.1404
	O4 Armrest Support for Body Structure	5	5	1/3	1	1	1/2	1/2	0.0783
	O5 Lumbar Curve Support	5	5	1/2	1	1	1	1/2	0.0896
	O6 Backrest Optimization	6	6	1	2	1	1	1/2	0.1157
	O7 Seating Experience	7	7	1	2	2	2	1	0.1614
A	A1 Landscape Adaptation	1	1/2	1/2	1/4	/			0.0273
	A2 Enhanced Multifunctionality	2	1	1/2	1/3				0.0423
	A3 Auxiliary Functional Module Expansion	2	2	1	1/3				0.0589
	A4 Appearance and Form	4	3	3	1				0.1321

AHP Results

As shown in Fig. 5, the weights of user demands for restorative seating in urban parks exhibited a clear hierarchical structure. The top ten indicators were ranked as follows: seating experience O7 (0.1614), ergonomic dimensional optimization O3 (0.1404), appearance and form A4 (0.1321), backrest optimization O6 (0.1157), lumbar curve support O5 (0.0896), armrest support for body structure O4 (0.0783), facility safety M1 (0.0708), auxiliary functional module expansion A3 (0.0589), enhanced multifunctionality A2 (0.0423), and cleaning and maintenance M2 (0.0354).

Among these indicators, seating experience, ergonomic dimensional optimization, and appearance and form ranked as the top three. This indicates that users prioritize immediate, stable, and comfortable usage experiences. Seating comfort and anthropometric compatibility determine whether users can remain seated for extended periods. In contrast, appearance and form influence users' willingness to approach the seating, as well as spatial recognition and emotional perception.

Backrest optimization, lumbar curve support, and armrest support ranked fourth to sixth, indicating that the comfort of restorative seating is not determined solely by the seat surface. Instead, it depends on an integrated bodily support system composed of the seat surface, backrest, lumbar region, and armrests. Although facility safety and cleaning and maintenance ranked lower than comfort-related indicators, they remain fundamental requirements for public facilities and must be ensured in terms of structural load-bearing

stability, edge protection, weather resistance, corrosion prevention, drainage performance, and ease of maintenance.

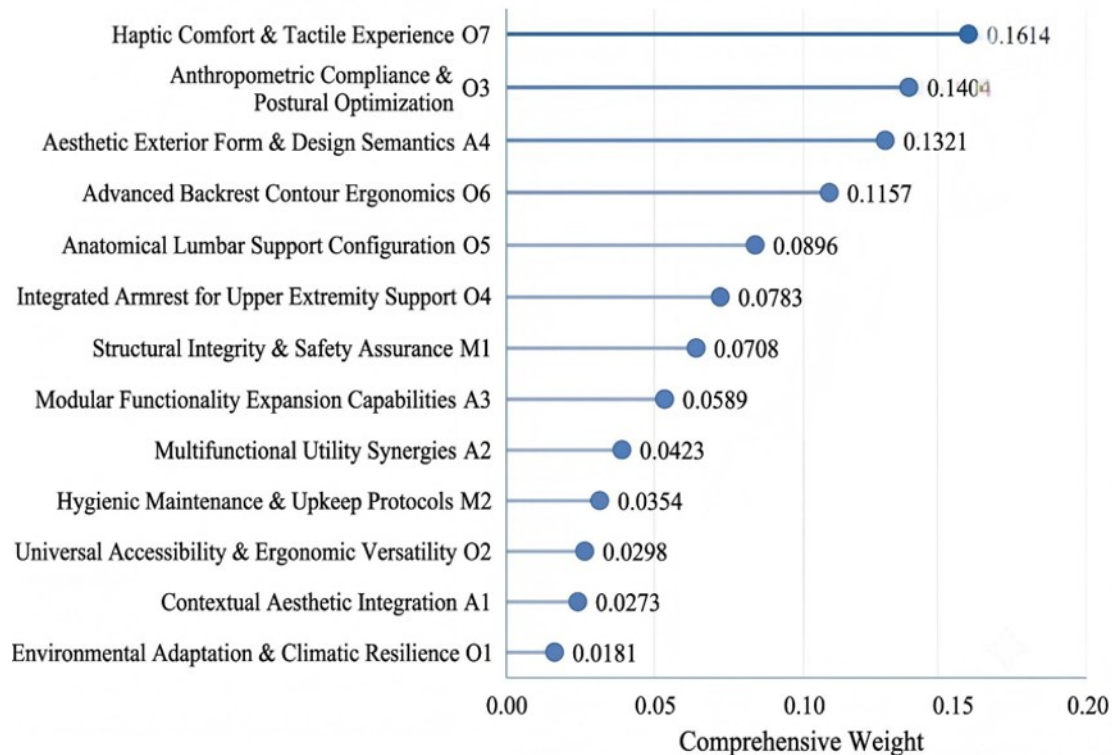


Fig. 5. Ranking results of user demand hierarchical analysis

Auxiliary functional module expansion and enhanced multifunctionality are considered value-added experiential factors. They can improve usability and contextual adaptability but should not replace basic seating functionality. Overall, the design of restorative seating in urban parks should prioritize seating experience and ergonomic dimensional optimization as core considerations, emphasize backrest, lumbar, and armrest support as key structural components, enhance visual appeal through natural and harmonious form design, and ensure comfort and restorative perception through adequate safety, maintenance, and moderate functional expansion.

As shown in Fig. 5, the results indicate that the identified user demands differ in their relative priority for the design of restorative seating in urban parks. Higher-priority demands are primarily associated with perceived seating comfort, safety, usability, and experiential value. Addressing these demands in subsequent design development may contribute to more favorable user evaluations of the proposed seating. However, the present study did not directly assess changes in actual usage frequency or public-space service performance, and these outcomes require further validation using physical prototypes and real-world deployment.

Consistency verification

Consistency testing was conducted to evaluate the validity of the judgment matrices. After deriving weights from each level of the judgment matrices, a consistency check was performed to assess the logical consistency of expert judgments and to ensure the statistical validity of the resulting weight system (Saaty 1980). First, the maximum eigenvalue ($\lambda_{\max}$) was computed using the eigenvector method, as shown below:

$$\lambda_{max} = \sum_{i=1}^n \frac{(P\omega)_i}{n\omega_i}, (i, j = 1, 2, 3, \dots, n) \quad (8)$$

where $(P\omega)_i$ denotes the i -th component of the vector obtained by multiplying the judgment matrix A by the weight vector ω , and n represents the order of the matrix. Next, the consistency index (CI) was calculated using Eq. 9:

$$CI = \frac{\lambda_{max} - n}{(n-1)} \quad (9)$$

Subsequently, the consistency ratio (CR) was obtained by dividing CI by the random index (RI), as proposed by Saaty and shown in Eq. 10:

$$CR = \frac{CI}{RI} \quad (10)$$

A CR value below 0.1 is generally considered acceptable, indicating satisfactory consistency (Saaty 1980). This suggests that the experts' judgments are sufficiently consistent and that the derived weights provide a reliable basis for subsequent decision-making (Padilla-Garrido *et al.* 2014).

Table 7. Consistency Test Results

Index	P	M	O	A
λ_{max}	3.039	2	7.388	4.081
CI	0.019	0	0.065	0.027
RI	0.58	0	1.32	0.9
CR	0.033	0	0.049	0.03

As shown in Table 7, the consistency test results indicated that the CR value of the criterion-level judgment matrix was 0.033. The CR values of the sub-criterion-level judgment matrices for must-be, one-dimensional, and attractive demands were 0.000, 0.049, and 0.030, respectively. All CR values are below the 0.1 threshold, indicating satisfactory consistency across all judgment matrices. This demonstrates that the derived weights are reliable and further confirms the logical robustness and methodological validity of the evaluation system, supporting its use in subsequent user demand weight analysis.

Design Requirement Transformation Based on QFD

Mapping and analysis of user demands and design elements

After completing the ranking of user demand weights for restorative seating in urban parks, this study applied the Quality Function Deployment (QFD) method to construct a relationship matrix between user demands and design elements. The core function of QFD is to translate user demands into operational technical characteristics that can be implemented in design practice. It further employs the House of Quality model to evaluate the correlation strength between user demands and design elements, thereby providing a structured basis for subsequent design generation and optimization (Hauser and Clausing 1988; Akao 1990).

Based on the AHP results, this study identified high-priority requirements—including seating experience, ergonomic dimensional optimization, backrest optimization, lumbar curve support, armrest structural support, and facility safety—as key inputs for the QFD analysis. In addition, a literature review combined with the Delphi method was used to further refine and translate user demands into corresponding design elements.

First, a literature review approach was employed to preliminarily identify design elements related to restorative seating in urban parks. The technical conditions, materials, functionality, and aesthetic attributes of urban furniture directly influence the comfort, attractiveness, and user evaluation of public spaces (Grabiec *et al.* 2022). In addition, restorative spatial characteristics in urban parks significantly affect users' perceived psychological restoration (Grave *et al.* 2024). Public seating design requires a structured integration of user demands, ergonomic performance, environmental sustainability, and design evaluation (Chang *et al.* 2025). Furthermore, research on furniture dimensional optimization indicates that decisions regarding furniture size not only affect functional performance but are also closely associated with structural integrity, material efficiency, and aesthetic proportion (Jasińska *et al.* 2024). Studies on wooden chair structures further demonstrate that variations in user body weight and anthropometric parameters influence structural component design. Accordingly, public seating must adequately account for load-bearing safety and structural reliability (Hitka *et al.* 2022). Furniture form, line quality, and stylistic characteristics can significantly influence users' emotional responses, thereby providing a theoretical foundation for the aesthetic design and emotional perception of restorative seating (Lin *et al.* 2024).

Based on the results of the literature review above, this study further employed the Delphi method to conduct expert evaluation and refinement of the initially derived design elements (Linstone and Turoff 1975). The expert panel consisted of professionals from industrial design, product design, ergonomics, environmental design, and public facility design. It included four university faculty members specializing in industrial or product design, four industrial designers with experience in public facilities or furniture design, and two researchers in environmental design or public space design.

The expert evaluation focused on the necessity and operability of each design element, its degree of alignment with user demands, its applicability in urban park contexts, and the presence of redundancy or conceptual overlap. A total of three rounds of Delphi consultation were conducted to validate and refine the design elements until expert opinions converged, resulting in a finalized set of design elements for subsequent QFD House of Quality analysis. Based on the literature review and Delphi-based refinement, the final mapping between user demands and design elements is presented in Table 8.

Construction of the QFD house of quality for restorative seating in urban parks

Based on the user demand importance values derived from the AHP analysis and the established mapping between user demands and design elements of restorative seating in urban parks, a Quality Function Deployment (QFD) House of Quality was constructed, as shown in Fig. 6.

In this model, user demands and their corresponding weights are placed on the left side of the House of Quality, while design elements are positioned at the top. The relationships between user demands and design elements are then evaluated and quantified, enabling a systematic translation of user demands into design elements. Relationship strengths are classified into three levels: strong correlation is assigned a value of 5 and marked with “●”; moderate correlation is assigned a value of 3 and marked with “○”; weak correlation is assigned a value of 1 and marked with “△”; and no significant relationship is left unassigned.

Table 8. User–Design Element Mapping for Park Seating

Goal Layer	Criterion Layer	User Demand (CA)	Design Elements (DP)
City Park Restorative seating Design	Must-Be Demand (M)	Facility Safety CA1	Load-bearing structure, anti-tip stability, anti-slip design, anti-pinch protection, rounded edge impact protection, connector safety (DP1)
		Cleaning & Maintenance CA2	Drainage structure, easy-to-clean surfaces, replaceable components, anti-corrosion and moisture resistance, low-maintenance structural design (DP2)
	One-Dimensional Demand (O)	All-Day Use CA3	Weather-resistant materials, nighttime identification/lighting, sun/rain protection, anti-waterlogging structure (DP3)
		Multi-User Adaptation CA4	Accommodating children, young adults, parent-child groups, middle-aged and elderly users, and post-exercise users (DP4)
		Ergonomic Dimensional Optimization CA5	Seat height, seat depth, seat width, backrest height, backrest angle, armrest height, leg movement space (DP5)
		Armrest Structural Support CA6	Armrest height, width, grip cross-section, rounded end design, support strength (DP6)
		Lumbar Curve Support CA7	Lumbar support curve, lumbar support height, lumbar–back fit, curved transition design (DP7)
		Backrest Optimization CA8	Backrest recline angle, back support surface, backrest height and width optimization (DP8)
		Seating Experience CA9	Seat curvature, softness/hardness, pressure distribution, material tactile quality, edge chamfering (DP9)
	Attractive Demand (A)	Landscape Adaptation CA10	Orientation coordinated with greenery, pathways, shade, and water bodies (DP10)
		Enhanced Multifunctionality CA11	Sunshade, storage, interactive prompts, lightweight multifunctional features (DP11)
		Auxiliary Module Expansion CA12	Standardized components, detachable connections, partial replacement, expandable interfaces, reduced maintenance and upgrade cost (DP12)
		Appearance and Form CA13	Soft contours, organic forms, low-pressure visual language, natural material textures, harmonious color schemes (DP13)

The technical importance of each design element was calculated by multiplying the weight of each user demand by the corresponding relationship strength and summing the results. The calculation formula is as follows:

$$D_j = \sum_{i=1}^n W_i \times R_{ij} \quad (11)$$

where D_j denotes the technical importance of the j -th design element, W_i represents the comprehensive weight of the i -th user demand, R_{ij} denotes the correlation coefficient between the i -th user demand and the j -th design element, and n is the total number of user demands.

Based on the resulting technical importance values, the design elements were further prioritized, providing a basis for subsequent structural optimization, functional configuration, material selection, and form design of restorative seating in urban parks.

User Need	Composite Weight	DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8	DP9	DP10	DP11	DP12	DP13
CA9	0.1614	△			○	●	○	○	○	●	△	△		○
CA5	0.1404	△			●	●	○	○	○	○				△
CA13	0.1321									△	○	△		●
CA8	0.1157	△				○		○	●	△				○
CA7	0.0896					○		●	○	△				△
CA6	0.0783	○			○	○	●			△				
CA1	0.0708	●	△	○		△	△					△	△	
CA12	0.0589		△	○	○						△	●	●	
CA11	0.0423			○	△						△	●	○	
CA2	0.0354	△	●	○						△			●	
CA4	0.0298	△			●	●	○	○	○	○		△		△
CA10	0.0273		△	△							●	△		○
CA3	0.0181	○	○	●							△	○	△	
SUM		1.1259	0.3883	0.74	1.7891	2.5796	1.4571	1.7899	1.8421	1.7687	0.6521	0.9817	0.6873	1.8335

Fig. 6. Quality house

QFD results analysis

Based on the user demand weights and the user demand–design element relationship matrix, this study calculated the technical importance of 13 design elements. These elements were then classified into first-, second-, and third-level design priorities, as shown in Table 9. The results indicate that the design focus of restorative seating in urban parks is not the simple aggregation of multiple functions. Instead, it reflects a systematic response centered on bodily comfort, postural support, public safety, and contextual adaptability. First-level design elements primarily determine the core user experience of the seating system. Second-level design elements mainly enhance tactile comfort, usability, and safety performance. Third-level design elements primarily support environmental adaptability, maintenance and renewal, and long-term service performance. Therefore, subsequent design development should prioritize the implementation of first- and second-level design elements, while treating third-level elements as supporting constraints integrated into the overall optimization framework.

Specifically, the top five first-level design elements in terms of technical importance are ergonomic dimensional optimization DP5 (2.5796), backrest optimization DP8 (1.8421), appearance and form DP13 (1.8335), lumbar curve support DP7 (1.7899), and multi-user adaptation DP4 (1.7891). These results indicate that seat height, seat depth, backrest angle, lumbar support, visual affinity, and adaptability to diverse user groups constitute the core control factors in restorative seating design. Seating experience DP9 (1.7687), armrest structural support DP6 (1.4571), facility safety DP1 (1.1259), and enhanced multifunctionality DP11 (0.9817) constitute the second-level design elements.

Table 9. Design Elements Sorting Table

Level	Criterion Layer	Design Element	Technical Importance	Rank
First-level	O	Control of seat height, seat depth, seat width, backrest height, backrest angle, armrest height, and leg movement space (DP5)	2.5796	1
	O	Optimization of backrest support through backrest recline angle, back support surface, backrest height, and width (DP8)	1.8421	2
	A	Soft contours, organic forms, low-pressure visual language, natural material texture, and harmonious color schemes (DP13)	1.8335	3
	O	Enhancement of lumbar support through lumbar curve design, lumbar support height, lumbar–back fit, and curved transitions (DP7)	1.7899	4
	O	Adaptation to diverse users including children, young adults, parent-child groups, middle-aged and elderly users, and individuals with limited mobility (DP4)	1.7891	5
Second-level	O	Improvement of contact comfort through seat curvature, softness/hardness, pressure distribution, material tactility, and edge chamfering (DP9)	1.7687	6
	O	Optimization of armrest height, width, grip cross-section, rounded ends, and structural support strength (DP6)	1.4571	7
	M	Load-bearing structure, anti-tip stability, anti-slip design, anti-pinch protection, rounded-edge impact safety, and connector safety (DP1)	1.1259	8
	A	Provision of lightweight multifunctional features such as sunshade, storage, and interactive prompts (DP11)	0.9817	9
Third-level	O	Improvement of seasonal and temporal adaptability through weather-resistant materials, nighttime visibility/lighting, sun and rain protection, and anti-waterlogging structures (DP3)	0.7400	10
	A	Reduction of maintenance and upgrade costs through standardized components, detachable connections, partial replacement, and expandable interfaces (DP12)	0.6873	11
	A	Environmental coordination with greenery, pathways, shade, and water bodies (DP10)	0.6521	12
	M	Drainage structure, easy-to-clean surfaces, replaceable components, anti-corrosion and moisture resistance, and low-maintenance structural design (DP2)	0.3883	13

These primarily address contact comfort, sit-to-stand assistance, structural safety, and lightweight functional extension. All-day use DP3, auxiliary functional module expansion DP12, landscape adaptation DP10, and cleaning and maintenance DP2, although lower in technical importance, remain essential factors influencing long-term usability and spatial adaptability in public environments. Overall, the QFD results establish a hierarchical design priority pathway for restorative seating in urban parks: “anthropometric control → body support optimization → natural and affinity-oriented form design → multi-user adaptability → safety and maintenance assurance.”

RESULTS AND DISCUSSION

Design Alternatives for Restorative Seating in Urban Parks

Based on the results of user demand weight ranking and the QFD House of Quality analysis, the core user demands for restorative seating in urban parks were derived in this study. Design optimization was primarily focused on high-weight factors, which included seating experience, ergonomic dimensional optimization, appearance and form, backrest optimization, lumbar curve support, armrest structural support, and facility safety. These requirements were subsequently translated into actionable and implementable product design elements. During the design process, priority was given to first-level design elements that are directly associated with bodily comfort, postural support, safe use, and emotional relaxation. Secondary design elements, such as multifunctional features and modular expansion, were selectively incorporated to enhance usability. However, excessive functional integration was avoided to prevent dilution of the fundamental resting function of the seating system.

Wood was selected as the primary material owing to its natural texture, warm tactile quality, and relatively low visual impact (Grabiec *et al.* 2022; Hitka *et al.* 2022; Lin *et al.* 2023; Jasińska *et al.* 2024). It can be effectively integrated into vegetation, pathways, and surrounding landscape elements within urban parks, thereby contributing to the creation of a natural, welcoming, and psychologically soothing resting environment. Compared with metal or stone materials, wood provides a softer tactile experience and is less likely to generate extreme thermal sensations (*e.g.*, excessive cold or heat) under varying climatic conditions, thereby enhancing user comfort during contact and seating. In addition, wood exhibits favorable machinability, which enables ergonomic seat, backrest, and lumbar support forms to be achieved through processes such as bending, joining, chamfering, and surface shaping. When high-quality wood treated for anti-degradative, moisture resistance, and weather resistance is used, both outdoor durability and structural safety can be ensured, and maintenance efficiency is also improved. Therefore, wood not only satisfies the functional requirements of restorative seating in urban parks but also enhances its natural character, emotional affinity, and landscape integration performance.

A restorative seating design scheme for urban parks was developed, targeting multiple user groups and aiming to enhance seating comfort, physical relaxation, perceived safety, and usage frequency in park environments. To efficiently and systematically translate user demands into implementable therapeutic design alternatives, a data-driven hybrid design workflow was developed and implemented. In this workflow, the reasoning capabilities of large AI language models (ChatGPT and Gemini) were integrated with image generation and editing technologies based on OpenAI GPT Image 2 and Google Gemini Nano Banana. These tools were embedded into the Quality Function Deployment

(QFD) analysis process (Choudhury *et al.* 2025). The proposed workflow was designed to address systemic limitations in traditional public furniture design, particularly semantic loss in requirement translation and geometric distortion in design visualization. It was further used to support concept expansion, prompt optimization, and iterative refinement of visual design schemes. The resulting set of restorative seating concepts for urban parks is presented in Fig. 7.



Fig. 7. Design alternatives for restorative seating in urban parks

Rather than pursuing the accumulation of complex functions, the design alternatives were developed to prioritize bodily comfort, postural support, safety, environmental coordination, and long-term maintenance. The proposed dimensional, tactile, structural, and formal strategies are expected to support perceived comfort and usability, while their actual effects on restorative experience and real-world performance require validation through physical prototyping and field-based evaluation.

Through continuous iterative refinement, multiple candidate prototypes of restorative seating for urban parks were developed, and an initial dataset of design alternatives was established (Fig. 7). The design content of the restorative seating for urban parks is presented in Table 10.

On this basis, three design alternatives with high overall alignment were selected based on evaluation criteria, including functional coverage, alignment with restorative-oriented requirements, and solution completeness. These three schemes were further developed along three distinct optimization pathways: ergonomic support, interactive multi-user adaptability, and support for perceived restoration. Collectively, they represent the phased core outcomes of this study on restorative seating design in urban parks.

Table 10. Design Content of Restorative Seating in Urban Parks

No.	Design Element	Main Design Content (English Translation)
1	Seating experience as the core focus for optimizing seat-surface contact comfort	Based on the results of user demand prioritization, seat-surface curvature, hardness, pressure distribution, material tactility, and edge chamfering were primarily optimized. A micro-arc seat surface design was adopted to ensure more uniform support across the buttocks and thigh contact areas. Localized pressure concentration and discomfort in leg contact areas were reduced, thereby enhancing user willingness to remain seated and overall resting comfort.
2	Ergonomic dimensional optimization as the foundation for multi-user adaptability	Seat height, seat depth, seat width, backrest height, backrest inclination, armrest height, and legroom were systematically controlled. The design was adapted to diverse user groups, including children, young adults, parent-child groups, elderly users, post-exercise users, and individuals with varying mobility levels, thereby improving universality in urban park settings.
3	Backrest optimization and lumbar curve support for enhanced restorative seating experience	A moderate backrest recline angle was adopted, while the backrest support surface, height, and width were optimized. In addition, a continuous and gently curved lumbar support structure was integrated to improve lumbar-back fit. Fatigue in the lower back caused by walking, standing, or physical activity was alleviated, thereby enhancing bodily relaxation and perceived restoration.
4	Armrest structural design to improve sit-to-stand assistance and perceived safety	Armrest height, width, grip cross-section, terminal rounding, and structural strength were optimized. Sit-to-stand assistance was provided for elderly users, children, and individuals with reduced mobility. At the same time, body boundary perception and postural stability were enhanced for general users. A rounded and continuous form was adopted to reduce collision risks.
5	Facility safety as the baseline for structural reliability in public seating	Structural stability, anti-tip performance, anti-slip properties, anti-pinch protection, rounded-edge impact resistance, and connector safety were ensured. Potential hazards caused by structural loosening, sharp edges, exposed joints, or slippery surfaces after rainfall were avoided. The base and supporting components were designed to meet multi-user loading, dynamic sitting/standing actions, and long-term outdoor composite load conditions.
6	Cleaning, maintenance, and weather resistance for long-term performance	Anti-degradation, moisture resistance, effective drainage, easy-to-clean surfaces, and replaceable components were emphasized in both material selection and structural design. Water accumulation on seat and backrest surfaces was avoided, and connection details were simplified to reduce dust and debris accumulation. For wood or wood-like materials, enhanced weather resistance, UV protection, and wear resistance were required.
7	Nature-oriented aesthetic design for enhanced restorative perception	Soft contours, organic forms, low-visual-pressure language, natural material textures, and coordinated color schemes were adopted to integrate the seating system with the urban park environment. Overly decorative and exaggerated forms were avoided. Instead, simplicity, stability, affinity, and naturalness were emphasized to enhance spatial recognizability and emotional soothing effects.
8	Lightweight multifunctional features as auxiliary enhancements without functional overload	Without interfering with basic resting functions, lightweight features such as shading, storage, and interactive prompts were moderately incorporated. Standardized components, detachable connections, partial replacement strategies, and expandable interfaces were adopted to reduce maintenance and upgrade costs, achieving a balance between functional stability and usability.

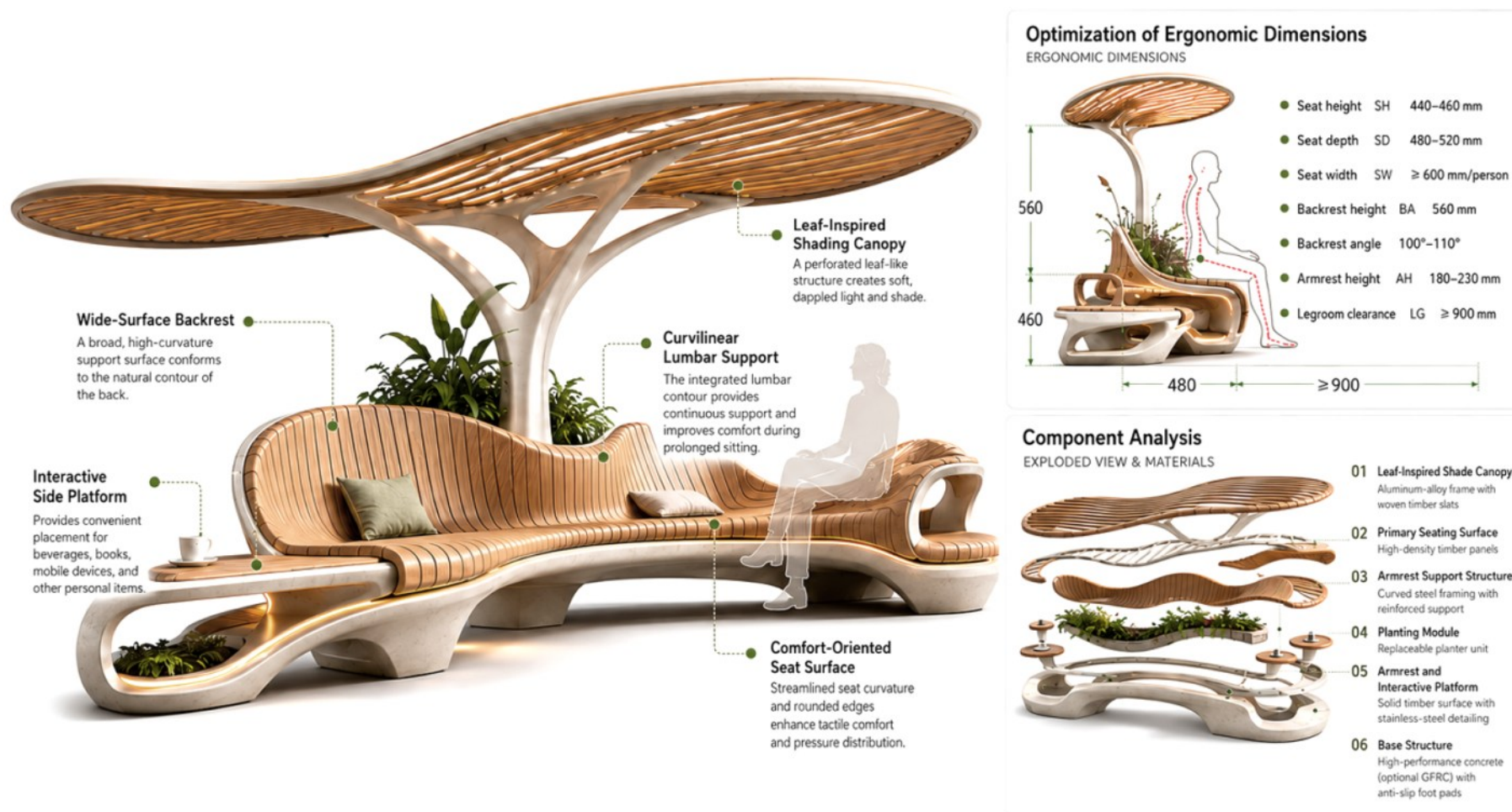


Fig. 8. Dataset of restorative seating for urban parks – Scheme 1

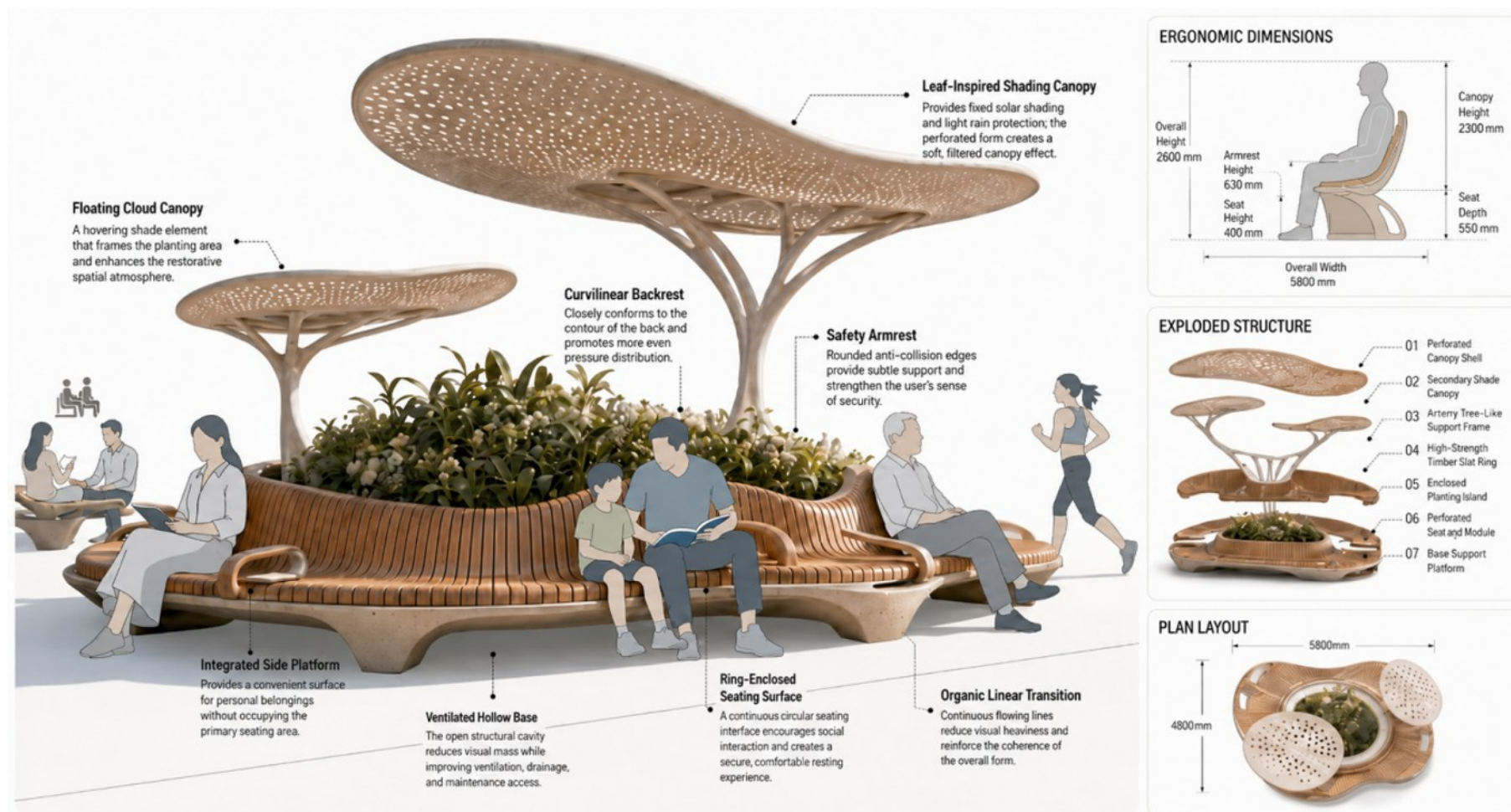


Fig. 9. Dataset of restorative seating for urban parks – Scheme 2

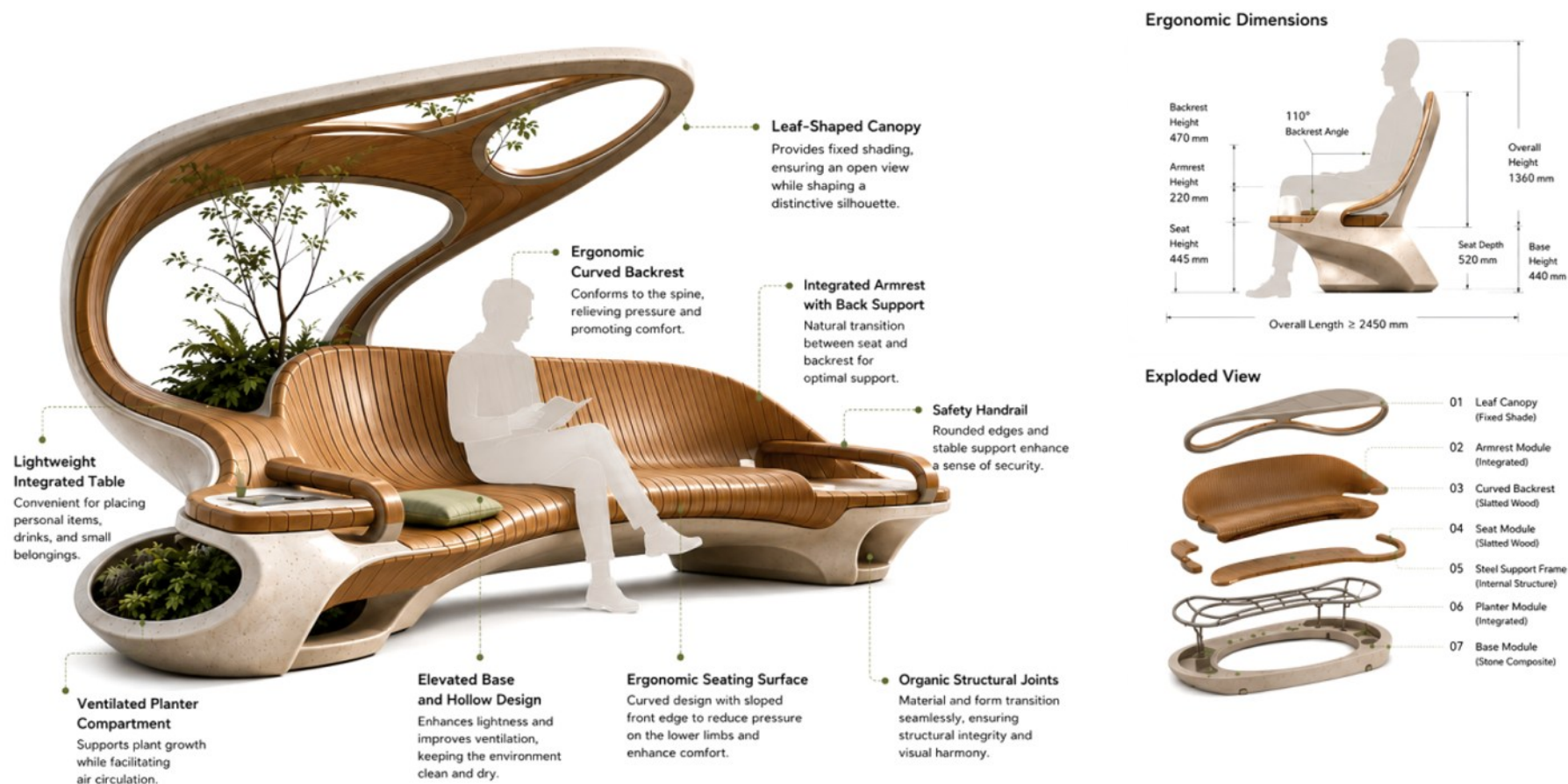


Fig. 10. Dataset of restorative seating for urban parks – Scheme 3

Scheme 1 (Fig. 8) was developed based on the core concept of “natural enclosure and shared therapeutic experience,” aiming to construct a restorative seating system for urban parks that supports prolonged stay, social interaction, and emotional relaxation through biomimetic shading structures, curved seating forms, and multifunctional resting units. As illustrated, a continuous enveloping layout was adopted for the overall spatial configuration. A streamlined canopy was designed to mimic tree canopy morphology, while curved wooden seating elements were arranged at the lower level to structure the resting space, thereby forming a semi-open sheltered environment. The design was primarily optimized with respect to ergonomic dimensions, backrest support, lumbar curvature, and seating comfort. Differentiated seating scales were provided to accommodate diverse user groups, including children, young adults, parent–child groups, middle-aged and elderly users, and post-exercise users. In terms of materials, wood was adopted as the primary material and was combined with metal structural supports, vegetation modules, lighting elements, and storage platforms. This material system ensured structural stability and seating comfort while enhancing integration between the seating system and the surrounding park environment. Overall, this scheme is suitable for installation in shaded woodland areas, waterfront zones, and key recreational nodes within parks, and it demonstrates strong performance in comfort, social interaction, and landscape recognition and spatial integration.

Scheme 2 (Fig. 9) was developed based on the core concept of “forest-island resting and shared social interaction,” aiming to transform urban park seating from a single-function resting facility into a multifunctional public furniture system that integrates shading, communication, viewing, and therapeutic functions. As illustrated, an island-type spatial layout combined with an umbrella-shaped biomimetic canopy was adopted for the overall design configuration. Seating elements were arranged around a central green planting core, thereby forming a semi-enclosed public resting node with a strong sense of enclosure and enhanced proximity to the natural environment. The design primarily emphasized ergonomic dimensional control, back support, lumbar support, and seating comfort performance. Continuous wooden seating surfaces, curved backrests, rounded edges, and multi-scale seating configurations were incorporated to accommodate diverse user scenarios, including parent–child interaction, young adults, elderly users, and group-based social activities. The canopy was designed as a lightweight perforated structure, which not only provided effective shading but also generated soft and dynamic light–shadow effects, thereby enhancing the therapeutic atmosphere of the space. Overall, this scheme integrates resting, companionship, social interaction, and environmental integration at the functional level, while exhibiting strong spatial recognizability in public environments. It is suitable for deployment in park plazas, forested resting areas, community activity nodes, and waterfront public recreational spaces.

Scheme 3 (Fig. 10) was developed based on the design theme of “ecological shelter and psychosomatic restoration,” with emphasis being placed on the integrated relationship among seating systems, shading structures, vegetation, and bodily support systems. As illustrated, a cloud-nest-shaped canopy combined with a semi-enclosed seating configuration was adopted to provide users with shaded, resting, and relaxation environments. The main seating structure was constructed using continuous curved wooden surfaces, with particular attention being given to seat height, seat depth, backrest angle, lumbar support, and legroom. These ergonomic parameters were optimized to ensure adequate postural support for users of different ages and physical conditions.

Armrests, storage platforms, vegetation planting zones, and localized lighting elements were incorporated to enhance user convenience and improve emotional comfort during use. In terms of materials, wood was used to provide a warm tactile experience, while metal structural components were used to ensure load-bearing stability. Vegetation and natural color elements were integrated to strengthen the therapeutic environmental atmosphere. Overall, this scheme effectively addresses high-priority QFD factors, including ergonomics, backrest optimization, lumbar support, multi-user adaptability, and seating experience. It is therefore suitable for installation in parent–child activity areas, slow-walking trail nodes, and open recreational spaces in urban parks.

In summary, the three restorative seating schemes for urban parks are identified as representing three distinct design approaches: natural enclosure, forest-island shared interaction, and ecological shelter. Together, they demonstrate the feasibility of systematically addressing diverse and heterogeneous user demands. All three schemes were developed based on the results obtained from QFD analysis. Iterative design optimization was conducted with a focus on high-priority factors, including ergonomic dimensional control, backrest optimization, lumbar support, multi-user adaptability, and seating experience. Comprehensive improvements were achieved in structural stability, environmental integration, functional completeness, and public usability. Through semantic filtering, functional comparison, and scheme evaluation, final design outcomes were obtained that integrate comfort in resting, emotional relaxation, parent–child interaction, and social interaction value. Overall, the design process demonstrates the supportive role of generative design tools in the development of restorative seating for urban parks. It also provides a transferable design pathway and methodological framework for advancing user-centered innovation in public furniture design.

Design Evaluation

To enhance the diversity and transparency of the design evaluation, 17 evaluators were recruited from participants who had previously taken part in the interviews or questionnaire survey. The evaluation panel consisted of 2 university faculty members specializing in product design, 3 public-facility designers, and 12 urban park users with practical experience of park seating. The professional evaluators were selected based on relevant teaching, research, or design-practice experience in product design, furniture design, or public-facility design. The user evaluators were selected on the basis of prior urban park use and actual experience with park seating, enabling the evaluation to incorporate both professional design judgments and user-based perceptions. Each evaluator independently rated all three design alternatives using the same evaluation criteria and scoring instructions, without discussion or consultation with the other evaluators. The three schemes were presented to all evaluators in the same fixed order (Scheme 1, Scheme 2, and Scheme 3). The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method (Hwang and Yoon 1981) was employed to perform a comprehensive comparative evaluation of the 13 indicators across the three alternative schemes.

Construction of the initial evaluation matrix

The evaluation indicators consisted of 13 user demands derived from both the Kano model and the Analytic Hierarchy Process (AHP). Each design scheme was evaluated and scored based on the established evaluation framework for restorative seating in urban parks. A 7-point Likert scale was adopted for all evaluations (Likert 1932; Preston and Colman 2000).

Table 11. Initial Evaluation Matrix

Design Alternative	Evaluation Metrics												
	M1	M2	O1	O2	O3	O4	O5	O6	O7	A1	A2	A3	A4
Scheme 1	5.59	5.53	5.59	5.35	5.76	5.29	5	5.41	5.88	5.24	5.65	5.53	5.88
Scheme 2	5.76	5.24	5.94	6.12	6.18	5.71	5.76	5.59	5.59	6	5.65	5.53	5.76
Scheme 3	5.94	6.06	5.76	5.88	5.82	6.06	6.06	6.29	6.24	6.24	5.94	6.12	6.12

Table 12. Normalized Evaluation Matrix

Design Alternative	Evaluation Metrics												
	M1	M2	O1	O2	O3	O4	O5	O6	O7	A1	A2	A3	A4
Scheme 1	0.5598	0.5681	0.5598	0.5333	0.5615	0.5363	0.5133	0.5408	0.5745	0.5178	0.5675	0.5569	0.5733
Scheme 2	0.5768	0.5383	0.5949	0.61	0.6024	0.5788	0.5913	0.5588	0.5462	0.5929	0.5675	0.5569	0.5616
Scheme 3	0.5949	0.6225	0.5768	0.5861	0.5673	0.6143	0.6221	0.6287	0.6097	0.6167	0.5966	0.6163	0.5967

Table 13. Weighted Normalized Evaluation Matrix

Design Alternative	Evaluation Metrics												
	M1	M2	O1	O2	O3	O4	O5	O6	O7	A1	A2	A3	A4
Scheme 1	0.0396	0.0201	0.0101	0.0159	0.0788	0.0420	0.0460	0.0626	0.0927	0.0141	0.0240	0.0328	0.0757
Scheme 2	0.0408	0.0191	0.0108	0.0182	0.0846	0.0453	0.0530	0.0647	0.0881	0.0162	0.0240	0.0328	0.0742
Scheme 3	0.0421	0.0220	0.0104	0.0175	0.0797	0.0481	0.0557	0.0727	0.0984	0.0168	0.0252	0.0363	0.0788

Table 14. Euclidean Distance and Relative Closeness

Design Alternative	Distance to Positive Ideal Solution S_i^+	Distance to Negative Ideal Solution S_i^-	Relative Closeness C_i	Ranking
Scheme 1	0.018638	0.004941	0.209554	3
Scheme 2	0.015236	0.010423	0.406215	2
Scheme 3	0.004989	0.020047	0.800731	1

Subsequently, for each scheme and evaluation indicator, the scores of the 17 evaluators were summarized using the arithmetic mean and standard deviation (SD). The mean scores were used to construct the initial TOPSIS evaluation matrix, whereas the corresponding SDs were reported as descriptive measures of inter-evaluator variation and were not used directly in the TOPSIS calculation. An initial evaluation matrix was then constructed accordingly, as presented in Table 11.

The initial evaluation matrix is expressed as follows:

$$X = (x_{ij})_{3 \times 13} \quad (12)$$

Construction of the normalized matrix

Since all evaluation indicators were positive (benefit-type) criteria, no negative transformation was required. The initial evaluation results of the three design schemes in Table 11 were normalized using Eq. 13. After dimensional normalization, a sum-of-squares normalization (SSN) procedure was applied to obtain the standardized evaluation matrix (Table 12). The normalized value was calculated as:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^m x_{ij}^2}} \quad (13)$$

Weighted normalized evaluation matrix

Based on Table 12, the weighted normalization process was performed using Eq. 14. The weighting coefficients were obtained from the relative weights presented in Table 6. The weighted normalized data were then calculated and are shown in Table 13. The weighted normalized value was computed as:

$$v_{ij} = w_j r_{ij} \quad (14)$$

Calculation of positive ideal solution, negative ideal solution, and comprehensive evaluation index

Based on the weighted standardized evaluation matrix, the positive ideal solution and negative ideal solution were constructed by selecting the maximum and minimum values of each evaluation indicator, respectively, across all schemes. Using Equations (15) and (16), the distances between each of the three schemes and the positive and negative ideal solutions were calculated using the Euclidean distance metric. Subsequently, Eq. 17 was used to compute the relative closeness of each scheme, and the results are summarized in Table 14. The Euclidean distance to the positive ideal solution was calculated as:

$$S_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2} \quad (15)$$

The Euclidean distance to the negative ideal solution was calculated as:

$$S_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2} \quad (16)$$

The relative closeness coefficient was calculated as follows:

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad (17)$$

Based on the ranking of relative closeness values, the comprehensive ordering was obtained as follows: Scheme 3 > Scheme 2 > Scheme 1. Scheme 3 was the closest to the positive ideal solution and the farthest from the negative ideal solution. Under the current

weighting and evaluation configuration, Scheme 3 therefore showed the strongest overall performance among the three evaluated alternatives and was identified as the preferred alternative for subsequent physical prototyping and field-based validation. Scheme 3 received comparatively favorable evaluations across the selected criteria; however, these results should not be interpreted as evidence of actual user satisfaction, restorative effects, or real-world performance.

Extension from General Public Seating to a Body–Psychological–Environmental Restorative Demand Structure

Compared with prior research that has primarily focused on seating dimensions, safety, and landscape coordination, this study extended the analytical scope by integrating physical relaxation, psychological safety, nature connectedness, and social interaction needs into a unified framework. It is demonstrated that restorative seating in urban parks functions as a micro-scale public facility shaped by the coupled interactions among bodily experience, psychological perception, and environmental context.

This finding is consistent with recent studies on restorative environments. Existing literature has shown that the restorative capacity of open spaces is not determined solely by natural elements, but is jointly shaped by spatial organization, multisensory experience, social connectivity, and facility quality (Dong *et al.* 2024; Grave *et al.* 2024; Xu *et al.* 2025). However, most prior studies have treated urban parks as holistic spatial units. In contrast, the present study further downscales the analytical focus to individual public seating and incorporates bodily support, psychological safety, nature connectedness, and social needs into a unified demand structure, thereby extending restorative environment theory toward its application in micro-scale public furniture design.

The interview results further indicated that the primary users of urban park seating are not limited to a single age group, but instead include diverse populations such as young adults, parent–child families, middle-aged and elderly users, and post-exercise individuals. Although differences exist among these groups in terms of duration of use, activity patterns, and purposes of stay, their needs for comfort support, perceived safety, environmental quietness, visual access to landscape, and connection to nature exhibit strong convergence. This finding addresses limitations in existing urban public space research, particularly the insufficient recognition of user heterogeneity and the inadequate explanation of perceptual differences (Zhu *et al.* 2025). It further suggests that restorative seating should enhance multi-user adaptability through dimensional inclusiveness, postural support, and flexible usage modes, rather than being restricted to age-specific designs.

Physical Comfort as the Foundation of Restorative Experience and the Role of Form Perception in Enhancing Approach Intentions

The results show that seating experience, ergonomic dimensional optimization, and appearance and form rank among the top three user-demand priorities, followed by backrest, lumbar, and armrest support at relatively high priority levels. These rankings are based on an integrated Kano–AHP–QFD weighting framework rather than a single-method assessment. This finding is broadly consistent with existing furniture ergonomics research, which emphasizes the integrated evaluation of anthropometric dimensions, postural load, and subjective comfort (Bai *et al.* 2024). However, prior studies have predominantly focused on seating dimensional rationality, structural support efficiency, or perceived comfort in isolation. In contrast, bodily support is further situated in the present study within the context of restorative experiences in urban parks. It is demonstrated that, for

restorative seating in urban parks, physical comfort is not merely a secondary attribute of emotional experience but a prerequisite condition that determines users' willingness to approach, sit, remain, and achieve relaxation. This emphasis on bodily support may be related to the functional characteristics of park seating, where users often transition from walking or physical activity to stationary rest, making immediate postural comfort particularly important for subsequent restorative perception. The seat surface, backrest, lumbar support, and armrests collectively constitute a continuous support system that reduces physical burden during use and facilitates subsequent restorative activities, including landscape viewing, social interaction, solitude, and emotional recovery. Accordingly, ergonomic comfort in public seating is extended in this study as a foundational design determinant in the formation of restorative perception.

At the same time, the third-ranking position of appearance and form suggests that urban park seating is initially perceived by users as a visual object. Its contours, proportions, material characteristics, color, and degree of environmental coherence significantly influence users' willingness to approach and remain. This finding aligns with prior research on aesthetic evaluation and spatial satisfaction in public seating (Mohamed 2024; Zhang and Sun 2024). The contribution of this study lies in repositioning appearance and form not merely as decorative attributes, but as a perceptual interface linking product morphology, natural material expression, and the environmental atmosphere of park settings. Soft contours, wooden textures, and low-contrast visual language can enhance perceived affinity and environmental integration. However, the boundary conditions of this effect should be clarified: visual appeal cannot replace ergonomic performance, structural safety, or maintenance feasibility. The results reflect user preferences and tendencies toward restorative perception but do not directly evidence psychological therapeutic outcomes. Therefore, the design of restorative seating in urban parks should prioritize physical comfort while strengthening formal affinity and environmental coordination, rather than attributing "therapeutic qualities" solely to aesthetic form or natural imagery.

Theoretical Contribution of the Staged User-Demand Translation Framework

The theoretical contribution of the proposed framework lies not simply in combining multiple methods, but in conceptualizing user-centered furniture design as a staged process of demand transformation. In this process, user demands are progressively transformed from subjective expressions into structured demand attributes, relative priorities, actionable design specifications, and finally comparable design alternatives. GT establishes the initial demand constructs from users' situated experiences; the Kano model introduces the asymmetric relationship between demand fulfillment and user satisfaction; AHP converts the classified demands into a relative priority structure; QFD translates this structure from the language of users into the language of design; and TOPSIS closes the decision loop by evaluating how alternative schemes collectively respond to the prioritized requirements. Thus, the five methods are linked by successive information transformations rather than being applied as independent analytical tools.

Within user-centered furniture design, this staged translation logic helps make explicit a decision process that is often implicit in designer judgment. Previous integrated approaches, such as the GT–Kano–AHP–QFD framework applied to parent–child seating, have demonstrated the value of combining demand identification, classification, weighting, and functional translation. The present study extends this logic by incorporating alternative evaluation as an explicit final stage, thereby connecting user-demand construction with

design-element translation and scheme selection within a single traceable framework. The theoretical significance of this extension is therefore not the creation of a new universal design theory, but the articulation of a reusable process model explaining how heterogeneous user demands can be progressively transformed into design decisions in public furniture development.

This process model is particularly relevant to restorative-oriented seating because the underlying user demands span bodily, perceptual, social, and environmental dimensions. By maintaining traceability across these dimensions, the framework provides a structured means of linking micro-scale furniture decisions with broader restorative-environment considerations. Its contribution should nevertheless be understood as conditional and context dependent; the specific demand priorities and preferred alternatives may vary across user groups, settings, and weighting configurations. The order of the methods is therefore path-dependent rather than interchangeable. Reversing the sequence would weaken the information logic of the framework: weighting before demand elicitation and classification would require predefined criteria, whereas scheme evaluation before design translation would disconnect alternative ranking from the upstream user-demand structure and design-translation logic.

The TOPSIS results indicate that Scheme 3 achieved a relative closeness value of 0.800731, higher than those of Scheme 2 and Scheme 1. This superiority is not attributed to excellence in a single performance dimension but rather to a balanced fulfillment of multiple high-weight criteria, including ergonomic support, seating experience, appearance and form, structural safety, and environmental integration. Accordingly, Scheme 3 is identified as the preferred solution for subsequent physical prototyping and scenario-based validation.

Although the framework was examined in the present study through the case of restorative-oriented wooden seating in urban parks, its methodological logic may be transferable to other user-centered furniture and public-facility design contexts. The transferability lies in the staged process itself rather than in the specific demand items or weights obtained in this case. For design problems in which heterogeneous user demands need to be elicited, classified, prioritized, translated into actionable design characteristics, and ultimately compared across alternative solutions, the GT–Kano–AHP–QFD–TOPSIS sequence may provide a reusable analytical structure. Potential applications may include other types of wooden furniture and public facilities that involve multiple user groups, competing design requirements, and multi-criteria alternative selection. However, application to a new product or context would require renewed user-demand elicitation, Kano classification, weighting, design-element mapping, and alternative evaluation rather than direct reuse of the demand structure or numerical results reported in this study.

Research Limitations and Future Directions

The sample was primarily obtained through purposive sampling, on-site interception, and online recruitment. As a result, its representativeness across regions and population groups remains limited. The evaluation of design schemes relied mainly on self-reported data, expert judgment, and visual renderings, and was not validated using physical prototypes or real-world usage environments. In addition, AHP-derived weights, QFD-based relationship strengths, and TOPSIS scoring inevitably involve a certain degree of subjectivity. These limitations are consistent with methodological issues identified in recent research on restorative environments. A systematic review by Xu et al. (2025) reported that most existing studies rely on cross-sectional designs and self-reported

measures, while objective measurements and experimental validation remain insufficient. Similarly, Grave *et al.* (2024) emphasized that the applicability of restorative design features across real-world settings and diverse user groups still requires further empirical verification (Xu *et al.* 2025; Grave *et al.* 2024). A further limitation concerns the generalizability of the proposed framework. The framework has currently been examined through a single design case involving restorative-oriented wooden seating in urban parks. Therefore, although its staged methodological logic may be transferable, its applicability to other types of wooden furniture or public facilities has not yet been empirically validated. In particular, the specific demand structure, Kano classifications, AHP weights, QFD design priorities, and TOPSIS rankings identified in this study are context dependent and should not be directly generalized to other products, user groups, or environmental settings.

Future research should expand sampling across different regions, age groups, and park typologies. Cross-case validation should also be conducted by applying the framework to other categories of wooden furniture and public facilities to examine which stages of the framework remain stable across contexts and which demand structures, weighting relationships, and design parameters require context-specific adaptation. Full-scale (1:1) physical prototypes should be developed, and comprehensive validation should be conducted through integration of pressure distribution analysis, postural behavior tracking, dwell-time measurement, and restorative perception scales. In addition, sensitivity analysis should be introduced to assess the robustness of design element rankings and scheme selection outcomes under variations in weighting parameters. Scheme 3 was identified as the preferred alternative under the current weighting and evaluation configuration; however, it should not be interpreted as a universally preferred alternative, as its relative ranking may vary depending on evaluator composition and weighting assumptions.

CONCLUSIONS

1. Urban park seating is reconceptualized in this study, shifting from a conventional resting facility to a micro-scale restorative system that integrates bodily support, emotional regulation, and environmental perception. Furthermore, the scope of the research is expanded beyond a single age group to encompass multiple user populations, including young adults, parent–child families, middle-aged and elderly users, and post-exercise individuals. This expansion broadens the scope of inquiry in therapeutic public furniture design.
2. A hybrid GT–Kano–AHP–QFD–TOPSIS framework was developed to conceptualize user-centered furniture design as a staged demand-transformation process. The framework links user expressions, demand attributes, relative priorities, design specifications, and alternative evaluation within a continuous and traceable decision pathway. Its main contribution therefore lies not only in methodological integration, but also in making explicit how heterogeneous user demands can be progressively transformed into actionable furniture-design decisions. The methodological structure may be adaptable to related user-centered furniture and public-facility design problems, although its transferability beyond the present seating context requires further cross-case validation.

3. The results indicate that seating experience, ergonomic dimensions, and appearance and form constitute the primary user concerns. Ergonomic dimensional optimization, backrest optimization, lumbar support, multi-user adaptability, and nature-oriented aesthetic form are identified as prioritized design elements for restorative seating. Restorative experience should be grounded in physical comfort and further extended through visual affinity and environmental integration.
4. A digital-intelligent workflow was developed by integrating requirement modeling, generative artificial intelligence, and multi-criteria decision-making. User requirement weights derived from AHP and relationships obtained via QFD were converted into structured design constraints, including ergonomic, functional, and environmental parameters. Generative AI tools (ChatGPT, Gemini, GPT Image 2, and Nano Banana) were employed for constraint interpretation and iterative visual generation under AHP–QFD guidance, enabling controlled translation of user demands into design concepts. Generated design alternatives were refined through expert review and evaluated using TOPSIS, establishing a closed-loop process encompassing requirement definition, constraint formulation, AI-assisted generation, expert validation, and multi-criteria evaluation. This workflow reduces information loss and improves decision traceability, thereby supporting restorative public furniture design. Within this framework, AI functions as a generative support tool rather than a decision-making agent, while final outcomes require validation through ergonomic assessment, structural analysis, and real-world testing.

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Conflict of Interest

We declare that we have no known competing financial interests or personal relationships that could have influenced the work reported in this manuscript.

Use of Generative AI

During the preparation of this manuscript, ChatGPT (OpenAI) was used to assist with translation and language editing. Generative AI tools were also used during the early-stage design development. ChatGPT and Gemini (Google) assisted with the interpretation and semantic restructuring of design requirements derived from the AHP and QFD analyses, as well as prompt development and iterative refinement. OpenAI GPT Image 2 and Google Gemini Nano Banana were used to assist with concept generation, image generation and editing, and visual iteration. Figure 7 presents the AI-assisted conceptual design alternatives developed during this stage.

All AI-assisted outputs were reviewed and screened by the authors and were not directly adopted as final designs. The selected concepts were subsequently further developed and refined by the authors through professional design judgment and detailed design development. In the design process, generative AI served solely as an assistive tool

during the early conceptual stage and did not independently determine the final design decisions, research findings, or conclusions. The authors reviewed and approved all final manuscript content and visual materials and take full responsibility for their accuracy, integrity, and presentation.

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