

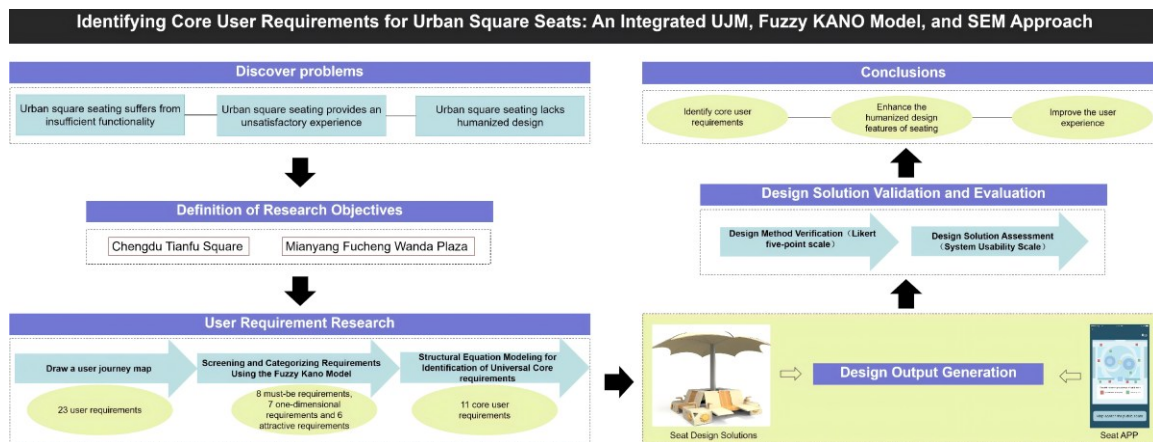
Identifying Core User Requirements for Urban Square Seats: An Integrated UJM, Fuzzy Kano Model, and SEM Approach

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GRAPHICAL ABSTRACT



Identifying Core User Requirements for Urban Square Seats: An Integrated UJM, Fuzzy Kano Model, and SEM Approach

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The current design of seats in urban squares struggles to meet the diverse social, rest, and aesthetic needs of users, highlighting the systematic lack of humanized design in public facilities. This paper took Chengdu Tianfu Square and Mianyang Fucheng Wanda Plaza as the research objects. Through the User Journey Map (UJM), 23 user requirements were sorted out. The Fuzzy Kano Model was used to screen and classify the attributes of the requirement set, obtaining eight must-be requirements, seven one-dimensional requirements, and six attractive requirements. On this basis, the Structural Equation Model (SEM) was introduced to identify 11 core user requirements. The seat design scheme of Chengdu Tianfu Square was output based on 11 core requirements. The scheme was verified by using the Likert five-level scale and the System Usability Scale (SUS) score of 72.38, indicating good usability and higher satisfaction compared to existing benchmarks. This study verified that the UJM-Fuzzy KANO Model-SEM integrated model can effectively help the designers of urban square seats identify the core requirements in the fuzzy and complex user requirements. The approach can quickly clarify the design direction and improve the user satisfaction of urban square seats.

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Keywords: Seat design for urban squares; User requirements identification; User Journey Map (UJM); Fuzzy KANO Model; Structural Equation Model (SEM); System Usability Scale (SUS); User satisfaction

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INTRODUCTION

As vital public spaces for leisure, entertainment, and social interactions, urban squares accommodate a wide range of activities—from quiet personal moments like reading, using electronic devices, or tending to children, to lively social engagements such as chatting with friends, joining public games, and participating in group exercises. Together, these activities shape the social value and use efficiency of urban squares (Elabd and Hallowell 2014; Mahmoud 2024). Seating is a public amenity provided by governments to support community life. Beyond offering a place to rest, it plays a vital role in facilitating and sustaining various activities mentioned above (Sokhibi *et al.* 2020; Paydar and Kamani Fard 2021). Relevant research indicates that over 50% of users believe that seating arrangements within urban squares significantly influence their participation in communal activities (Wu 2012).

To encourage the public to stay in the space for a long time, seating designs must align closely with actual user requirements (Yuan and Xiong 2023). Nonetheless, prevalent urban square seat designs often overly prioritize streamlined aesthetics and cost efficiency, neglecting comprehensive factors such as the characteristics of crowd behavior and activities, square attributes, and the ambient environment. This oversight compromises user experience and leads to inefficient utilization of available space and resources (Mumcu and Yilmaz 2016). Therefore, this study systematically identified users' pain points and requirements using the User Journey Map (UJM) methodology, quantified requirement priorities through the application of the Fuzzy KANO Model, and determined core user needs with the assistance of Structural Equation Modeling (SEM). This progressive analytical framework not only significantly enhances the precision of user requirements identification but also provides an empirical basis for scientific design decision-making.

A thorough review of existing domestic and global research on urban square seats reveals a focus on dimensions such as seat role, functions, and design principles. International scholars Song and Bao (2019) emphasized the pivotal role of urban seats in harmonizing various components within public spaces, while Shaftoe (2009) critiqued current designs for prioritizing aesthetics over functionality and alignment with environmental and activity-oriented requirements, leading to low seat utilization. Moreover, studies by Mohammad and Asal (2021) showed that the quality and quantity of square seats significantly increase the frequency of crowd interaction. Contributions by Guo *et al.* (2023) analyzed user behavior concerning urban furnishings and revealed user needs and influencing factors, deriving insights for furniture optimizations tailored to varied urban settings. Yan *et al.* (2023) examined the fusion of functionality and artistry in public space furniture through the conceptual design of public seats, and Yuan *et al.* (2023) analyzed the public attributes and unique construction characteristics of outdoor seats as urban furniture, providing valuable insights for design and subsequent research of outdoor seat systems. While domestic and foreign scholars have achieved significant advancements in urban furniture research, there are still few studies on the combination of quantitative and qualitative analyses of user requirements specific to urban square seat design. Such limited emphasis has consistently hindered these designs from meeting the needs of people for square activities (Dai 2024).

In recent years, relevant studies on the integrated use of UJM, Fuzzy Kano Model, and SEM have emerged. Notably, Li *et al.* (2023) demonstrated that integrating the Fuzzy Kano Model with Structural Equation Modeling (SEM) effectively identifies core user requirements through a study on the design of home smart fitness chairs. Additionally, Li *et al.* (2022) categorized user requirements utilizing the Fuzzy Kano Model, applied the SEM to identify core user requirements, and completed a white cane design. This study develops a framework for identifying and evaluating user requirements for urban square seats by integrating the UJM, Fuzzy Kano Model, and SEM. This approach addresses the limitations of traditional methods by quantitatively prioritizing user requirements and their impact on satisfaction, allowing for a correlation analysis between user needs and product evaluations. Through revealing the causal pathways of critical user requirements, this study provides a theoretical foundation and practical tools to enhance user experiences for urban square seats. This work holds practical significance for optimizing public infrastructure design and fostering community satisfaction with urban spaces.

EXPERIMENTAL

Research Workflow

This study used Chengdu Tianfu Square and Mianyang Fucheng Wanda Plaza as case studies. First, a UJM is constructed through on-site observations, in-depth interviews, and context simulations. This process identifies explicit and implicit user requirements across various interaction scenarios related to seat usage. User requirements are then categorized and prioritized using the Fuzzy Kano Model and SEM, effectively identifying the core needs of users. Subsequently, the core requirement elements are embedded into the design proposals for seats at Chengdu Tianfu Square, and the Likert scale and the System Usability Scale (SUS) are used to evaluate these proposals. This approach verifies the scientific validity and applicability of the UJM-Fuzzy Kano Model-SEM integration in analyzing user requirements and enhancing design solutions (Li and Jiang 2022). This tripartite approach works synergistically to thoroughly explore the usage requirements of various user types and identify their core requirements, allowing for accurate transformation from user behaviors into design elements, as shown in Fig. 1.

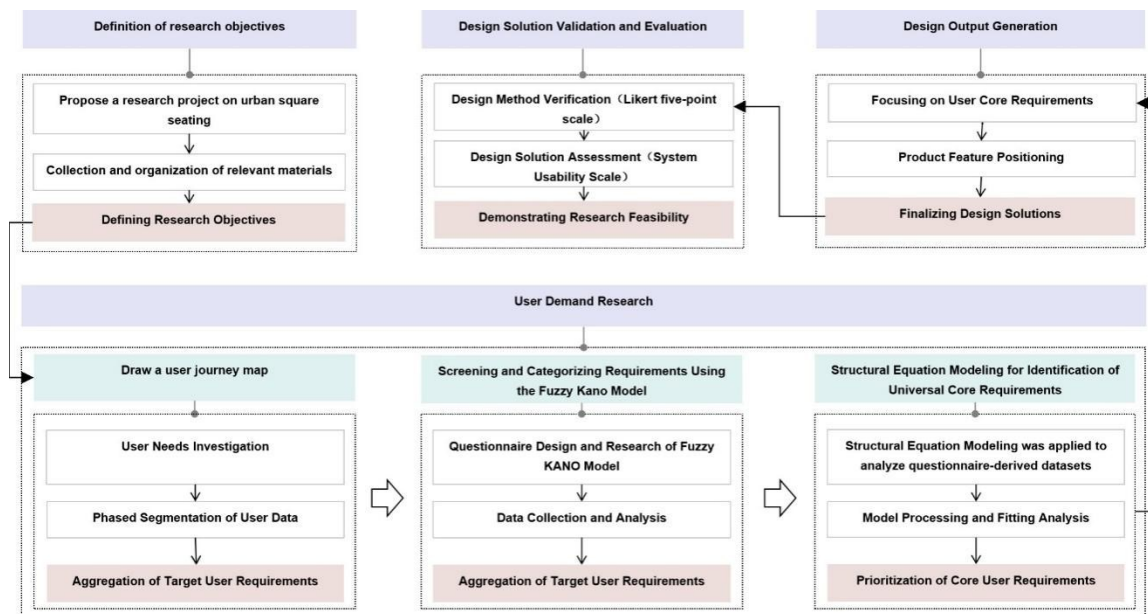


Fig. 1. Research workflow for urban square seat design based on user requirements

UJM Construction and Analysis for Urban Square Seats

User journey maps integrate customer personas, journey paths, touchpoint behaviors, and evaluations through timelines and visual representations (Yoo and Pan 2014). They aim to pinpoint critical pain points and improvement opportunities (Shafei *et al.* 2024), enabling designers to deeply understand users and create intuitive, enjoyable experiences (Ambrusevič and Išoraitė 2025).

User role model construction

This study selected Chengdu Tianfu Square and Mianyang Fucheng Wanda Plaza as case sites. Chengdu has recently emphasized improving the quality of its urban environment. Tianfu Square, as its core landmark, exemplifies optimal public facility configurations. As a commercial complex, Mianyang Fucheng Wanda Plaza has the

characteristics of a high-density area. The two squares differ notably in functional positioning and user groups, reflecting the diversity of research samples for this study. The specifics regarding the two plazas are detailed in Table 1.

Table 1. Overview of Study Cases

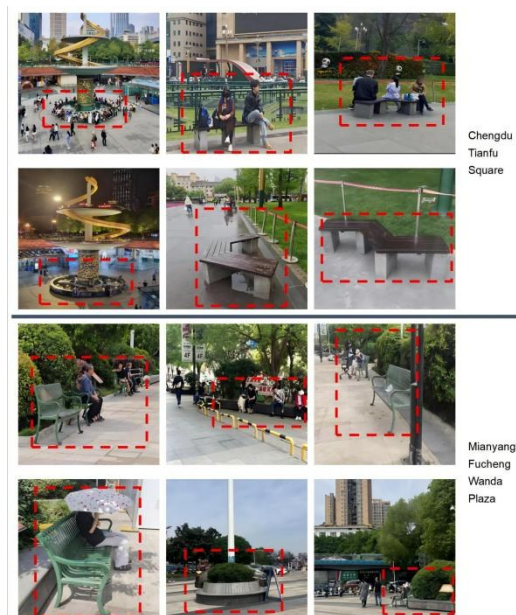
Square Name	Area (m ²)	Location	Main Features	Research Value	Photo
Chengdu Tianfu Square	About 88,000	Renmin South Road, Jinjiang District, Chengdu	A political and cultural hub with historical significance	Seat configuration logic for urban symbolic space	
Mianyang Fucheng Wanda Plaza	About 453,000	Huayuan Road, Fucheng District, Mianyang	A commercial and leisure hub where diverse individuals gather	User needs in contexts of high seat utilization intensity	

Adopting a non-probability approach that combines purposive and quota sampling (Whyte 1980), this study collected data from Chengdu Tianfu Square and Mianyang Fucheng Wanda Plaza from March to May 2023. The study commenced with 124 hours of structured observation, capturing 418 valid behavioral records over 76 hours in Chengdu and 182 records over 48 hours in Mianyang, forming a foundational profile of user behaviors. Subsequently, 335 questionnaires were distributed, yielding 312 valid responses—a response rate of 93%. The sample composition is detailed in Table 2. Together, the two methods thoroughly documented user behaviors and explicit pain points related to seat usage. Finally, semi-structured interviews were conducted with 36 representative users to gain deeper insights into their needs, building on prior questionnaire analysis. At Chengdu Tianfu Square, long-term users made up 69.2%, while at Mianyang Fucheng Wanda Plaza, brief rest users accounted for 63.6%. This approach further revealed users' hidden pain points (Sun *et al.* 2020).

To comprehensively and precisely assess the user requirements for seats, the priority was to identify target user groups and specify their roles. The process primarily occurred in three phases. Phase 1 involved identifying target users. Prior survey data were organized into insight cards, coded using NVivo 12, and categorized into two dimensions of behaviors and attitude, identifying four main user groups: non-users, brief rest users, general users, and long-term users. Phase 2 consisted of identifying core users. Card sorting was used for cluster analysis, identifying three core user groups: long-term users, general users, and brief rest users, as these groups have high requirement and stickiness for seat facilities. Phase 3 involved determining user roles. The three user groups identified in Phase 2 were profiled based on their shared traits and distinct needs, hence classified as user roles. Drawing on the cluster analysis results, the study developed detailed user profiles for the three core user groups. Conversely, the group that did not utilize urban square seats exhibited low demand for seats and therefore was not included in the first batch of core target users (Darma Paramartha *et al.* 2024). The process for identifying user roles for urban square seats is shown in Fig. 3.

Table 2. Research Sample Profile

Variable	Category	Frequency	Percentage (%)	Type
Age Groups	Youth and below (≤ 18 years old)	13	4	Playing, chasing, skateboarding, waiting for someone
	Young adults (19-30 years old)	42	14	Socializing, dating, taking a break, using electronic devices
	Middle-aged and young adults (31-45 years old)	66	21	Accompanying children, watching over belongings, family leisure
	Middle-aged and elderly population (46-60 years old)	102	33	Caring for young children, resting after walks, light exercise, sunbathing, socializing
	Elderly population (≥ 60 years old)	89	28	Prolonged sitting, deep social interaction
Square Visit Frequency	Daily	86	28	Nearby residents and office workers taking their lunch break
	3-5 times/week	112	35	Nearby residents, office workers (during lunch break), students
	1-3 times/week	77	25	Families and couples shopping or relaxing
	<1 time/week	37	12	Tourists or people visiting for specific purposes
User Groups	Long-term users	98	31	Extended breaks (>45 minutes) Sitting quietly, playing chess, deep social interactions, sunbathing
	General users	113	36	Medium-length breaks (15–45 minutes), reading, childcare, casual socializing
	Brief rest users	72	23	After a brief break (<15 minutes), waiting for someone, replying to messages, or taking a phone call, leave immediately
	Unused users	29	9	Not used the seat within the past month, but has used it previously or is considered a potential user

**Fig. 2.** Current seat conditions in the studied squares

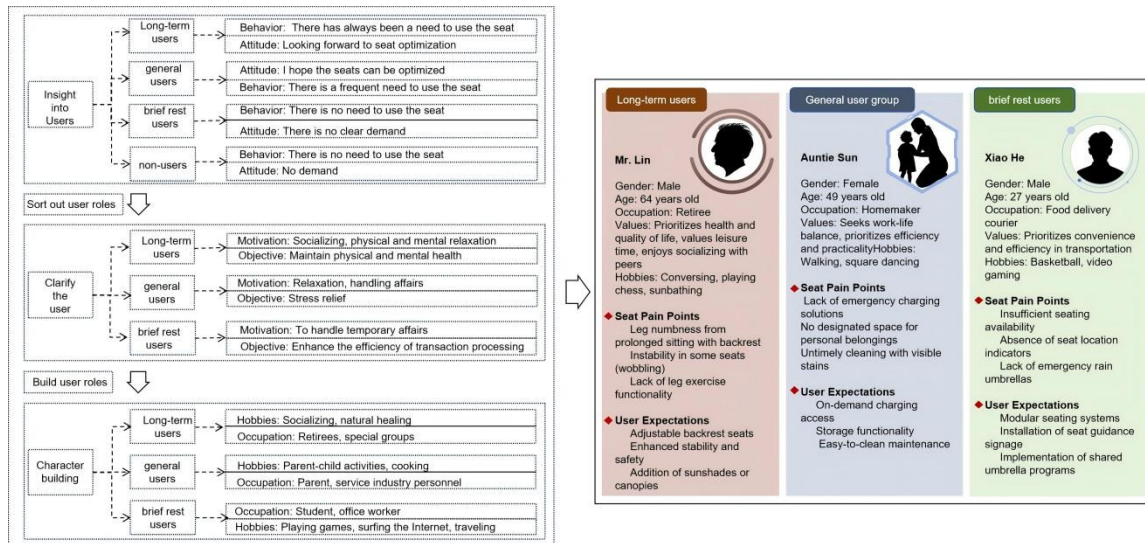


Fig. 3. Flowchart for defining urban square seat user roles

Construction and analysis of target user journey

Prior field surveys at Chengdu Tianfu Square and Mianyang Fucheng Wanda Plaza revealed that target users' square activity goals mainly include social guardianship, leisure interaction, and emergency resting.

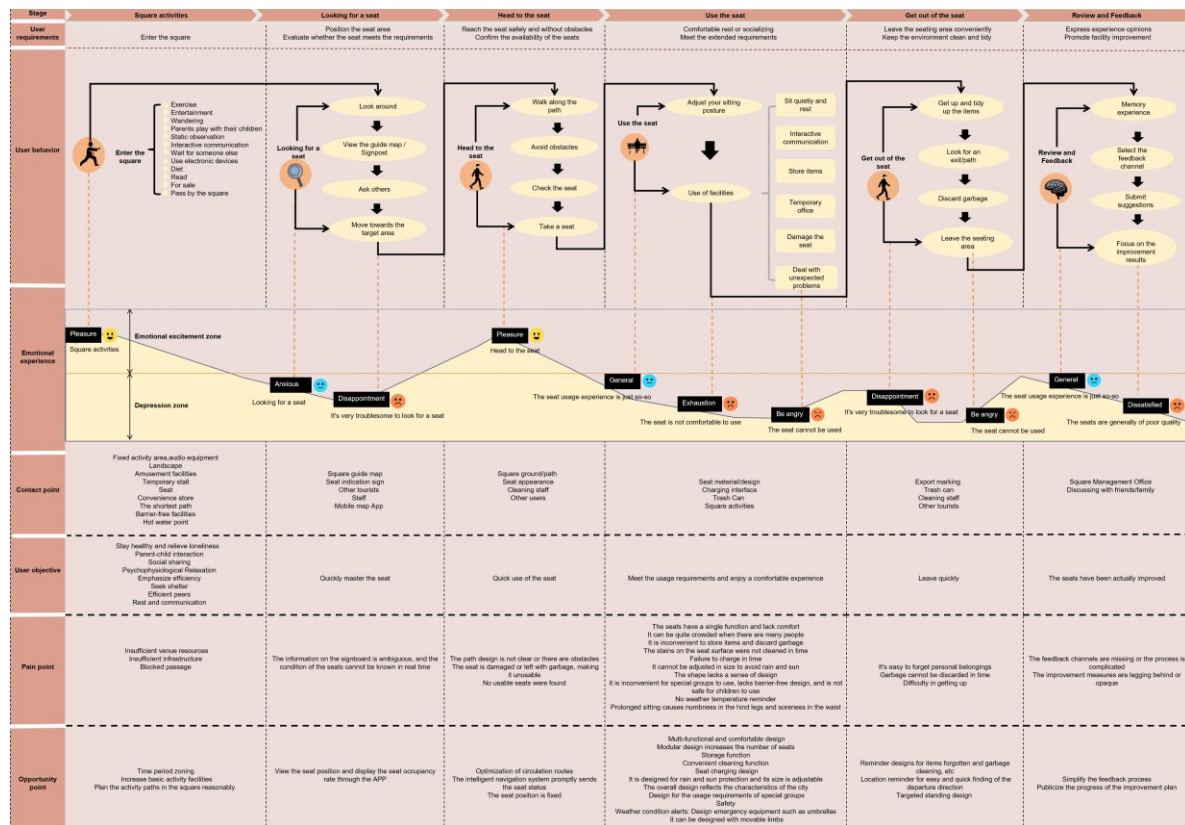


Fig. 4. Target user journey map

Combining observations, questionnaire surveys, and interviews, the study identified six stages in the full experience of urban square seats: engaging in activities, locating seats, approaching seats, using seats, leaving seats, and reviewing or providing feedback. The study analyzed the survey data through coding, created a target user journey map for urban square seats (Fig. 4), and pinpointed pain points at each stage. Noticeable emotional drops were identified at points associated with challenges such as difficulty locating seats, inaccessibility, and poor user experiences. Addressing these issues helps clarify pain points, identify interaction opportunities, and explore potential seating improvements.

User requirements gathering

The urban square seat user journey analysis clarified user pain points and translated them into corresponding requirements, as shown in Table 3.

Table 3. Comprehensive User Requirements

S/N	Pain Points	User Requirements
F1	Insufficient space resources	Implement time-based partitioning
F2	Inadequate infrastructure	Enhance infrastructure
F3	Traffic obstruction	Optimize urban space design
F4	Ambiguous signage causing difficulties in accessing real-time seat information	App-based seat positioning and real-time occupancy displays
F5	Ambiguous or obstructed path design	Route optimization
F6	Unusable seat due to damage or litter	Smart navigation promptly communicates seat statuses
F7	No usable seats found	Fixed seat positions
F8	Limited seat function with insufficient comfort	Multifunctional and comfortable design
F9	Overcrowding occurs during high foot traffic periods	Modular design for increased seat capacity
F10	Challenges in storing belongings and disposing of waste	Storage function
F11	Persistent dirt on seat surfaces	Seat cleaning function
F12	Inability to charge devices promptly	Charging-enabled lighting designs
F13	Inability to shelter from rain or sun, nor adjust size	Adjustable designs for rain and sun protection
F14	A design-less appearance	Urban character-reflecting aesthetics
F15	Challenges faced by special groups due to lack of accessible design	Inclusive design tailored for special user groups
F16	Inadequate measures to ensure children's safety	Safety
F17	Absence of weather and temperature notifications	Incorporate weather updates and emergency utilities like umbrellas into the design
F18	Discomfort such as numbness or backaches after prolonged sitting	Features to promote limb movement
F19	Easy to forget personal belongings	Alerts for forgotten items or locations
F20	Issues with timely garbage disposal	Design for timely garbage disposal
F21	Difficulty in standing up	Stand-up aiding designs
F22	Complex or unavailable feedback processes	Streamlined feedback mechanisms
F23	Delayed or opaque improvement measures	Provide visible updates on improvement plans

If all the 23 requirement elements mentioned above are fully realized, this may lead to an excessive focus on comprehensive functionality, resulting in issues such as overly high development costs and unclear product positioning, which could hinder subsequent design. Therefore, a systematic and practicable methodology for prioritizing requirements must be employed to focus on core needs, ensuring the precision and feasibility of the seat design.

Evaluating and Categorizing User Requirements with the Fuzzy Kano Model

Fuzzy Kano model

By integrating traditional Kano analysis with fuzzy mathematics, the Fuzzy Kano Model effectively addresses uncertainties in assessing user requirements. This approach utilizes $[0, 1]$ range fuzzy numbers in questionnaires to represent the strength of user preferences, making subjective need data reflect requirement traits in real-world scenarios. This study developed a Fuzzy Kano Model survey questionnaire derived from the traditional Kano Model, utilizing a design that included both positive and negative two-way questions. Each question offered five response options: “satisfied,” “necessary,” “indifferent,” “acceptable,” and “unsatisfied.” The questionnaire structure is detailed in Table 4. According to the requirement classification table based on the Fuzzy Kano Model (Table 5), the survey data were classified into six types: Must-be (M), One-dimensional (O), Attractive (A), Indifferent (I), Reverse (R), and Questionable (Q) (Avikal *et al.* 2020). The process of requirement classification in the Fuzzy Kano Model consisted of the following steps:

In the process of requirement classification, a matrix of existing requirement elements is defined as $X = (0.5, 0.2, 0.3, 0, 0)$ and the missing requirement elements matrix as $Y = (0, 0, 0, 0.8, 0.2)$. Then, the evaluation matrix can be formulated as follows:

$$S = X^T Y = \begin{bmatrix} 0 & 0 & 0 & 0.40 & 0.10 \\ 0 & 0 & 0 & 0.16 & 0.04 \\ 0 & 0 & 0 & 0.24 & 0.06 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad (1)$$

The next step is to compute the category membership vector T associated with this requirement element. This refers to the requirement classification table based on the Fuzzy Kano Model, and it is used to calculate the evaluation matrix S to derive the following:

$$T = \left[\frac{0.10}{M}, \frac{0.10}{O}, \frac{0.40}{I}, \frac{0.40}{A}, \frac{0}{R} \right] \quad (2)$$

As the classification of user requirement categories is influenced by the value of the membership vector T , a confidence level α (where $0 \leq \alpha \leq 1$) can be introduced to further refine the category attribution of the requirements elements. Through empirical analysis, the optimal parameter is identified as $\alpha = 0.4$. When the membership value for a requirement element is not less than this threshold, it is confirmed to belong to the corresponding category (Kano *et al.* 1984; Matzler and Hinterhuber 1998).

The classification of requirement elements is decided based on the category with the maximum frequency, so it is necessary to count the number of occurrences of each requirement element across five attribute categories. In cases where requirement elements exhibit equal occurrences across multiple categories, their priority is determined according to a predefined priority rule: $M > O > A > I > R$ (Chrysafis and Papadopoulos 2009; Karakurt and Cebi 2025).

Table 4. Fuzzy Kano Model Questionnaire

Requirement Elements		Satisfied	Necessary	Indifferent	Acceptable	Unsatisfied
What is your opinion on the seat's features for providing protection from rain and sun?	Present	0.2	0.8			
	Absent			0.1	0.2	0.7

Table 5. Fuzzy Kano Model Requirement Classification

Negative Questions						
Requirement Indicators		Satisfied	Necessary	Indifferent	Acceptable	Unsatisfied
Positive Questions	Satisfied	Q	A	A	A	O
	Necessary	R	I	I	I	M
	Indifferent	R	I	I	I	M
	Acceptable	R	I	I	I	M
	Unsatisfied	R	R	R	R	Q

Table 6. Reliability Analysis Statistical Results

Scale	Item	Cronbach's α
Total Scale	All items	0.891
Dimensional Scale	Satisfied	0.883
	Necessary	0.857
	Indifferent	0.797
	Acceptable	0.815
	Unsatisfied	0.862

Table 7. Validity Analysis Statistical Results

Category	Metric	Result	Evaluation Criteria	Conclusion
EFA	KMO	0.832	> 0.7	Excellent
	Bartlett	$p < 0.001$	< 0.05	Significant
	Variance(%)	71.3%	> 60%	Good
CFA	χ^2/df	1.92	< 3.0	Good
	CFI	0.936	> 0.90	Good
	TLI	0.928	> 0.90	Good
	RMSEA	0.058	< 0.08	Good
	Factor Loadings	0.65-0.84	> 0.60	Good
	CR	0.81-0.87	> 0.70	Good
	AVE	0.53-0.64	> 0.50	Acceptable

Note: EFA, CFA, KMO, χ^2/df , CFI, TLI, RMSEA, CR and AVE represent Exploratory Factor Analysis, Confirmatory Factor Analysis, Kaiser-Meyer-Olkin Measure, Chi-square to Degrees of Freedom Ratio, Comparative Fit Index, Tucker-Lewis Index, Root Mean Square Error of Approximation, Composite Reliability, Average Variance Extracted, respectively.

Prioritization and classification of user requirements

Initially, a Fuzzy Kano Model questionnaire was devised to set positive and negative questions for each analyzed requirement within the user journey (Lizarelli *et al.* 2021). Following the principle of informed consent, this study distributed 100 Fuzzy Kano Model questionnaires to individuals who had used square seats in the past week, and

collected 92 valid responses, with an effective response rate of 92%. The sample demonstrated reasonable distribution across gender, age, and occupation. The results from SPSS 26 (Yang *et al.* 2024) and AMOS 24 (Becerra *et al.* 2024) indicate that the questionnaire data exhibited good reliability and validity, as shown in Table 6 and Table 7.

Table 8. Classification of User Requirement Elements for Urban Square Seats

Requirement Number	Requirement Category	User Requirement	Analysis Result (Membership (%))					
			M	O	A	I	R	Category Classification
		Secondary Indicator						
C1	Must-be requirements	Multifunctional and comfortable design	75	20	3	2	0	M
C2		Modular design for increased seat capacity	77	15	5	3	0	M
C3		Storage function	70	25	3	2	0	M
C4		Seat cleaning function	78	18	2	2	0	M
C5		Adjustable designs for rain and sun protection	80	14	4	2	0	M
C6		Safety	85	11	3	1	0	M
C7		Inclusive design tailored for special user groups	51	31	16	2	0	M
C8		Urban character-reflecting aesthetics	50	30	15	5	0	M
C9	One-dimensional requirements	Enhance infrastructure	26	54	13	7	0	O
C10		Charging-enabled lighting designs	20	55	20	5	0	O
C11		Features to promote limb movement	29	43	25	3	0	O
C12		Alerts for forgotten items or locations	28	48	18	6	0	O
C13		Design for timely garbage disposal	20	53	20	7	0	O
C14		Incorporate weather updates and emergency utilities like umbrellas into the design	17	44	25	14	0	O
C15		Optimize urban space design	17	55	22	6	0	O
C16	Attractive requirements	Implement time-based partitioning	19	28	38	15	0	A
C17		App-based seat positioning and real-time occupancy displays	8	18	68	6	0	A
C18		Route optimization	15	20	55	10	0	A
C19		Smart navigation promptly communicates seat statuses	5	15	71	9	0	A
C20		Streamlined feedback mechanisms	18	22	52	8	0	A
C21		Provide visible updates on improvement plans	10	27	46	17	0	A

Note: M, A, O, I, and R represent Must-be Requirement, Attractive Requirement, One-dimensional Requirement, Indifferent Requirement, and Reverse Requirement, respectively.

Subsequently, the Fuzzy Kano Model analysis method was applied to systematically evaluate the questionnaire data. By quantifying the frequency of selection across the five categories for each requirement and expressing these as percentages of the total 92 samples, the study derived the membership of each requirement element, thereby determining the attributions of the requirement categories (Becerra *et al.* 2024). Through data organization, classifications for requirement elements were achieved, as listed in Table 8.

SEM-based Identification of Core Customer Requirements

SEM development

Structural equation modeling (SEM) can effectively analyze the relevance among complex user requirements and identify core user requirements by establishing priorities (Berger 1993; MacCallum and Austin 2000; Tarka 2018).

Table 9. Descriptive Statistics for Observed Variables

Latent Variable	Observed Variable	Mean	Standard Deviation	Skewness	Kurtosis
MQ	MQ1	4.43	0.83	-1.32	-1.44
	MQ2	4.45	0.78	-1.35	-1.42
	MQ3	4.39	0.81	-0.90	-1.08
	MQ4	4.27	0.87	-0.65	-1.08
	MQ5	4.52	0.75	-1.50	-1.37
	MQ6	4.54	0.74	-1.55	-1.50
	MQ7	4.50	0.77	-1.45	-1.44
	MQ8	4.30	0.84	-0.73	-0.96
OQ	OQ1	3.90	1.11	-0.09	-0.85
	OQ2	4.08	0.87	-0.49	-0.56
	OQ3	3.84	1.17	-0.31	-0.80
	OQ4	3.78	1.19	-0.57	-0.67
	OQ5	4.11	0.86	-0.18	-0.90
	OQ6	4.02	0.91	0.29	-0.78
	OQ7	3.96	1.01	0.04	-0.83
AQ	AQ1	3.18	1.37	-0.57	-0.13
	AQ2	3.45	1.21	-0.79	-0.29
	AQ3	3.15	1.39	-0.62	-0.12
	AQ4	3.32	1.29	-0.66	-0.26
	AQ5	3.24	1.32	-0.63	-0.31
	AQ6	3.38	1.27	-0.61	-0.33
US	US1	4.08	0.80	-0.40	-0.49
	US2	3.98	0.98	-0.06	-0.73

Note: MQ, AQ, OQ, and US represent Must-be Quality, Attractive Quality, One-dimensional Quality, User Satisfaction, respectively.

A structural equation model was constructed based on the outcomes derived from Fuzzy Kano Model analysis. This model incorporated three exogenous latent variables—Must-be Quality (MQ), One-dimensional Quality (OQ), and Attractive Quality (AQ)—alongside related exogenous observed variables including MQ1 to MQ8, OQ1 to OQ7, and AQ1 to AQ6 (Kline 2023). Additionally, user satisfaction (US) functioned as an

endogenous latent variable within the model, corresponding to endogenous observed variables (US1) and (US2) (Zhai *et al.* 2022).

Table 10. Reliability Analysis Statistical Results

Latent Variable	Item	Cronbach's α	Total Cronbach's α
MQ	MQ1-MQ8	0.923	0.911
OQ	OQ1-OQ7	0.912	
AQ	AQ1-AQ6	0.904	

Note: MQ, AQ and OQ represent Must-be Quality, Attractive Quality, One-dimensional Quality, respectively.

Table 11. Validity Analysis Statistical Results

	Path	Estimate	CR	AVE
MQ	MQ1 $\leftarrow$ MQ	0.817	0.948	0.695
	MQ2 $\leftarrow$ MQ	0.850		
	MQ3 $\leftarrow$ MQ	0.811		
	MQ4 $\leftarrow$ MQ	0.802		
	MQ5 $\leftarrow$ MQ	0.862		
	MQ6 $\leftarrow$ MQ	0.867		
	MQ7 $\leftarrow$ MQ	0.856		
	MQ8 $\leftarrow$ MQ	0.803		
OQ	OQ1 $\leftarrow$ OQ	0.722	0.894	0.548
	OQ2 $\leftarrow$ OQ	0.818		
	OQ3 $\leftarrow$ OQ	0.674		
	OQ4 $\leftarrow$ OQ	0.615		
	OQ5 $\leftarrow$ OQ	0.845		
	OQ6 $\leftarrow$ OQ	0.758		
	OQ7 $\leftarrow$ OQ	0.724		
AQ	AQ1 $\leftarrow$ AQ	0.633	0.869	0.528
	AQ2 $\leftarrow$ AQ	0.835		
	AQ3 $\leftarrow$ AQ	0.606		
	AQ4 $\leftarrow$ AQ	0.754		
	AQ5 $\leftarrow$ AQ	0.733		
	AQ6 $\leftarrow$ AQ	0.771		
US	US1 $\leftarrow$ US	0.843	0.826	0.704
	US2 $\leftarrow$ US	0.835		

Note: MQ, AQ, OQ, US, US1 and US2 represent Must-be Quality, Attractive Quality, One-dimensional Quality, User Satisfaction, Overall Satisfaction, Satisfaction relative to expectations, respectively.

The data required for the model were collected using a questionnaire survey method, with all observed variables measured on a 5-point Likert scale (Baki 2022). Out of 385 distributed questionnaires, 369 valid ones were collected. Descriptive statistics of the observed variables (Table 9) indicate that the mean values for MQ, OQ, and AQ decreased in order, while the standard deviation increases successively. This distribution aligned with the results of the Fuzzy Kano Model analysis. Additionally, the skewness and kurtosis for all observed variables were within acceptable ranges, meeting the basic requirement for univariate normality in structural equation modeling.

Reliability and validity were tested using SPSS 26, with results shown in Tables 10 and 11. The results show that each factor's Cronbach's α coefficient exceeded 0.8, CR value was above 0.7, and AVE value was above 0.5, indicating strong reliability and validity in the questionnaire data (Hu *et al.* 2021; Zheng *et al.* 2023). The path analysis of the model was conducted using AMOS 24 (IBM Corp, Armonk, NY, USA) software, as shown in Fig. 5. The model demonstrated a good fit across various evaluation metrics (Table 12), indicating that it can be utilized for subsequent studies (Li and Wu 2023). The SEM's overall performance aligns with the Fuzzy Kano Model's requirement priority ranking: MQ > OQ > AQ, and the specific requirement elements, as measurement indicators of latent variables, indirectly influence user satisfaction.

Table 12. Fit Analysis Statistical Results

Test Indicator	Value	Reference Range	Adaptation Result
Chi-square/Degree of freedom	2.57	< 5	Ideal
RMSEA	0.065	< 0.1	Ideal
GFI	0.988	> 0.9	Ideal
CFI	0.915	> 0.9	Ideal
NFI	0.912	> 0.9	Ideal
IFI	0.915	> 0.9	Ideal

Note: RMSEA, GFI, CFI, NFI and IFI represent Root Mean Square Error of Approximation, Goodness-of-Fit Index, Comparative Fit Index, Normed Fit Index, Incremental Fit Index, respectively.

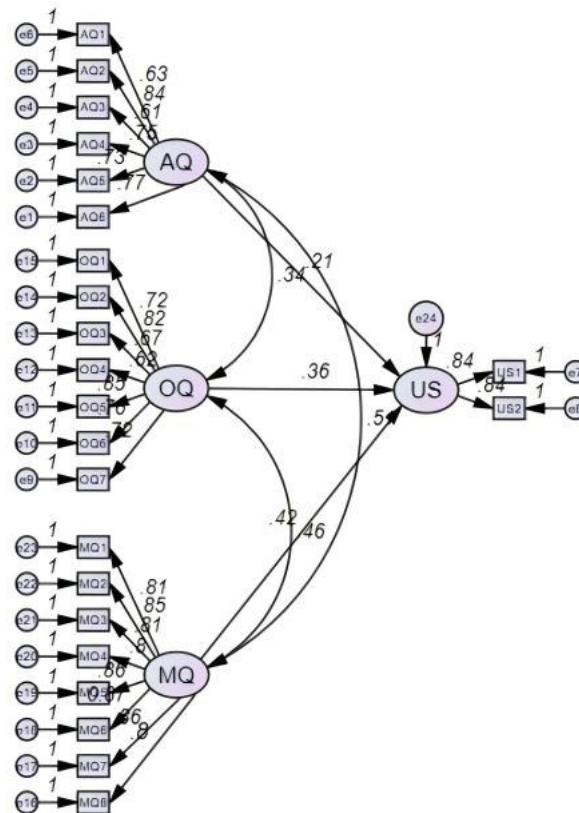


Fig. 5. Model running results

Identification of user core requirements

(1) Analysis of Requirement Category Priorities

The path coefficient directly indicates the correlation between variables and the significance of each requirement element, aligning with the core goal of urban square seat design. Table 13 lists the standardized path coefficients between variables obtained from running the model.

Table 13. Standardized Path Coefficient Statistical Results

Path	Estimate	Path	Estimate
MQ1←MQ	0.817	OQ6←OQ	0.758
MQ2←MQ	0.850	OQ7←OQ	0.724
MQ3←MQ	0.811	AQ1←AQ	0.633
MQ4←MQ	0.802	AQ2←AQ	0.835
MQ5←MQ	0.862	AQ3←AQ	0.606
MQ6←MQ	0.867	AQ4←AQ	0.754
MQ7←MQ	0.856	AQ5←AQ	0.733
MQ8←MQ	0.803	AQ6←AQ	0.771
OQ1←OQ	0.722	US1←US	0.843
OQ2←OQ	0.818	US2←US	0.835
OQ3←OQ	0.674	MQ	0.417
OQ4←OQ	0.615	OQ	0.359
OQ5←OQ	0.845	AQ	0.207

Note: MQ, AQ, OQ, US, US1 and US2 represent Must-be Quality, Attractive Quality, One-dimensional Quality, User Satisfaction, Overall Satisfaction, Satisfaction relative to expectations, respectively.

As indicated by the standardized path coefficients for MQ, OQ, and AQ, the user requirement priorities for urban square seats were as follows: MQ > OQ > AQ. This aligns closely with the findings of current seat design research (Li and Wu 2023). The path coefficient between MQ and user satisfaction was 0.417, indicating a medium to strong effect. This shows that users were most concerned about improved basic functions. Therefore, basic functions should be prioritized in the design of urban square seats. Furthermore, the path coefficient for OQ was 0.359, indicating a moderate effect that was notably lower than MQ. It shows that users had high expectations for additional functions such as timely garbage disposal and charging-enabled lighting designs. The optimization of these functions can further enhance user satisfaction. Lastly, the path coefficient for AQ was 0.207, which, though below the moderate threshold, was statistically significant. This suggests that while features such as app-based seat positioning and real-time occupancy displays have a minimal impact on satisfaction, these innovative functions may bring surprises to users and, when conditions permit, can be gradually implemented to enhance user experience.

(2) Analysis of the Importance of Requirement Elements

This study assessed the relative effect of each observed variable on user satisfaction by calculating standardized indirect effect values, which were obtained by multiplying the factor loadings with the relevant path coefficients (Bollen 1987; Kline 2023). Table 14 presents the indirect effect values of the observed variables on user satisfaction.

Table 14. Analysis of Demand Factor Effects

Observed Variable	Factor Loading (λ)	US Path Coefficient (β)	Indirect Effect ($\lambda \times \beta$)
MQ1	0.817	0.417	0.341
MQ2	0.850	0.417	0.355
MQ3	0.811	0.417	0.338
MQ4	0.802	0.417	0.334
MQ5	0.862	0.417	0.359
MQ6	0.867	0.417	0.362
MQ7	0.856	0.417	0.357
MQ8	0.803	0.417	0.335
OQ1	0.722	0.359	0.258
OQ2	0.818	0.359	0.292
OQ3	0.674	0.359	0.242
OQ4	0.615	0.359	0.221
OQ5	0.845	0.359	0.304
OQ6	0.758	0.359	0.271
OQ7	0.724	0.359	0.259
AQ1	0.633	0.207	0.131
AQ2	0.835	0.207	0.173
AQ3	0.606	0.207	0.151
AQ4	0.754	0.207	0.155
AQ5	0.733	0.207	0.148
AQ6	0.771	0.207	0.159

Note: MQ, AQ and OQ represent Must-be Quality, Attractive Quality, One-dimensional Quality, respectively.

Based on the indirect effect values ($\lambda \times \beta$) calculated through the structural equation modeling, this study ranks the priority of requirement elements and identifies the degree of influence of three types of requirements on user satisfaction, the order of influence for Must-be Qualities (MQ) was: MQ6 > MQ5 > MQ7 > MQ2 > MQ1 > MQ3 > MQ8 > MQ4; the order of influence for One-dimensional Qualities (OQ) was: OQ5 > OQ2 > OQ6 > OQ7 > OQ1 > OQ3 > OQ4; and the order of influence for Attractive Qualities (AQ) was: AQ2 > AQ6 > AQ4 > OQ5 > AQ1 > AQ3.

The evaluation followed the widely accepted principle of relative importance in mediating effect analysis and integrated the Fuzzy Kano Model attributes for a comprehensive analysis: in terms of must-be qualities, the indirect effect values of the observed variables of the latent variable MQ exceeded 0.3, with the factor loadings over 0.8. Therefore, all eight qualities should be considered in the design of urban square seats. The order of priority from highest to lowest was Safety(MQ6), Adjustable designs for rain and sun protection(MQ5), Inclusive design tailored for special user groups(MQ7), Modular design for increased seat capacity(MQ2), Multifunctional and comfortable design(MQ1), Storage function(MQ3), Urban character-reflecting aesthetics(MQ8), and Seat cleaning function(MQ4). For one-dimensional qualities, the observed variables with indirect effect values of nearly 0.3 included timely garbage disposal and charging-enabled lighting designs, with their factor loadings above 0.8. Hence, these two aspects should be prioritized. Priority should be given to Design for timely garbage disposal(OQ5), followed by the Charging-enabled lighting designs (OQ2). Regarding attractive qualities, fulfilling these requirements greatly enhances user satisfaction, but it necessitates evaluating development costs and maintenance difficulties comprehensively. Practically, these attractive qualities can serve as standout features for differentiated services and be gradually improved while

ensuring the implementation of basic functions and one-dimensional qualities. Given the highest indirect effect value of AQ2 in AQ, and its factor loading of over 0.8, the features, such as app-based seat positioning and real-time occupancy displays, can be prioritized in the design of urban square seats to effectively enhance user satisfaction. These 11 core user requirements serve as the primary functional aspects of urban square seat design and should all be reflected in the design.

RESULTS AND DISCUSSION

Design Practice and Verification

Design plan creation

According to the diverse requirement elements, conceptual designs for seat solutions were developed to address the current seat issues at the Tianfu Square. As a central public space of Chengdu, Tianfu Square demonstrates functional diversity and representative population characteristics, providing a typical case for scheme design.

First, in terms of the MQ element, given that there are no protective facilities in the pool and live areas of Tianfu Square, the original pool facilities were removed from the seat design to enhance user safety. Additionally, anti-tipping structures and rounded edges were adopted to prevent accidental collisions and injuries. All seats were made of cast aluminum and plastic-wood composites, ensuring durability while offering non-slip and waterproof properties. Ergonomically designed with a slightly inclined backrest and properly sized dimensions, the seats conform to the natural body curves of most users for optimal safety and comfort. The existing two types of seats lack protection from rain and sunlight and are built with fixed structures. However, the new design addresses these issues by adopting a retractable awning featuring a solar film covering, offering both shade and rain protection. Additionally, the solar film powers the seat's built-in USB ports to meet users' emergency charging requirements. The seat is designed to be adjustable to meet the needs of various users. Additionally, it features a liftable armrest tailored for specific groups and individuals who sit for extended periods (Gong and Wang 2022). The modular structure of some seats allows for simultaneous use by multiple people, effectively alleviating the scarcity of seats during peak hours. A retractable tabletop located above the seat back helps reduce the physical burden and psychological stress on users caused by insufficient space to place their belongings. Recognizing the outdated seat design at Tianfu Square, which lack regional character and do not align with the overall environment of the square, the proposed design incorporates the Golden Sun Bird pattern and its promotional text on the side and back panels of the seats to celebrate Tianfu Square's cultural identity. The color palette is beige and light wood tones, which harmonize with the patterns to create a relaxed and visually comforting experience while enhancing integration with the surrounding environment. The solution incorporates a high-density composite material that is both corrosion-resistant and dirt-resistant. Additionally, holes are designed into the panel to make cleaning easier.

Second, in terms of the OQ element, garbage bins are integrated beneath and within the seats located at the four corners to handle temporary waste. Notably, the shading surface adopts a full-coverage solar film that converts sunlight into energy, powering the LED energy-efficient lights on the main column of the canopy. This design meets nighttime illumination needs while showcasing an environmentally sustainable approach to energy utilization.

Third, in terms of the AQ element, the seat situation can be displayed at the square navigation app through the IoT technology. Users can check specific seat location and the availability efficiently, enhancing the usability of seat services. Moreover, the system can mine and analyze seat usage data. Combined with user feedback and data analysis results, designers can promptly address shortcomings in seat design, thereby providing a more optimized resting experience for all square visitors. The finalized seat design scheme for Tianfu Square is presented in Figs. 6 through 9.

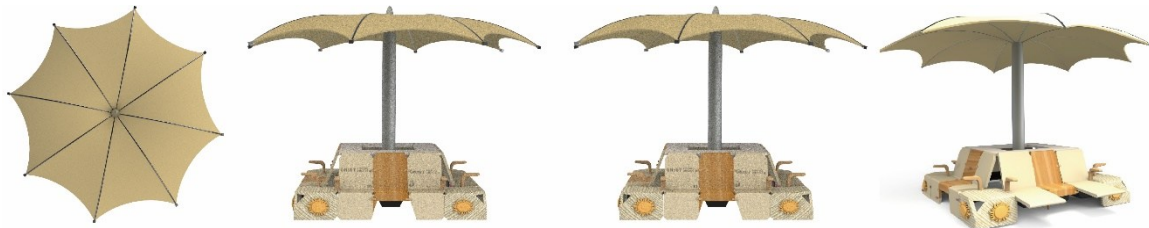


Fig. 6. Three views (front, side, and top views) and a perspective view of the Tianfu square seat design

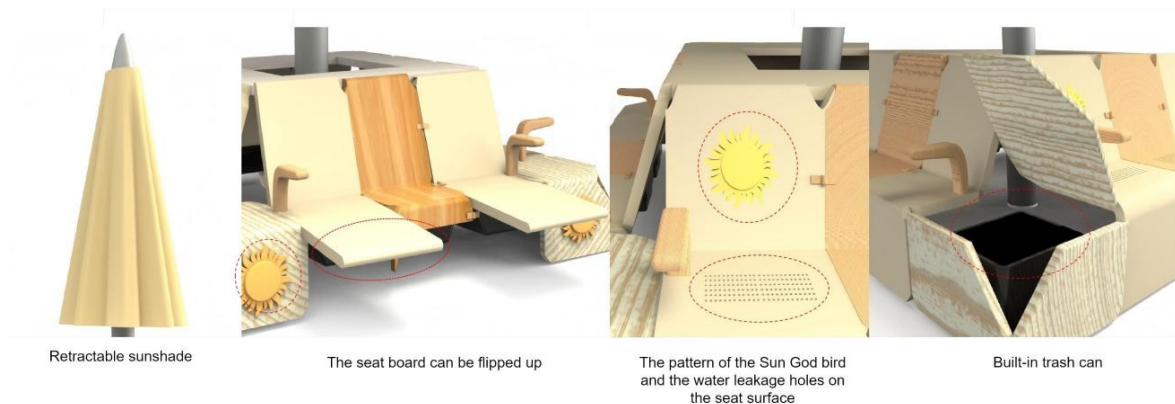


Fig. 7. Detailed illustrations of the seat features at Tianfu square



Fig. 8. Visual representation of the Tianfu square seating arrangements

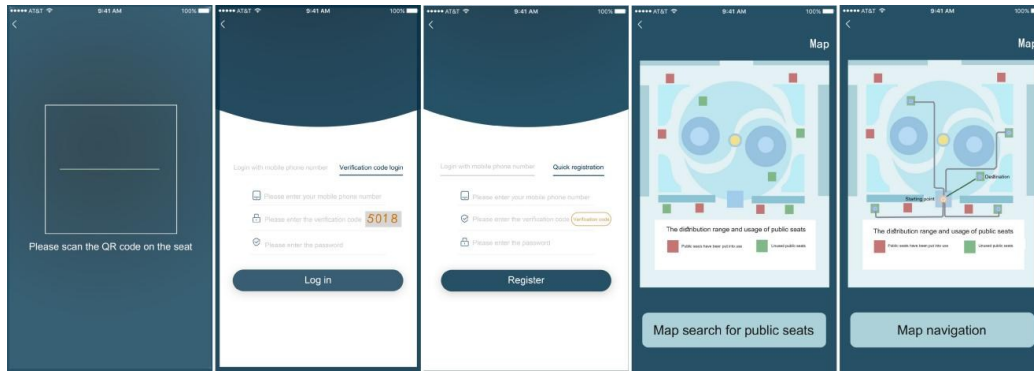


Fig. 9. QR code scanning and seat positioning query processes

Verification of the design methodology

This study assesses the design scheme's compliance with user requirement analysis results, identifying eight key points for innovation. A total of 32 participants, including furniture designers, structural engineers, square seat users, and managers, evaluated the design features using a five-point Likert scale. This process aimed to validate the efficacy of the design methodology through mean-score analysis. The results of the questionnaire analysis are presented in Fig. 10. The average satisfaction score for all 11 indicators exceeded 4 points, indicating the strong applicability and reliability of the research methodology in assessing user requirements for seats in urban squares (Zhang *et al.* 2025).

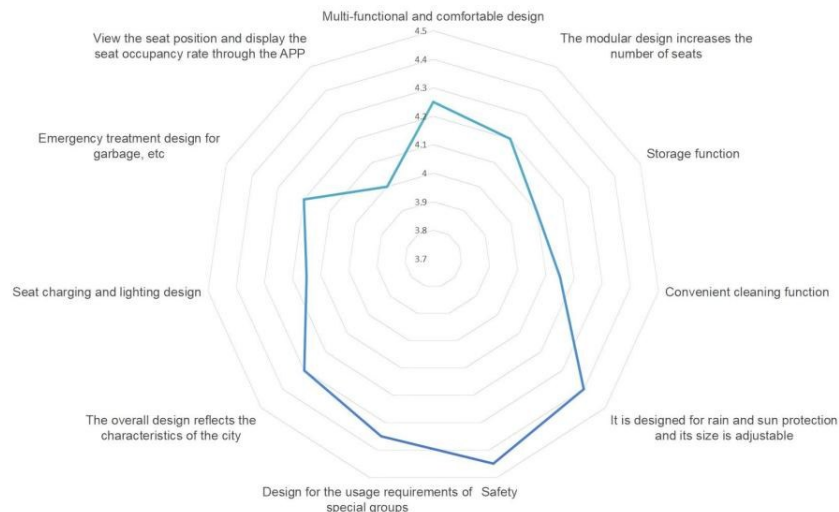


Fig. 10. Evaluation of the design methodology

Evaluation of the design scheme

To assess user satisfaction with the proposed design scheme, the system usability scale (SUS) was employed for evaluating the urban square seat designs. The 10 SUS questions were highly relevant, with questions 1, 3, 5, 7, and 9 being positively worded, while questions 2, 4, 6, 8, and 10 were negatively worded. Responses were evaluated using a 5-point Likert scale, and a higher SUS score indicates better product usability (Brooke 1996; Lewis 2018).

The final SUS score was calculated as: $[(\text{Sum of scores for odd-numbered questions} - 1) + (5 - \text{Sum of scores for even-numbered questions})] \times 2.5$ (Clark *et al.* 2021). A SUS

score of 85 or higher indicates “excellent” or “high user satisfaction”, while a score of 70 or higher suggests “good” usability. Conversely, a SUS score of 50 or lower indicates poor usability (Ran *et al.* 2024).

The evaluation covered two existing types of seat facilities as well as the proposed seat design scheme for Tianfu Square. Please refer to Fig. 11 for the SUS questionnaire regarding seats at Chengdu Tianfu Square. A questionnaire survey and interviews were conducted, involving 35 participants at Tianfu Square to evaluate three seat types. Using the collected survey data for each seat type, the learnability score, usability score, and SUS score were calculated based on the values of each item. Details are illustrated in Fig. 12.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
F1	I think that I would like to use this seat frequently.				
	1	2	3	4	5
	☐	☐	☐	☐	☐
F2	I found the seat unnecessarily complex.				
	1	2	3	4	5
	☐	☐	☐	☐	☐
F3	I thought the seat was easy to use.				
	1	2	3	4	5
	☐	☐	☐	☐	☐
F4	I think that I would need the support of a technical person to be able to use this seat.				
	1	2	3	4	5
	☐	☐	☐	☐	☐
F5	I found the various functions in this seat were well integrated.				
	1	2	3	4	5
	☐	☐	☐	☐	☐
F6	I thought there was too much inconsistency in this seat.				
	1	2	3	4	5
	☐	☐	☐	☐	☐
F7	I would imagine that most people would learn to use this seat very quickly.				
	1	2	3	4	5
	☐	☐	☐	☐	☐
F8	I found the seat very cumbersome to use.				
	1	2	3	4	5
	☐	☐	☐	☐	☐
F9	I felt very confident using the seat.				
	1	2	3	4	5
	☐	☐	☐	☐	☐
F10	I needed to learn a lot of things before I could get going with this seat.				
	1	2	3	4	5
	☐	☐	☐	☐	☐

Fig. 11. SUS questionnaire for seats at Chengdu Tianfu Square

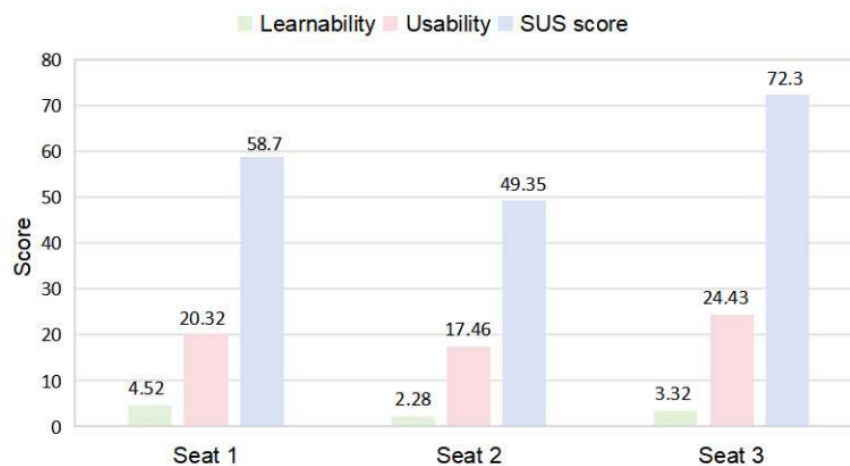


Fig. 12. Learnability, usability, and SUS scores of three seat types

As shown in the score situation above (Fig. 12), the SUS score of Seat 3 was the highest at 72.38, suggesting the best usability, followed by Seat 1 scoring 58.7 and Seat 2

scoring the lowest at 49.35. Only Seat 3 reached a “good” usability level. The usability scores for the seats can be derived by summing up scores from questions F1, F2, F3, F5, F6, F7, F8, and F9 in Fig. 11. The resulting usability rankings were: Seat 3 > Seat 1 > Seat 2, consistent with the overall SUS rankings. The learnability scores for the seats were determined by adding up the scores of questions F4 and F10. The variations in learnability results among the three types of seats were relatively minimal. The analysis above indicates that users were most satisfied with the seat design scheme, thereby affirming the effectiveness of the UJM-Fuzzy Kano Model-SEM integrated model in the urban square seat design research. The scheme can enhance the activity experience for users at urban squares.

CONCLUSIONS

1. By analyzing the seat design in Chengdu Tianfu Square and Mianyang Fucheng Wanda Plaza based on 312 valid questionnaires, in-depth interviews with 36 users, and behavior observations of 687 participants, a seat UJM was obtained, summarizing 23 user requirement elements across multiple dimensions such as rest, social interaction, environmental coordination, and emergency functions. This approach combined user behavior observation with emotional touch point analysis to fully capture the explicit and implicit needs of users, laying a solid foundation for ranking requirement priority.
2. Through the analysis of 92 valid questionnaires employing the Fuzzy Kano Model, 23 requirement elements were screened and classified to identify eight must-be qualities, seven one-dimensional qualities, and six attractive qualities. This method addressed the uncertainties in the user requirement assessment of urban square seats and clarified the priority of requirement realization.
3. According to the SEM built based on an analysis of 369 valid questionnaires, the path coefficient of must-be qualities was 0.417, which achieved the highest impact on user satisfaction, followed by one-dimensional qualities and attractive qualities. By evaluating the impact of each requirement element on user satisfaction, it further identified 11 core requirement elements and their importance. The model revealed the transformation path from the core requirement elements of seat users to key design points, ensuring a higher user experience in subsequent design solutions.
4. The seat design scheme of Chengdu Tianfu Square was completed based on the core requirements, with user satisfaction evaluated using a five-point Likert scale and SUS. Thirty-five seat users at the square were selected to compare and assess the new design (seat 3) against the two existing types (seat 1 and seat 2). The results showed that the average satisfaction score of 11 design elements in the design scheme (seat 3) exceeded 4 points, and the overall SUS score reached 72.3 points, which was higher than the scores for seat 1 (58.7 points) and seat 2 (49.35 points). These findings demonstrate that the seat design scheme achieved good performance in usability, learnability, and user satisfaction. It was also verified that the UJM-Fuzzy Kano Model-SEM combination can effectively identify the core needs of urban square seat users. This approach provides a new direction and strategy for the design of square seats, offering valuable reference for improving user satisfaction with square seats and other public facilities.

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