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Aesthetic Design and Evaluation of Public Facilities in Railway Stations under the Background of Sustainable Development: A Case of an Information Counter at Xiong'an Railway Station

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Abstract: Sustainable development is an important trend for railway stations, and public facilities are essential parts of railway stations. With the sustainable development of railway station construction, the aesthetic design of public facilities is a problem that needs to be solved in the field of industrial design. In this context, this study proposed an aesthetic design and evaluation method for public facilities in railway stations. This method is constructed by combining the Kansei image and AHP (analytic hierarchy process)–FCE (fuzzy comprehensive evaluation) model, and takes the information counter at Xiong'an railway station as an example to illustrate the method. JACK^{TM} is applied to evaluate the ergonomics of the design scheme. The results are as follows. (1) Ecological culture is an important source of Kansei images for aesthetic designs in the context of sustainable development. Kansei words, such as understated, delicate, dynamic, and others, which reflect original simplicity and original nature, are typical semantic features. Simple and smooth shapes are typical form features. (2) An aesthetic design is a system of various elements; the core content of an aesthetic design is to reflect the original aesthetic feeling. On this basis, the elements of simple, harmonious, humanized, and natural constitute the aesthetic design principle. This method is suitable for the aesthetic design and evaluation of public facilities in railway stations, which could provide valuable guidance for the aesthetic design of public facilities in railway stations under the background of sustainable development.

Keywords: sustainable development; Kansei image; AHP–FCE model; aesthetic design; public facilities in railway stations; industrial design

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1. Introduction

With the development of China's rail system, the total length of railways in China has extended 159,000 km; China has built the world's largest railway network [1]. Sustainable development is one of the important research trends in the field of railway stations [2]. Xiong'an railway station is representative of a sustainable railway station [3]. Xiong'an railway station is located in Xiong'an new district, Hebei Province, China [4]. The architectural design of Xiong'an railway station fully reflects the development direction of the railway station under the background of sustainable development. The overall shape of the railway station is an oval; the architectural design style and interior design style adopt the concept of integration. Sunlight shines into the interior through the gap at the top of the station building. The interior structure of the station is decorated with clear concrete columns, which reflect the natural, simple, and elegant design style. Xiongan new area has a good ecological environment, with rivers and canals, developed water systems, and widespread lakes. Based on data analysis from Xiong'an's official website, the photos of Xiong'an railway station and the regional river system are shown in Figure 1.



Figure 1. The photos of Xiong'an railway station and Xiong'an ecological environment.

As an important component of railway stations, the public facilities design has an important impact on railway stations; its aesthetic design and evaluation is an important challenge for sustainable railway station development. How to effectively improve the aesthetic effect of public facilities in railway stations and establish an objective evaluation method is one of the problems that need to be solved in the context of railway sustainable development.

This study aims to summarize the aesthetic design points in the context of sustainable development, and it proposes a design and evaluation method. It takes the information counter at Xiong'an railway station as an example to explain the method. The Kansei image method is combined with the AHP-FCE model to analyze the factors that enhance the aesthetic effect of the information counter design under the background of sustainable development. JACK^{TM} is used to analyze the ergonomics of the design scheme. The research framework of this paper is shown in Figure 2.

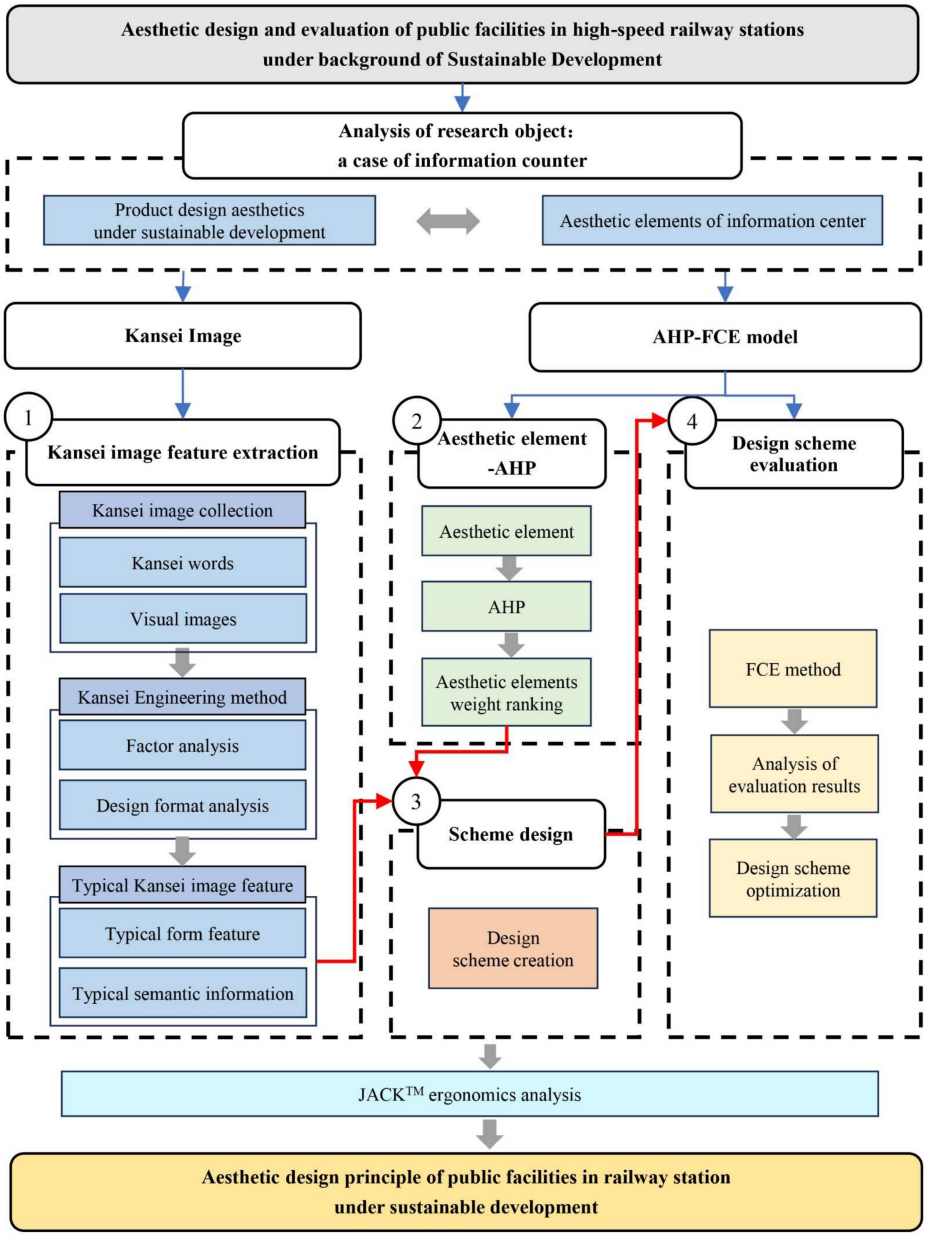


Figure 2. Research framework.

2. Literature Review

With the wide application of sustainable development in the field of transportation, it has gradually become an important trend in the research field of railways in recent years. Liu Xinyu et al. studied the transformation and development of Jingmen high-speed railway station infrastructure from the perspective of sustainable development and the circular economy and analyzed the development strategy of high-speed railway station infrastructure in the context of sustainable development [5]. Vilotijevic, Milica et al. analyzed the problems with sustainable railway infrastructure and the specific environment in the Republic of Serbia and pointed out that the railway infrastructure needs to meet the requirements of society, economy, protection, and improvement of the environment [6]. Alessandra Bianchi et al., by evaluating the discussed railway cultural heritage and analyzing its adaptive transformation methods on the basis of cases, provided a reference standard for the sustainable adaptive reuse of railway cultural heritage [7]. Agnes Wanjiku Wangai et al. studied the foresight method applicable to railways' sustainable development in developing countries [8].

The Kansei image is important research content in industrial design theory [9], product emotional design [10], Kansei Engineering [11], and other fields. It serves as a crucial factor for design scheme creation [12] and users' cognitive processes of product design [13]. The concept of an "image" is a psychological domain, which refers to the emotional cognition of individuals regarding objects. The relevant research on the Kansei image mainly discusses the emotional cognitive process of product design [14], aiming to effectively quantitatively analyze the emotional information of product design [15]. Kansei image cognitive cues can be decomposed into visual cues and semantic cues [16,17]. With the emergence of interdisciplinary trends in industrial design theory, the research methods on the Kansei image encompass both quantitative and qualitative approaches. The quantitative research method mainly combines factor analysis, design format analysis, and other methods to extract the emotional information of products [18]. The qualitative research methods are combined with cognitive psychology [19], prototype theory [20], grounded theory [21], and others. The Kansei image is an important theoretical tool for analyzing product emotional design.

Scheme evaluation is one of the important contents of decision-making research [22], among which the AHP is a common and simple decision method. The AHP (analytic hierarchy process) is a decision analysis method that is extensively applied in management, program evaluation, scheme optimization, and other research fields [23]. Analyzing various indicators and elements of product design, the AHP provides an importance ranking for each element and index [24]. The AHP is used in combination with other methods to solve decision problems with multiple influence factors, and such combinations include the AHP with fuzzy comprehensive evaluation [25] and the Kano model [26], which provide references for decision-making problems.

The FCE (fuzzy comprehensive evaluation) is a multi-factor evaluation method that considers the influence of various factors, aiming to achieve an effective and objective evaluation for design schemes. The FCE method is widely utilized in diverse domains, including product user demand analysis [27], automobile form design [28], plan analysis for engineering scheme design [29], architectural space evaluation [30], infrastructure evaluation [31], and others.

The AHP-FCE model is a combination of the analytic hierarchy process (AHP) and fuzzy comprehensive evaluation (FCE). It is used for quantitative evaluation and analysis of design schemes [32,33]. Tao Wang et al. used the AHP-FCE model to explore the creative design of 2022 World Cup lamps. Using the AHP-FCE model, the design scheme is quantitatively evaluated, and the relevant evaluation information of the design method is obtained [34]. Hu Sun et al. used the AHP-FCE model to study reusable takeaway containers and proposed design suggestions [33]. Kucuk, Pelin Ofluoglu et al. used the AHP and FCE to analyze the satisfaction of student residential apartment building environments [35]. Fang, XS et al. used the AHP and FCE methods to evaluate the health status of Guangdong Xinhui national wetland park and provided a health evaluation index system for the rapidly developing wetland park [36].

Aesthetic design and evaluation are one of the research hotspots in the field of industrial design. Product aesthetic design is primarily involved in the exploration of people's aesthetic cognitive activities and the principles of product aesthetic design [37]. Studying the aesthetic perception of product design provides an effective reference for designers to create design schemes [38]. In aesthetic design and evaluation, the AHP and FCE methods are widely used [39,40]. Feng M M used the AHP–fuzzy comprehensive evaluation to study the aesthetic feeling of urban plant landscape and took Hangzhou regional landscape as the object to explain the effectiveness of the method [41]. Zhang N et al. used the AHP to study the aesthetic image of the man–machine interface form element layout design [42].

Based on the above literature analysis, it can be seen that the concept of sustainable development is an important development direction in the field of transportation. Kansei image theory and the AHP-FCE model are widely used in the research of aesthetic eval-

uation. However, relevant theories and research methods are not applied in the public facilities of railway passenger stations.

3. Materials and Methods

3.1. Analysis of Research Object

Aesthetics are an important factor for product design. Users elicit psychological responses through visual stimuli, subsequently perceiving the aesthetic perception of the design effect [43,44]. The aesthetics of product design is both the embodiment of the explicit visual characteristics of the product exterior and the implicit emotional characteristics expression of the product connotations.

The content of product design aesthetics in the context of sustainable development includes reliable usability, good man–machine interaction, simple product upgrading, and product design to reflect simple social values. In this context, the product design style presents a unique aesthetic feeling. Combined with the analysis of various representative sustainable product design styles, its aesthetics present that product design recovers original simplicity and returns to original nature.

The core concept of product design aesthetics under the background of sustainable development is the harmonious development of products and various factors, reflecting the original aesthetic characteristics of products. For example, the rationality of product use, the simplicity of product upgrade, the rationality of product human–computer interaction, and lower resource consumption constitute the aesthetic design characteristics in the context of sustainable development, as shown in Figure 3.



Figure 3. Product design principles under the background of sustainable development.

The information counter is an important public facility in railway stations [45,46]. Elements of the information counter include display screens, stand columns, and platforms. The design elements of the information counter include form, color, material, decorative elements, and others; the combination of design elements and component elements constitutes the foundation for aesthetic design in the information counter. At the same time, the aesthetic design of the information counter is influenced by various factors, including regional culture, station architectural style, and others, as shown in Figure 4.

The factors of aesthetic design can be categorized into explicit and implicit levels. The explicit level includes design features and a combination of design elements, and the implicit level refers to emotional information.

To sum up, aesthetic design can be divided into feature, structure, and concept layers. The feature layer aesthetic mainly refers to the aesthetic impact of form, color, and other concrete elements within the design scheme. The structure layer aesthetic mainly refers to the aesthetic feeling generated by combinatorial relations in the design elements and components for the information counter appearance. The concept layer aesthetic mainly

refers to implicit aesthetic feelings, such as cultural characteristics and symbolic traits, as shown in Figure 5.

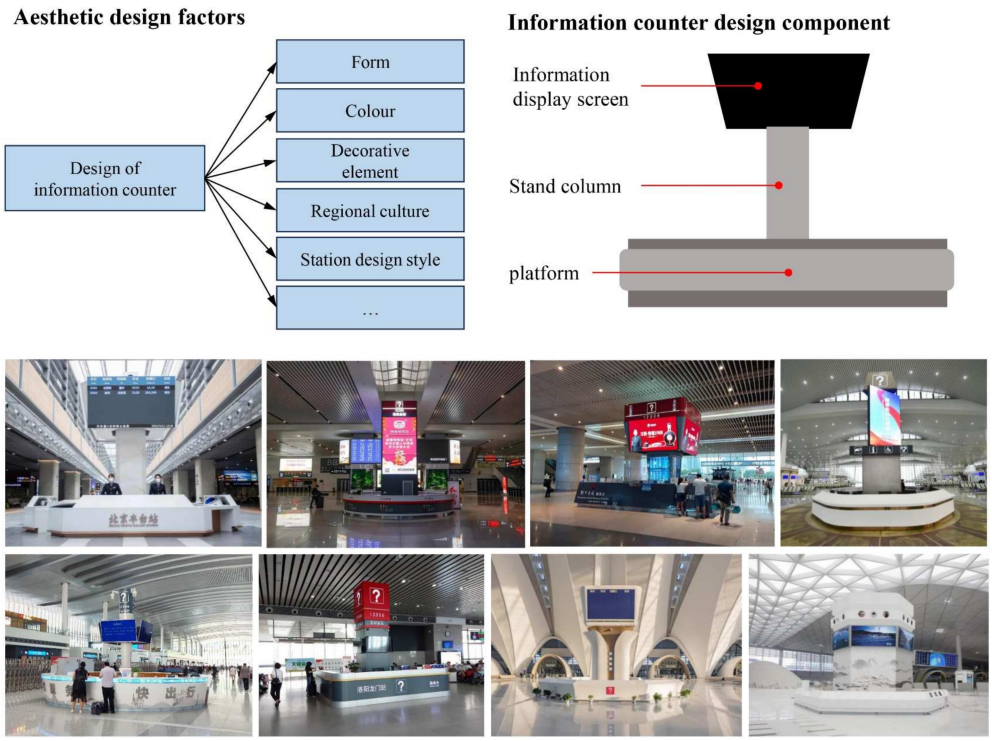


Figure 4. Examples and analysis of the research object.

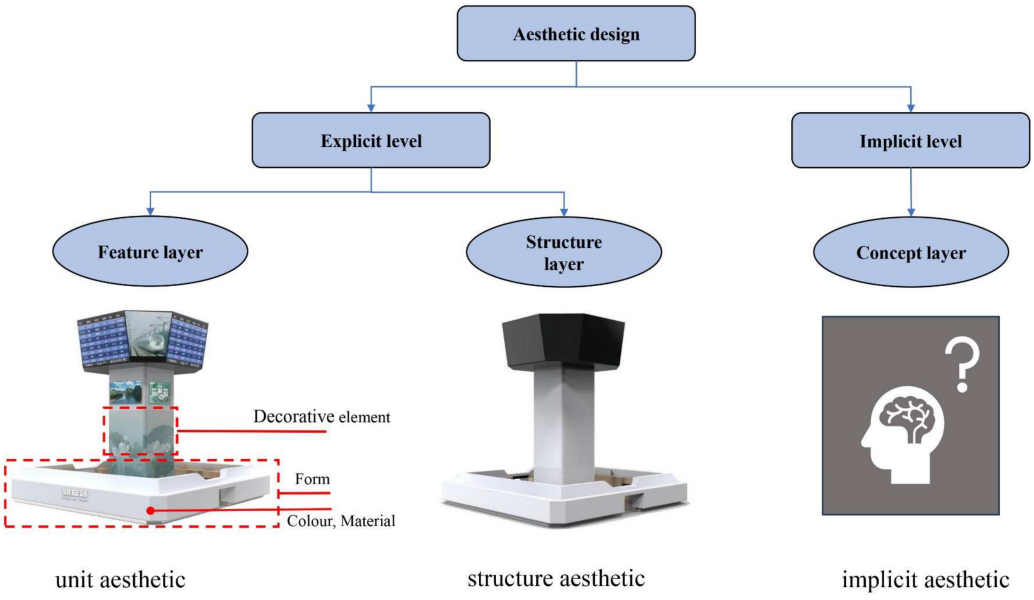


Figure 5. Aesthetic cognitive layer analysis.

Based on the analysis of product aesthetic trends in the context of sustainable development and relevant research [47], information counter aesthetic element indicators can be divided into the feature layer, structure layer, and concept layer. The aesthetic evaluation system as shown in Figure 6. The meaning analysis of each aesthetic index is shown in Table 1.

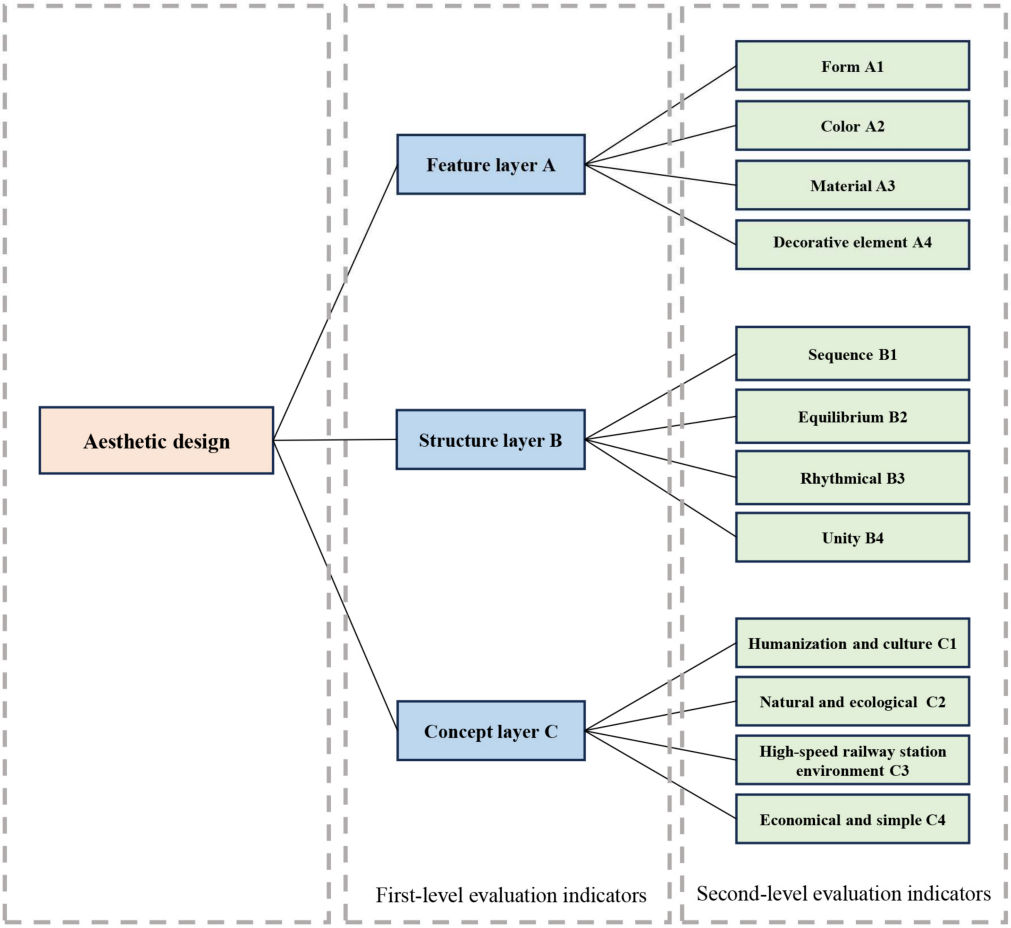


Figure 6. Indicator system of the aesthetic element.

Table 1. Definitions of indicators.

Level	Aesthetic Element	Meaning
Feature layer	Form	Form aesthetic feeling is the sustainable design aesthetics for the product form design
	Color	Color aesthetic feeling is the sustainable design aesthetics for the product color design
	Material	Material aesthetic feeling is the sustainable design aesthetics for the product material design
	Decorative element	Decorative element aesthetic feeling is the sustainable design aesthetics for the product decorative design
Structure layer	Sequence	Sequence feeling refers to the arrangement of relationships in the design elements and components for the information counter appearance
	Equilibrium	Equilibrium is a stabilization of the relationship between the design elements and components for the information counter appearance
	Rhythm	Rhythm feeling refers to regular patterns of changes in the design elements and components for information counter appearance. This regular pattern of changes can help to make spirituality
	Unity	Unity feeling is coherence and wholeness of relationships in the design elements and components for the information counter appearance
Concept layer	Humanization and culture	Harmony with the humanization of local culture
	Natural and ecological	Harmony with the local natural environment
	railway station environment	Harmony with the railway station environment
	Economical and simple	Simplicity of processing and manufacturing

3.2. Kansei Image and Kansei Engineering

The Kansei image is the emotional cognition and response of the design concept, which is a relatively abstract description of the initial state of the design. The specific description of the Kansei image primarily includes visual images and semantic words, which represent explicit features and implicit features, respectively.

Kansei Engineering is a quantitative research method for the emotional cognition of products, and it was proposed by Mitsuo Nagamachi in the 1970s [48,49]. Kansei Engineering involves the transformation of emotional elements into design elements through analysis of users' perceptual cognition to help designers create schemes. This method was widely applied in different domains, such as product design, clothing design, and others, and was often used to evaluate design schemes, extract cultural features, and analyze user images [50,51].

Kansei Engineering is frequently utilized for feature extraction of Kanei images by the Kansei word scale. Yuedi Huang [52] et al. used Kansei Engineering to extract intangible cultural heritage features. Hartono, M [53] used a modified Kansei Engineering method to explore service demand attraction and applied it to sustainable service design. Kansei Engineering has become an important method for emotional feature extraction.

The semantic differential method (SD method) [54] is a quantitative analysis about people's emotional cognition; the SD method uses a pair of adjectives to describe a person's perception. Kansei Engineering extracts crucial perceptual information by Kansei words [55], as shown in Figure 7.

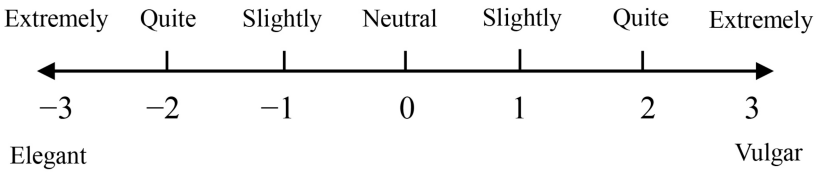


Figure 7. SD method diagram.

The design format analysis (DFA) [56,57] is a quantitative analysis of appearance features and was proposed by Anders Warell in 2001. Firstly, the DFA method needs to collect a series of descriptions of explicit form features, such as circles, squares, and others. Secondly, the feature correlation of the samples was scored based on the form feature description. Finally, the form feature of samples was analyzed by mathematical statistical methods (Equation (1)) [58].

$$\overline{X}_{ijk} = \frac{\sum_{k=1}^{n} X_{ijk}}{n} \quad (1)$$

where i represents the number of samples, j represents the number of features, and n represents the number of participants in the experiment. The horizontal column represents the features of each product and the vertical column represents each product sample, and the experimental results were obtained by calculating scores. The principal analysis is shown in Figure 8.

In this study, the critical Kansei image feature (such as semantic features and form features) is obtained through the factor analysis method and design format analysis method based on a typical Kansei image sample; it provides guidance on semantic and form features for designers to create a design scheme, as shown in Figure 9.

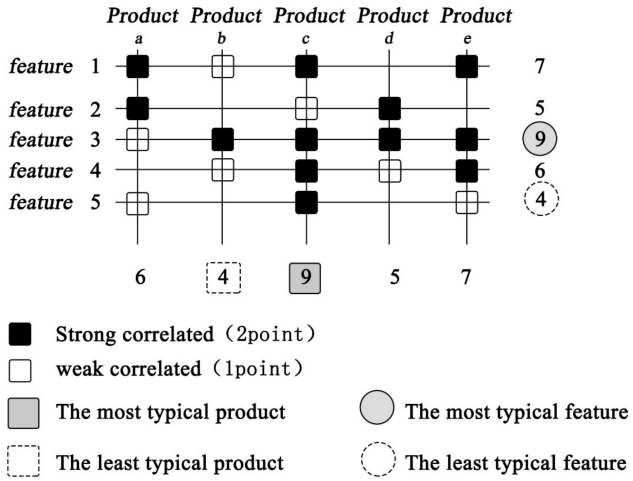


Figure 8. DFA method diagram.

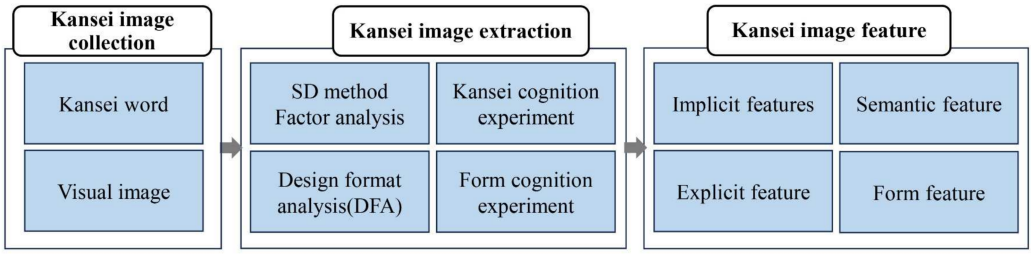


Figure 9. Kansei image feature extraction method process.

3.3. AHP Method

The AHP proposed by T.L. Saaty in 1988 combines qualitative and quantitative analysis with multi-dimensional index analysis methodology [59,60].

To determine the weight value of each element index, a judgment matrix was constructed through comparison, and the importance evaluation of two indexes was conducted using the 1–9 scale, as presented in Table 2.

Table 2. The 1–9 scale values and meaning.

Scale Values	Significance	Meaning
1	Equally important	Both elements are equally important
3	Slightly important	The former element is slightly more important than the latter
5	Significantly important	The former element is clearly more important than the latter
7	Very importance	The former element is strongly more important than the latter
9	Absolutely important	The former element is absolutely more important than the latter
2, 4, 6, 8	Midpoint	Indicates the median of the above two elements
1, 1/2,. . ., 1/9	Inverse comparison	The latter element is the inverse of the above value when compared to the former element

The fuzzy judgment matrix M was established based on the scale values obtained from expert rating data. The relative importance of index i compared to index j was denoted as α_{ij}. Thus, the expression for the fuzzy judgment matrix M is as described in Equation (2).

$$M = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \cdots & \alpha_{1n} \\ \alpha_{21} & \alpha_{22} & \cdots & \alpha_{2n} \\ \cdots & \cdots & \cdot & \cdots \\ \alpha_{n1} & \alpha_{n2} & \cdots & \alpha_{nn} \end{bmatrix} \quad (2)$$

The geometric average method is employed to determine the weight value of each index. The procedure is as follows:

1. Calculate the product M_i for each row value in the fuzzy judgment matrix M.

$$\mathrm{M_i} = \prod_{j=1}^{n} \alpha_{ij} (i = 1, 2, \ldots, n) \tag{3}$$

2. The geometric mean value of the fuzzy judgment matrix is derived.

$$\overline{W_i} = \sqrt[n]{M_i} (i = 1, 2, \ldots, n) \tag{4}$$

3. After the process of normalization, the relative weight Wi is derived in the following manner:

$$W_\mathrm{i} = \frac{\overline{W_i}}{\sum_{i=1}^{n} \overline{W_i}} (i = 1, 2, \ldots, n) \tag{5}$$

4. The consistency index is calculated according to the maximum eigenvalue λ max.

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1} \tag{6}$$

5. The consistency ratio, CR, can be calculated as follows:

$$CR = \frac{CI}{RI} \tag{7}$$

Based on Table 3, the random consistency coefficient value RI corresponding to the order n of the matrix is retrieved. If the obtained CR value is less than 0.1, it indicates an acceptable level of consistency in the judgment matrix; otherwise, readjustment of the judgment matrix is required.

Table 3. Random consistency index.

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

3.4. FCE Method

The FCE (fuzzy comprehensive evaluation) is a comprehensive evaluation method based on fuzzy set theory [61,62]; the concept of fuzzy mathematics was proposed by Professor L.A. Zadeh in 1965 [63]. It used the maximum membership principle to conduct a quantitative comprehensive evaluation.

The main calculation process is as follows:

1. Establish the evaluation factor index set U, U = {$U1$, $U2$, $U3$, . . .}.
2. Create an evaluation set. The evaluation set is V, V = {$V1$, $V2$, . . .,Vp}, and evaluation level is categorized into 5 levels: excellent, good, general, poor, and very poor. The 5 grades of excellent, good, general, poor, and very poor translate to scores of 10, 8, 6, 4, and 2.
3. Establish the fuzzy matrix R. The percentage method is used to calculate the membership and determine the fuzzy matrix R, as described in Equation (8).

$$R = \begin{bmatrix} \mathrm{r_{11}} & \mathrm{r_{12}} & \cdots & \mathrm{r_{1m}} \\ \mathrm{r_{21}} & \mathrm{r_{22}} & \cdots & \mathrm{r_{2m}} \\ \cdots & \cdots & \cdots & \cdots \\ \mathrm{r_{p1}} & \mathrm{r_{p2}} & \cdots & \mathrm{r_{pm}} \end{bmatrix} \tag{8}$$

4. Determine the weight vector of evaluation factors, W = ($\mathrm{a_1}$, $\mathrm{a_2}$,...,$\mathrm{a_p}$).

5. According to the determined weight vector W and matrix R, the fuzzy evaluation vector X was calculated, as described in Equation (9).

$$X = W \cdot R \tag{9}$$

6. Calculate the comprehensive score Y, as described in Equation (10).

$$Y = X \cdot V \tag{10}$$

3.5. AHP-FCE Model

The AHP-FCE model integrates the analytic hierarchy process (AHP) and fuzzy comprehensive evaluation (FCE); the model used the AHP to calculate the weight and the FCE method to evaluate the design scheme comprehensively.

The AHP-FCE model for the information counter design is shown in Figure 10. Firstly, the weight ranking of each aesthetic element index is determined using the AHP. Secondly, based on aesthetic weight analysis, combined with Kansei image features, the design schemes are created. Finally, the design schemes are evaluated by the FCE method, and the resulting analysis is utilized for optimizing the scheme.

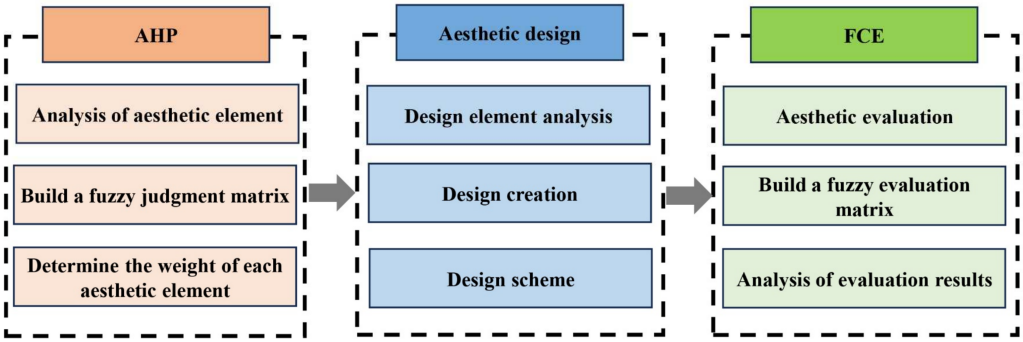


Figure 10. AHP-FCE model for aesthetic design.

4. Research Case

4.1. Kansei Image Features Extraction

Through the data analysis of Xiong'an railway station, the architectural design of the railway station is inspired by water droplets on lotus leaves in Baiyangdian Lake [61], as shown in Figure 11. Therefore, this study takes Xiong'an ecological culture as the theme, collecting relevant visual images and Kansei words.



Figure 11. Typical visual image samples.

Firstly, ecological and cultural data related from Xiong'an district (as referenced on the website of Xiong'an China) were gathered. By systematically analyzing the Xiong'an ecological culture, nine typical visual image samples (M1–M9) were selected from concept level, style level, and feature level, as shown in Figure 12.



Figure 12. Typical visual image samples.

Through the investigation of historical and cultural data of Xiong'an district, eight typical Kansei word groups were obtained and formulated opposite descriptive phrases, as presented in Table 4. Table 5 is an example of the Kansei cognition questionnaire using the SD method; the positive Kansei word meaning is represented on the right side of the scale, while the negative Kansei word meaning is depicted on the left side. The scores at both ends (−3 and 3) signify a strong correlation.

Table 4. Collection of Kansei words.

Number	Kansei Words	Number	Kansei Words
S1	Elegant–Vulgar	S5	Light–Heavy
S2	Introverted–Extraverted	S6	Concise–Trival
S3	Gentle–Hard	S7	Exquisite–Rough
S4	Delicate–Rough	S8	Flow–Quiet

Table 5. Kansei image cognition questionnaire.

Kansei Words	−3	−2	−1	0	1	2	3	Kansei Words
	Extremely	Quite	Slightly	Neutral	Slightly	Quite	Extremely	
S1 Elegant								Vulgar
S2 Introverted								Extraverted
S3 Gentle								Hard
S4 Delicate								Rough
S5 Lithe								Heavy
S6 Concise								Cumbersome
S7 Exquisite								Rough
S8 Flow								Quiet

In order to obtain crucial Kansei information, Kansei image cognition experiments were conducted on the nine samples (Figure 12, M1–M9) in conjunction with the utilization

of the image cognition questionnaire (Table 5). The experiment rating data come from 40 people (the 40 people all know Xiong'an culture), and the average scores obtained are shown in Table 6.

Table 6. Average score of the imagery perception experiment.

	S1	S2	S3	S4	S5	S6	S7	S8
M_1	−2.275	−1.125	−1.525	−1.650	−1.025	−1.900	−2.125	−1.250
M_2	−1.950	−2.050	−1.825	−1.825	−2.275	−2.150	−1.075	−2.300
M_3	−0.925	1.125	−0.575	1.200	0.900	1.175	1.350	−2.150
M_4	−2.025	−2.100	−2.125	−1.525	−1.125	−2.250	−1.550	−2.450
M_5	−0.950	2.350	2.600	−1.250	−1.050	2.150	2.550	−2.350
M_6	−1.825	1.475	−1.375	1.425	0.075	2.150	2.300	−2.575
M_7	−2.500	−2.450	−2.400	−2.350	−1.225	−2.150	−2.125	−2.600
M_8	−2.350	−2.175	−1.725	−1.250	−1.825	−1.875	−1.475	−2.050
M_9	−2.400	−2.500	−2.425	−2.400	−1.175	−2.550	−2.175	−2.150

The experimental results were factor analyzed using SPSS 22 software. The KMO is 0.577, and Bartlett's test of sphericity is 0.000, indicating that the results can be factor analyzed. The total variance results are presented in Table 7, and gravel diagram analysis is shown in Figure 13. The rotated component matrix is displayed in Table 8. The 3D component diagram analysis is shown in Figure 14.

Table 7. Factor analysis of total variance explained.

Components	Initial Eigenvalue			Extract the Sum of Squares of Loads			The Sum of the Squares of Rotating Loads		
	Total	Percentage of Variance	Accumulate %	Total	Percentage of Variance	Accumulate %	Total	Percentage of Variance	Accumulate %
1	5.467	68.336	68.336	5.467	68.336	68.336	3.741	46.759	46.759
2	1.094	13.670	82.007	1.094	13.670	82.007	2.705	33.816	80.575
3	1.008	12.604	94.610	1.008	12.604	94.610	1.123	14.036	94.610

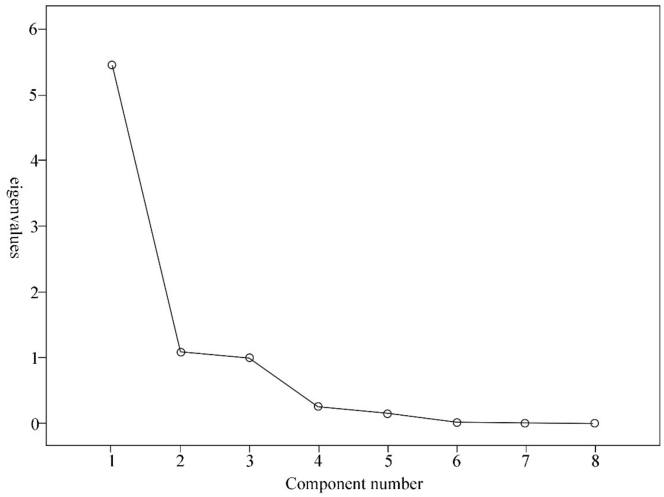


Figure 13. Gravel diagram.

According to Table 7 and Figure 13, the first three factors can explain 94.610% of implicit Kansei information of Xiong'an ecological culture. In Table 8 and Figure 14, we can obtain the Kansei word group included in each factor.

In factor 1, S1 (elegant–vulgar), S2 (introverted–extraverted), S3 (gentle–hard), S6 (concise–trivial), and S7 (exquisite–rough) have a greater load, which mainly reflect the refined and understated aesthetic of Xiong'an ecological culture.

In factor 2, S4 (delicate–rough) and S5 (light–heavy) have a greater load, which mainly reflect the delicate aesthetics of Xiong'an ecological culture.

In factor 3, S8 (flow–quiet) has a greater load, which mainly reflects the dynamic aesthetic of Xiong'an ecological culture.

To sum up, the culture of Xiong'an can be summarized as elegant, gentle, and intelligent. According to the analysis of the factor analysis total variance explained (Table 7) and the induction of each semantic, the variance contribution rate/cumulative variance contribution rate is used to calculate the weight of each factor, as shown in Table 9.

Table 8. Rotated component matrix.

	Main Ingredients		
	1	**2**	**3**
S1	0.835	0.392	−0.060
S2	0.835	0.528	−0.039
S3	0.991	−0.011	0.042
S4	0.299	0.908	−0.115
S5	0.209	0.921	0.022
S6	0.770	0.580	−0.192
S7	0.797	0.510	−0.284
S8	−0.066	−0.051	0.992

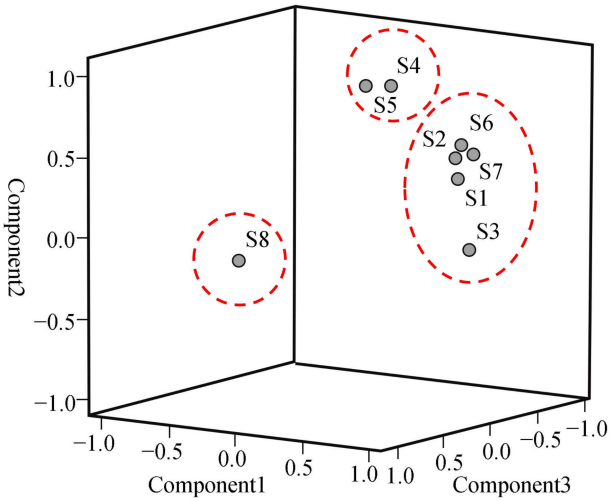


Figure 14. Diagram of each factor component.

Table 9. Weight analysis of each factor.

	Semantic	**Description of Factor Characteristics**	**Weight**	**Ranking by Importance**
factor 1	S1 (elegant–vulgar) S2 (introverted–extraverted) S3 (gentle–hard) S6 (concise–trival) S7 (exquisite–rough)	refined aesthetic, understated aesthetic	0.494	1
factor 2	S4 (delicate–rough) S5 (light–heavy)	delicate aesthetic	0.357	2
factor 3	S8 (flow–quiet)	dynamic aesthetic	0.148	3

In order to extract the form feature description of typical visual image samples, the explicit form feature information of typical visual image samples (M1–M9) was extracted by the DFA method.

Based on nine visual image samples (M1–M9), six phrases of form features description were collected, as shown in Table 10. The form feature description is derived from both the overall shape and detailed shape levels, such as square, circular, abstract, and others. The scale is 1–3 points, and higher scores indicate a strong correlation of corresponding features.

Table 10. Collection of form feature description and score.

Number	From Feature Description	Unrelated (1)	Correlated (2)	Strong Correlated (3)
F1	shape is a circle			
F2	shape is a square			
F3	shape turning arc			
F4	shape turning straight line			
F5	shape is an abstraction			
F6	shape is smooth			

The experiment involved a total of 40 adults. The experimental results are calculated based on Equation (1) and the DFA method principle (Figure 8) to form experimental results, as shown in Figure 15, and the statistical results are shown in Figure 16.

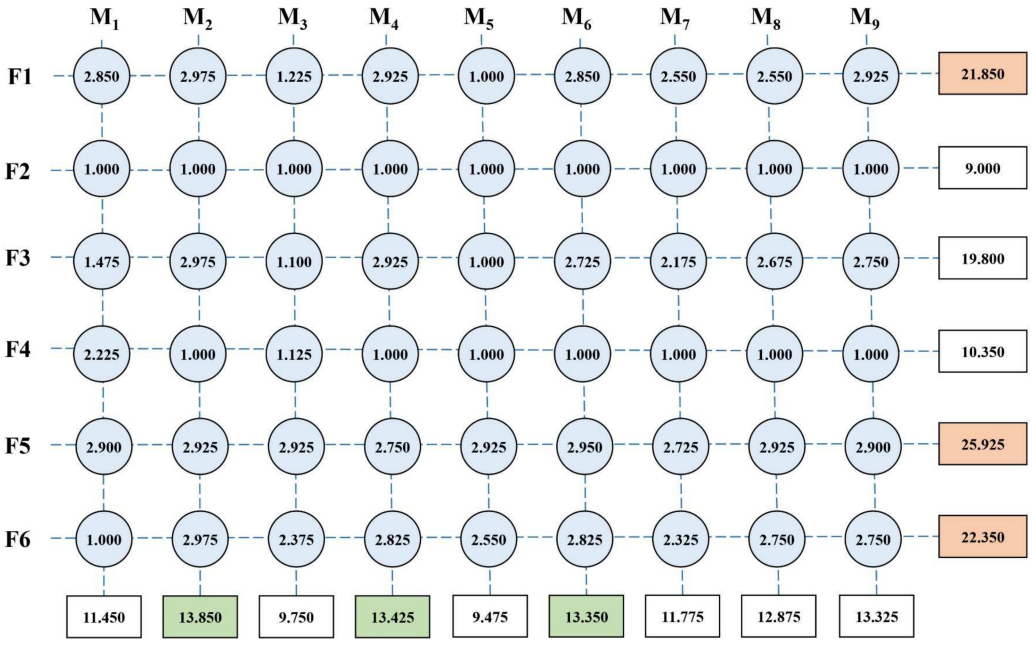


Figure 15. Design format analysis of experimental results.

According to Figure 15, features F1, F5, and F6 have higher scores, which shows that its feature recognition is good, and the features can be used as the main sources of form features. Visual images M2, M4, and M6 have higher scores, which shows that their recognition is good, and the visual images can be used as important image sources.

Figure 16 illustrates the score fluctuation of F1-F6 features. Most of the image scores of F2 and F4 are lower than two points, indicating that F2 and F4 have poor feature recognition. This shows that square and straight turns are not typical.

To sum up, the form feature of Xiong'an ecological cultural samples can be described as follows. In the overall shape level, the main features are circles, streamlines, and abstractions. In the detail form level, an arc shape with smooth contours is observed. In the

form transition level, rounded corners are evident. Visual images M2, M4, and M6 can be used as important image sources. The analysis of each feature is shown in Table 11.

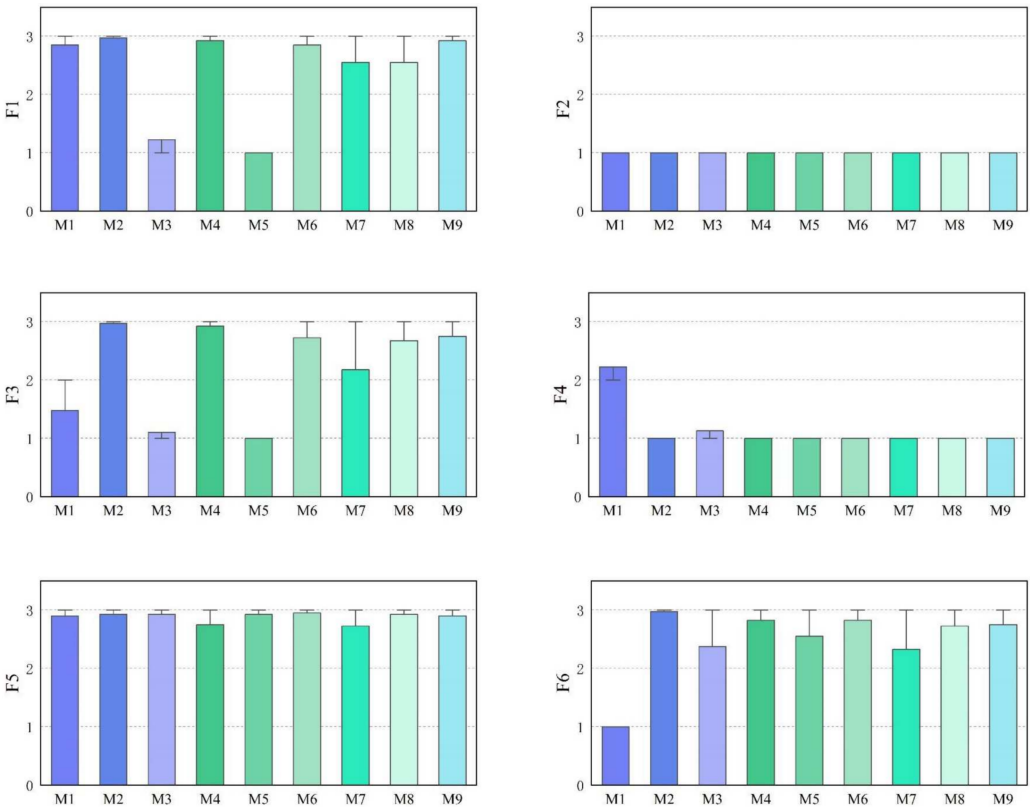


Figure 16. Statistical chart of design format analysis.

Table 11. The analysis of typical form features.

Feature Classification	Feature Description	Visual Image Screening
Overall shape	The main features are circles, streamlines, and abstractions	
Detail shape	The main features are the smooth arc shape	
Shape transition	Rounded corners are evident	

4.2. Aesthetic Weight Analysis Based on the AHP

Based on the aesthetic index (Table 1 and Figure 6), the AHP is used to calculate the weight of aesthetic elements (Equations (2)–(7)), and the rating data come from 10 experts (the experts are from the research field of industrial design). The results are shown in Tables 12–15.

Table 12. Judgment matrix and weight value of the first layer.

	A	*B*	*C*	ω	λ_{max}	*CI*	*CR*
A	1	3.6	4.6	0.6481			
B	0.30	1	3.4	0.2513	3.09089	0.04545	0.07836
C	0.20	0.29	1	0.1006			

Table 13. Judgment matrix and weight value of the A layer.

A	A_1	A_2	A_3	A_4	ω (A_i)	λ_{max}	*CI*	*CR*
A_1	1	4.3	4.1	5.4	0.5566			
A_2	0.23	1	3.3	4.6	0.2608	4.2131	0.07104	0.07982
A_3	0.24	0.30	1	1.43	0.1053			
A_4	0.19	0.22	0.70	1	0.0774			

Table 14. Judgment matrix and weight value of the B layer.

B	B_1	B_2	B_3	B_4	ω (B_i)	λ_{max}	*CI*	*CR*
B_1	1	0.29	0.72	0.18	0.0914			
B_2	3.45	1	3.4	0.76	0.3482	4.1834	0.06114	0.06869
B_3	1.40	0.30	1	0.72	0.1625			
B_4	5.65	1.32	1.39	1	0.3847			

Table 15. Judgment matrix and weight value of the C layer.

C	C_1	C_2	C_3	C_4	ω (C_i)	λ_{max}	*CI*	*CR*
C_1	1	4.8	3.8	1.93	0.4844			
C_2	0.21	1	3.9	0.52	0.1742	4.2411	0.08036	0.09030
C_3	0.26	0.26	1	0.32	0.0835			
C_4	0.52	1.94	3.125	1	0.2653			

The calculation results satisfy the criterion CR < 0.1 in Tables 12–15, which passes the consistency test. According to the aforementioned formula, the weight values of indicators for all layers of aesthetic elements can be derived, as shown in Table 16.

Table 16. Weight of aesthetic elements.

First-Level Indicators	Weight (*W1*)	Sorting	Second-Level Indicators	Weights (*W2*)	Sorting
A	0.6281	1	A_1	0.5566	1
			A_2	0.2608	2
			A_3	0.1053	3
			A_4	0.0774	4
B	0.2675	2	B_1	0.0914	4
			B_2	0.3482	2
			B_3	0.1625	3
			B_4	0.3847	1
C	0.1006	3	C_1	0.4844	1
			C_2	0.1742	3
			C_3	0.0835	4
			C_4	0.2579	2

Based on Table 16, the aesthetic weight of the first-level index is as follows: feature layer A > structure layer B > concept layer C. In the feature layer, $A_1 > A_2 > A_3 > A_4$. In the structure layer, $B_4 > B_2 > B_3 > B_1$. In the conceptual layer, $C_1 > C_4 > C_2 > C_3$.

4.3. Design Scheme Creation

The design scheme is formulated by integrating Kansei image features and aesthetic importance analysis. Subsequently, comprehensive evaluation analysis uses the FCE method, and the process as shown in Figure 17.

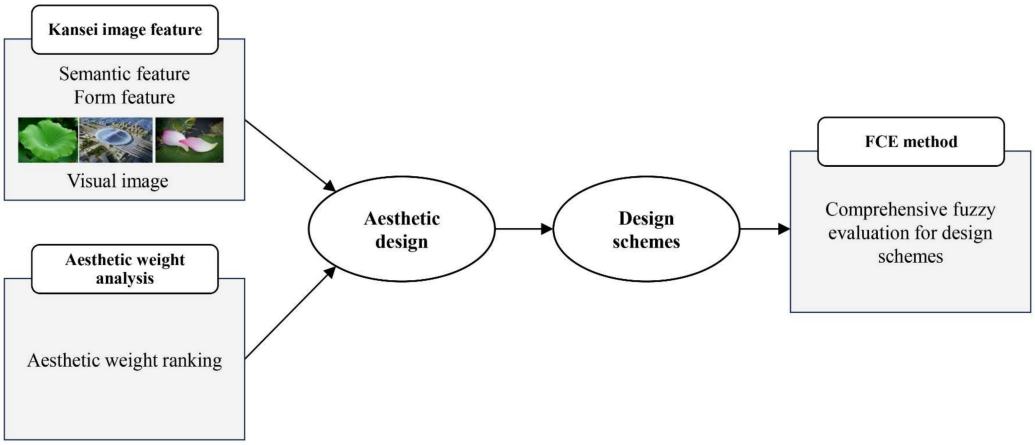


Figure 17. Formation process of the design scheme.

Based on the analysis of Xiong'an Kansei image features and the aesthetic weight ranking in the previous study, we have created four information counter design schemes in the railway station (K1–K4), as shown in Figure 18.

4.4. FCE Method for Design Schemes

In order to further optimize the scheme, the FCE method is used to evaluate the aesthetic effect of each design scheme. The evaluation level is categorized into five levels: excellent, good, general, poor, and very poor, and the rating data come from thirty persons.

Based on the statistical data presented, the fuzzy comprehensive evaluation matrix R1–R4 for the evaluation index of the design scheme K1–K4 is as follows.

$$R_1 = \begin{bmatrix} 14/30 & 13/30 & 3/30 & 0/30 & 0/30 \\ 13/30 & 14/30 & 3/30 & 0/30 & 0/30 \\ 12/30 & 13/30 & 5/30 & 0/30 & 0/30 \\ 14/30 & 13/30 & 3/30 & 0/30 & 0/30 \\ 10/30 & 15/30 & 5/30 & 0/30 & 0/30 \\ 9/30 & 15/30 & 6/30 & 0/30 & 0/30 \\ 8/30 & 13/30 & 9/30 & 0/30 & 0/30 \\ 7/30 & 17/30 & 6/30 & 0/30 & 0/30 \\ 13/30 & 10/30 & 7/30 & 0/30 & 0/30 \\ 8/30 & 11/30 & 11/30 & 0/30 & 0/30 \\ 7/30 & 7/30 & 16/30 & 0/30 & 0/30 \\ 11/30 & 15/30 & 4/30 & 0/30 & 0/30 \end{bmatrix}$$

$$R2 = \begin{bmatrix} 21/30 & 8/30 & 1/30 & 0/30 & 0/30 \\ 16/30 & 9/30 & 5/30 & 0/30 & 0/30 \\ 15/30 & 8/30 & 7/30 & 0/30 & 0/30 \\ 16/30 & 8/30 & 6/30 & 0/30 & 0/30 \\ 19/30 & 7/30 & 4/30 & 0/30 & 0/30 \\ 24/30 & 4/30 & 2/30 & 0/30 & 0/30 \\ 18/30 & 9/30 & 3/30 & 0/30 & 0/30 \\ 23/30 & 5/30 & 2/30 & 0/30 & 0/30 \\ 19/30 & 7/30 & 4/30 & 0/30 & 0/30 \\ 13/30 & 10/30 & 7/30 & 0/30 & 0/30 \\ 15/30 & 8/30 & 17/30 & 0/30 & 0/30 \\ 22/30 & 5/30 & 3/30 & 0/30 & 0/30 \end{bmatrix}$$

$$R3 = \begin{bmatrix} 11/30 & 13/30 & 6/30 & 0/30 & 0/30 \\ 9/30 & 14/30 & 7/30 & 0/30 & 0/30 \\ 12/30 & 12/30 & 6/30 & 0/30 & 0/30 \\ 10/30 & 13/30 & 7/30 & 0/30 & 0/30 \\ 13/30 & 11/30 & 6/30 & 0/30 & 0/30 \\ 12/30 & 10/30 & 8/30 & 0/30 & 0/30 \\ 18/30 & 11/30 & 3/30 & 0/30 & 0/30 \\ 9/30 & 16/30 & 5/30 & 0/30 & 0/30 \\ 10/30 & 13/30 & 7/30 & 0/30 & 0/30 \\ 8/30 & 15/30 & 17/30 & 0/30 & 0/30 \\ 9/30 & 12/30 & 9/30 & 0/30 & 0/30 \\ 12/30 & 13/30 & 5/30 & 0/30 & 0/30 \end{bmatrix}$$

$$R4 = \begin{bmatrix} 16/30 & 8/30 & 6/30 & 0/30 & 0/30 \\ 15/30 & 10/30 & 5/30 & 0/30 & 0/30 \\ 15/30 & 9/30 & 6/30 & 0/30 & 0/30 \\ 15/30 & 10/30 & 5/30 & 0/30 & 0/30 \\ 14/30 & 9/30 & 7/30 & 0/30 & 0/30 \\ 13/30 & 8/30 & 9/30 & 0/30 & 0/30 \\ 18/30 & 9/30 & 3/30 & 0/30 & 0/30 \\ 14/30 & 7/30 & 9/30 & 0/30 & 0/30 \\ 16/30 & 8/30 & 7/30 & 0/30 & 0/30 \\ 19/30 & 9/30 & 2/30 & 0/30 & 0/30 \\ 16/30 & 9/30 & 3/30 & 0/30 & 0/30 \\ 15/30 & 12/30 & 3/30 & 0/30 & 0/30 \end{bmatrix}$$

According to Equation (9), we can obtain the fuzzy evaluation vector X1a–X1c for the feature layer, structure layer, and concept layer of design scheme K1.

$$X_{1a} = W \times R_{1a} = (0.5566,\ 0.2608,\ 0.1053\ ,\ 0.0774) \bullet \begin{bmatrix} 0.47 & 0.43 & 0.10 & 0 & 0 \\ 0.43 & 0.47 & 0.10 & 0 & 0 \\ 0.40 & 0.43 & 0.17 & 0 & 0 \\ 0.47 & 0.43 & 0.10 & 0 & 0 \end{bmatrix} = (0.451, 0.442, 0.107, 0, 0)$$

$$X_{1b} = W \times R_{1b} = (0.0914,\ 0.3482,\ 0.1625\ ,\ 0.3847) \bullet \begin{bmatrix} 0.33 & 0.50 & 0.17 & 0 & 0 \\ 0.300 & 0.50 & 0.20 & 0 & 0 \\ 0.27 & 0.43 & 0.30 & 0 & 0 \\ 0.23 & 0.57 & 0.20 & 0 & 0 \end{bmatrix} = (0.268, 0.508, 0.211, 0, 0)$$

$$X_{1c} = W \times R_{1c} = (0.4844,\ 0.1742,\ 0.0835\ ,\ 0.2579) \bullet \begin{bmatrix} 0.43 & 0.33 & 0.23 & 0 & 0 \\ 0.27 & 0.37 & 0.37 & 0 & 0 \\ 0.23 & 0.23 & 0.53 & 0 & 0 \\ 0.37 & 0.50 & 0.13 & 0 & 0 \end{bmatrix} = (0.370, 0.374, 0.256, 0, 0)$$

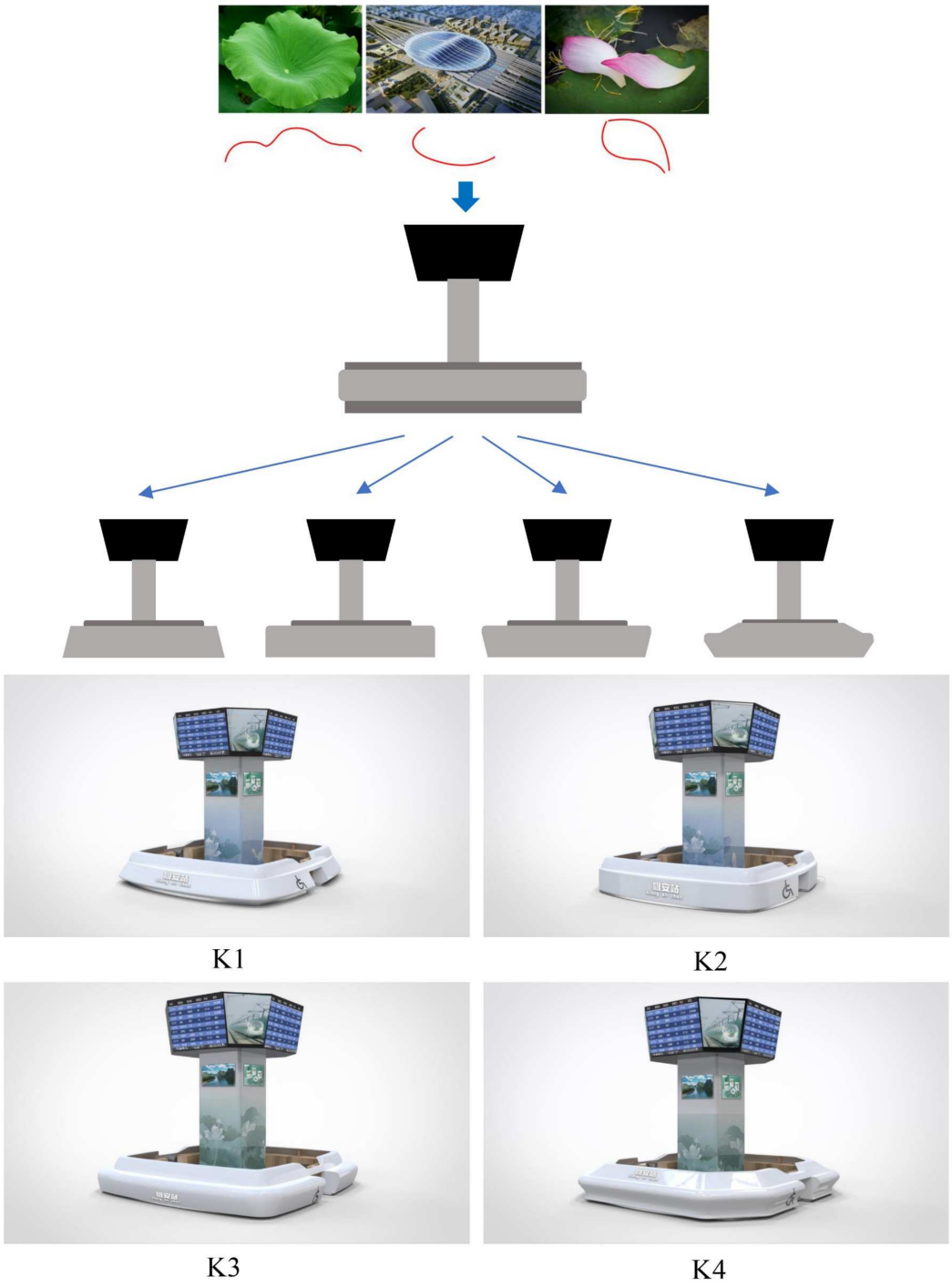


Figure 18. Design scheme effect.

The total fuzzy evaluation vector X1 of design scheme k1 is calculated as follows:

$$X_1 = W \times R'_1 = (0.6281,\ 0.2675,\ 0.1006) \bullet \begin{bmatrix} 0.451 & 0.442 & 0.107 & 0 & 0 \\ 0.268 & 0.508 & 0.211 & 0 & 0 \\ 0.370 & 0.374 & 0.256 & 0 & 0 \end{bmatrix} = (0.392, 0.451, 0.149, 0, 0)$$

Using the same method, the fuzzy evaluation vector and the total fuzzy evaluation vector for schemes K2–K4 can be calculated.

The fuzzy evaluation vector X_{2a}–X_{2c} and the total fuzzy evaluation vector X_2 for scheme K2 are as follows:

$$X_{2a} = W \times R_2 = (0.623,\ 0.275,\ 0.102,\ 0,\ 0)$$

$$X_{2b} = W \times R_2 = (0.729,\ 0.181,\ 0.077,\ 0,\ 0)$$

$$X_{2c} = W \times R_2 = (0.613,\ 0.236,\ 0.151,\ 0,\ 0)$$

$$X_2 = W \times R'_2 = (0.648\ 0.255,\ 0.100,\ 0,\ 0)$$

The fuzzy evaluation vector X_{3a}–X_{3c} and the total fuzzy evaluation vector X_3 for scheme K3 are as follows:

$$X_{3a} = W \times R_{3a} = (0.350,\ 0.439,\ 0.211,\ 0,\ 0)$$

$$X_{3b} = W \times R_{3b} = (0.392,\ 0.414,\ 0.192,\ 0,\ 0)$$

$$X_{3c} = W \times R_{3c} = (0.336,\ 0.442,\ 0.222,\ 0,\ 0)$$

$$X_3 = W \times R'_3 = (0.359,\ 0.431,\ 0.206,\ 0,\ 0)$$

The fuzzy evaluation vector X_{4a}–X_{4c} and the total fuzzy evaluation vector X_4 for scheme K4 are as follows:

$$X_{4a} = W \times R_4 = (0.519,\ 0.293,\ 0.189,\ 0,\ 0)$$

$$X_{4b} = W \times R_4 = (0.471,\ 0.259,\ 0.257,\ 0,\ 0)$$

$$X_{4c} = W \times R_4 = (0.542,\ 0.310,\ 0.159,\ 0,\ 0)$$

$$X_4 = W \times R'_4 = (0.506,\ 0.284,\ 0.203,\ 0,\ 0)$$

According to Equation (10), by converting the five grades of excellent, good, general, poor, and very poor to scores of 10, 8, 6, 4, and 2, respectively, the comprehensive evaluation score Y_1–Y_4 for design scheme K1–K4 was calculated.

$$Y_1 = 0.392 \times 10 + 0.451 \times 8 + 0.149 \times 6 + 0 \times 4 + 0 \times 2 = 8.422$$

$$Y_2 = 0.648 \times 10 + 0.255 \times 8 + 0.100 \times 6 + 0 \times 4 + 0 \times 2 = 9.120$$

$$Y_3 = 0.359 \times 10 + 0.431 \times 8 + 0.206 \times 6 + 0 \times 4 + 0 \times 2 = 8.274$$

$$Y_4 = 0.506 \times 10 + 0.284 \times 8 + 0.203 \times 6 + 0 \times 4 + 0 \times 2 = 8.550$$

By comparing the scores, it can be determined that the comprehensive evaluation of K2 is the best.

5. Result and Discussion

5.1. Evaluation Result Analysis

According to the above analysis of the fuzzy evaluation vector for schemes K2–K4, the fuzzy evaluation vector of each scheme is shown in Figure 19.

According to Figure 19, the fuzzy evaluation vector of design scheme K2 in various aspects is excellent and has high membership. In order to analyze the design information of scheme K2, the scores of scheme K2 in each feature level can be calculated.

The comprehensive evaluation score for design scheme K2 is presented as follows.

Evaluation vector of feature layer A.

$$Y_a = 10 \times 0.623 + 8 \times 0.275 + 6 \times 0.102 + 4 \times 0 + 2 \times 0 = 9.092$$

Evaluation vector of structure layer B.

$$Y_b = 10 \times 0.729 + 8 \times 0.181 + 6 \times 0.077 + 4 \times 0 + 2 \times 0 = 9.200$$

Evaluation vector of concept layer C.

$$Y_c = 10 \times 0.613 + 8 \times 0.236 + 6 \times 0.151 + 4 \times 0 + 2 \times 0 = 8.924$$

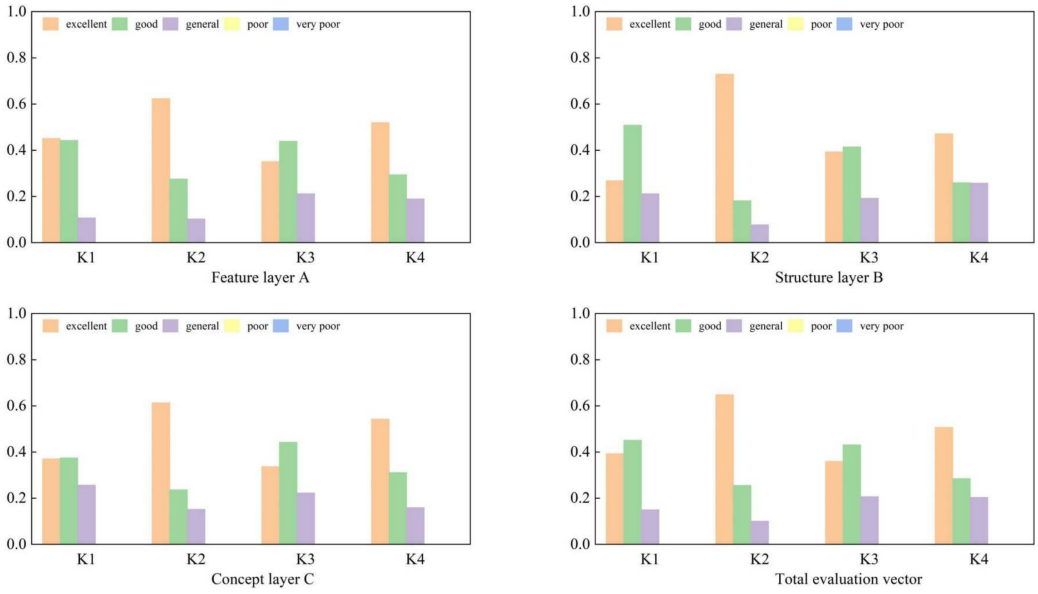


Figure 19. Fuzzy evaluation vector of each scheme.

The scores of each secondary indicator score are calculated using the same method, and the evaluation score is presented in Table 17.

Table 17. Comprehensive evaluation score of each indicator.

First-Level Indicator Score		Second-Level Indicator Score	
Feature layer A	9.092	Form A_1	9.33
		Color A_2	8.73
		Material A_3	8.53
		Decorative element A_4	8.67
Structure layer B	9.200	Sequence B_1	9.00
		Equilibrium B_2	9.47
		Rhythmical B_3	9.00
		Unity B_4	9.40
Concept layer C	8.924	Humanization and culture C_1	9.00
		Natural and ecological C_2	8.40
		railway station environment C_3	8.53
		Economical and simple C_4	9.27

According to Table 17, the design scheme K2 has a great structure and aesthetic feeling (B = 9.200, B_1 = 9.00, B_2 = 9.47, B_3 = 9.00, B_4 = 9.40), and the secondary indicator scoring value is greater than 9 points, which reflects a strong sense of unity, equilibrium, rhythm, and orderliness in design elements and components. The equilibrium feeling B_2 receives the highest rating, which indicates the good coordinate and sequence relationship in the design elements of this scheme. In feature layer A, the A_1 score is 9.33, which shows that the aesthetic effect of form design is good. In concept layer C, the C_1 score is 9.00 and the C_4 score is 9.27, which shows that the design reflects the human and local cultural

characteristics very well, and its design effect is simple, indicating that its manufacturing cost is low, reflecting an excellent economy.

5.2. Kansei Image Analysis of Aesthetic Design under the Background of Sustainable Development

Ecological culture is an important theme for the product aesthetic design in the context of sustainable development. In the ecological culture data, the regional plant is an important source of visual image, by analyzing the Kansei image by combining the factor analysis and design format analysis methods, designers can achieve effective visualization of image information and extract critical Kansei image features. The Kansei features of the information counter in the railway station is analyzed as follows:

(1) In the semantic feature level, Kansei words such as elegant, introverted, and other words that reflect refined, understated, delicate, and dynamic aesthetics can be used as an aesthetic design guide in the context of sustainable development.
(2) In the form features level, the simple and smooth form can better make people perceive the sustainable design aesthetic characteristics.

5.3. Aesthetic Elements Analysis under the Background of Sustainable Development

The weight values of indicators for each layer of aesthetic elements are shown in Figure 20. According to the ranking of the weight scores of indicators in each layer, the importance of aesthetics is analyzed as follows:

(1) In the first-level evaluation indicators, the visual feature of appearance have the most significant influence on aesthetics, which shows that the basis of aesthetic perception is the explicit appearance design features, such as form, color, material, and others.
(2) In the feature layer, simple and natural forms exert a significant influence on public facilities in railway stations, which shows that simple forms, humanized colors, natural materials, and natural decorations have an important impact on the aesthetic perception of sustainable design.
(3) In the structure layer, the sense of unity and equilibrium have a great influence on aesthetic feeling. For the public facilities in railway stations under the background of sustainable development, the harmony and unity between the design elements are important factors in structural aesthetics.
(4) In the concept layer, humanized design and a sense of simplicity are important contents of sustainable design aesthetics. In addition, the natural aesthetic and the harmony of the station environment are also important factors.

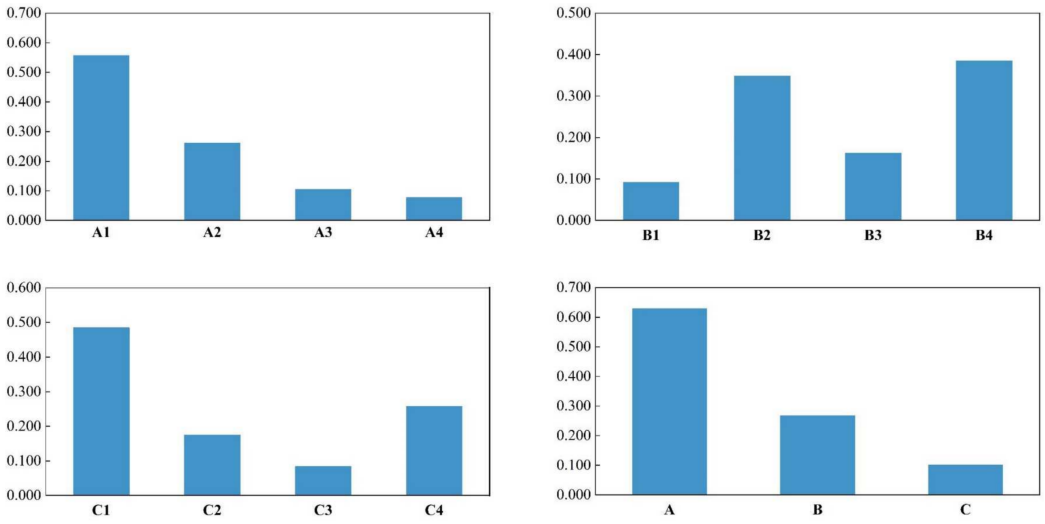


Figure 20. Weight analysis diagram of aesthetic element indicators.

Based on the above analysis, the aesthetic design principles of public facilities in railway stations under the sustainable background are shown in Figure 21. The original aesthetic is the core content of the design principle of railway station public facilities. On this basis, an integral combination system of original aesthetic, simple aesthetic, humanized aesthetic, harmonious aesthetic, and natural aesthetic constitutes the aesthetic design principles of public facilities in railway stations under the background of sustainable development.

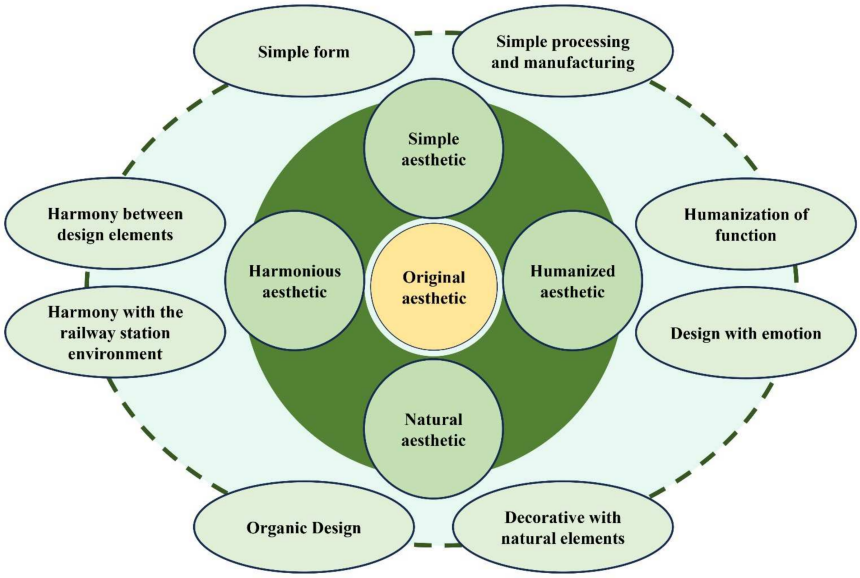


Figure 21. Aesthetic design principles of public facilities in railway stations.

5.4. Design Scheme Improvement

Based on the above analysis, information counter aesthetic design also needs to meet ergonomic standards. The man–machine adaptability of the design case is simulated and verified by using JACK^{TM}.

In the ergonomic analysis, the 95th percentile of Chinese adult males and the 95th percentile of Chinese females were selected for human factors analysis, and the ergonomic design of each region was good. The height of the design scheme is in line with the normal view of the passenger and the workspaces for at least two staff members to pass. The desk height of the counter can meet the normal inquiries of passengers, and there are accessible areas for wheelchair users to make inquiries. Figure 22 shows the static simulation of ergonomics.

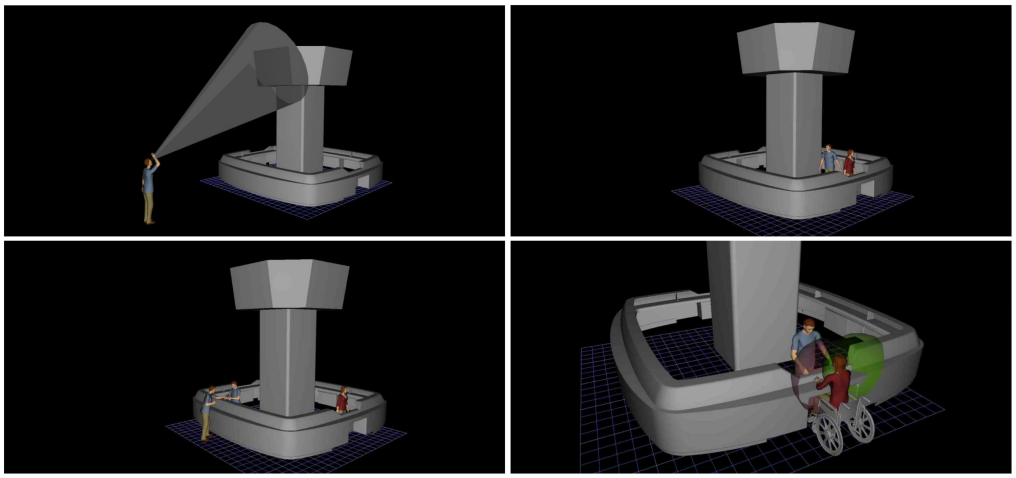


Figure 22. Ergonomics/human factors analysis of the design scheme.

Based on the above analysis, the design scheme K2 is taken as a prototype, combined with the indoor environment constraints of Xiongan railway station, and its local details are modified and improved to be used in the engineering scheme; the real picture is shown in Figure 23.



Figure 23. Final design scheme effect.

6. Conclusions

This study proposed the aesthetic design principles of public facilities in railway stations under the background of sustainable development based on the Kansei image and AHP-FCE model, and it takes the information counter design of Xiong'an railway station as an example to explain the method. The principal findings of the aesthetic design of public facilities in railway stations under the background of sustainable development are as follows:

(1) The typical semantic features of the Kansei words and the typical form features of the visual images are obtained through the factor analysis and design format analysis methods, respectively. The plant elements in the ecological environment can be used as the Kansei image source for aesthetic design under the background of sustainable development. At the semantic feature level, Kansei words, such as understated, delicate, dynamic, and others, which reflect original simplicity and original nature, are typical semantic features. At the level of form features, simple and smooth shapes are typical form features.

(2) Aesthetic design is a system composed of various elements. The core content of an aesthetic design is to reflect the original aesthetic feeling, such as simple, harmonious, and organic form design, low manufacturing costs, humane design, harmony with the station environment, and a natural sense of decoration, and these constitute the design aesthetic principles.

(3) The AHP-FCE model is an effective design evaluation method. The AHP method can effectively determine the weight ranking of various aesthetic elements. The FCE method enables an objective evaluation of the design scheme, and it can quantitatively evaluate various aspects of the design scheme and provide an objective reference for designers to optimize the scheme. The combination of the AHP-FCE model and the Kansei image method can provide guidance for the creation and improvement of public facilities design in railway stations and offer a comprehensive and objective evaluation method for aesthetic designs. The ergonomic analysis of the design scheme can be combined with JACK^{TM}. Future research can integrate computer-aided designs and psychological cognitive experiments to conduct quantitative investigations on Kansei image information and aesthetic elements.

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