A Quantitative Evaluation System of Yan'an Red Cultural and Creative Product Design Based on AHP-TOPSIS Method

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Abstract. The purpose is to find the design optimization of Yan'an red cultural and creative products. The method is to apply Analytic Hierarchy Process(AHP) to the determination of the hierarchical structure of Yan'an red cultural and creative product evaluation, then to construct evaluation matrix analysis to obtain the quantitative index of Yan'an cultural and creative product evaluation, and finally to exert the Technique for Order Preference by Similarity to Ideal Solution(TOPSIS) to calculate the the distance of each scheme from the ideal solution, so as to obtain Yan'an red cultural and creative product with the highest degree of user satisfaction and cultural content transmission. The result is that a more scientific evaluation system of Yan'an cultural and creative product innovation is achieved on basis of the model combined with AHP and TOPSIS. The conclusion is that this method reduces the subjectivity of designers, enhances the rationality, and provides a reliable basis for the improvement of Yan'an red cultural and creative products.

Keywords: Yan'an red culture; Cultural and creative product design; Evaluation system; Analytic hierarchy process(AHP); Technique for Order Preference by Similarity to Ideal Solution(TOPSIS);

1   Introduction

At present, there are relatively few researches on the evaluation of Yan'an red cultural and creative product in China. Ye Yong[1], et al. used Michael Porter Diamond Model to analyze the competitiveness and current situation of Yan'an red cultural and creative industry; Mi Gaofeng[2], et al. took Yan'an red-culture bookstore as the starting point and discussed the development strategy of Yan'an red cultural and creative products; Yu Yuanyuan[3], et al. used SPSS to conduct data analysis on the demand and preference questionnaire of Yan'an red tourism cultural and creative products, then defined new variables according to factor analysis, and analyzed the preferences of different consumers. The scholars above have analyzed the current situation or demand preference of Yan'an cultural and creative product industry, but have not put forward a reasonable design evaluation system for the design focus of Yan'an red cultural and creative products. This paper mainly aims to solve the design optimization problem of Yan'an red culture and creative products, involving numerous elements and complex relations, so the method of Analytic Hierarchy Process(AHP) is used here as a method to calculate the

weight of each design evaluation element, and relevant designers can design with targets and directions according to the weight ranking of design evaluation elements. Technique for Order Preference by Similarity to an Ideal Solution(TOPSIS) is used to calculate the distance from several Yan'an cultural and creative schemes to the ideal solution, and finally the best Yan'an red cultural and creative products are obtained. Using the combination of AHP and TOPSIS model to give a quantitative design evaluation method can improve the scientific nature of the process of design evaluation selection, in hope of providing a more reasonable method for evaluation and selection of conception design in Yan'an red cultural and creative product.

2   The extraction of key points from Yan'an red cultural and creative product evaluation based on AHP method

2.1   AHP model of Yan'an red cultural and creative product evaluation

The analytic hierarchy process model of Yan'an Red cultural and creative product evaluation is divided into three hierarchies[4]. Target hierarchy(A): the best scheme of Yan'an red cultural products; Through reading literature, questionnaire survey and expert interview, the following elements in the model are determined. Rule hierarchy(B): three elements are included, which are constituent elements, functional experience and cultural characteristics; Project hierarchy(C): It is divided into 16 items of evaluation elements. As shown in Figure 1:
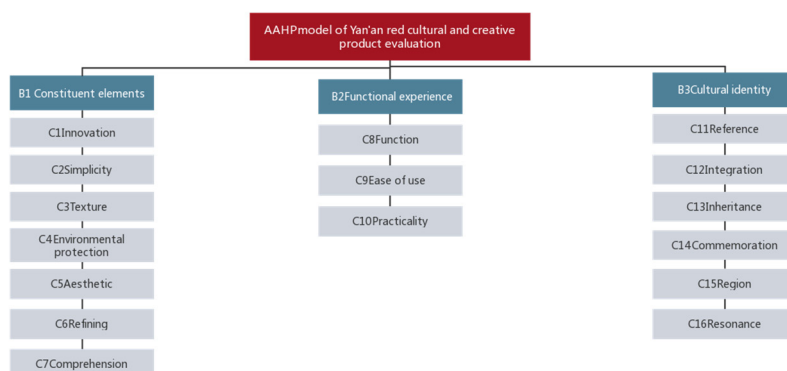

Fig. 1. AHP model of Yan'an red cultural and creative product evaluation[Self-drawn]

Rule hierarchy B1 is constituent elements. The constituent elements are the external physical information of the product, which are the foundation constituting the product[5]. The components of cultural and creative products are mainly divided into four parts: shape, color, material and pattern. Products bring instinctive, intuitive, visual perception through shape, color, material and patterns to customers.Yan'an red cultural and creative products often appear in the form of re-engraving the modeling pattern of Yan'an red revolutionary sites or printing their patterns and colors, lacking novelty and individuality. Therefore, innovation is the primary consideration of Yan'an cultural and creative products. Simplicity refers to whether the product is simple and

ingenious, or conforms to the general aesthetic of the public. Texture and environmental protection respectively refer to the advantages and disadvantages of materials and the safety and environmental protection of materials. Aesthetic refers to the aesthetic perception of the modeling style, color matching and patterns of cultural and creative products. Refining and comprehension refer to refusal to copy and paste decorative patterns, and refer to understanding, refining and recreating the connotation and significance of patterns.

Rule hierarchy B2 is functional experience. Functional experience is the personal experience of users and the foundation of interactive experience[6]. Yan'an red cultural and creative products should pay attention to the practicality and ease of use in physical functions of products. In addition to that, it is necessary to lay emphasis on the humanistic experience in the interactive mode of single product[7], integrate Yan'an red behavioral culture into it, and in the true sense, promote the communication between people and culture.

Rule hierarchy B3 is cultural identity. Cultural identity is the value embodiment of cultural and creative products, the transmission of cultural connotation and the satisfaction of customers' spiritual demands. Reference refers to whether cultural and creative products echo their cultural connotations[8]. Integration refers to the combination of Yan'an red culture and modern products. Inheritance refers to Yan'an red cultural and creative products, which take Yan'an red culture as the starting point to inherit Yan'an's unique spiritual and cultural outlook. Commemoration is the significance of the existence of cultural and creative products. Seeing Yan'an red cultural and creative products reminds people of the local scene in Yan'an. Region and resonance refer to having the local style and characteristics of Yan'an, so as to meet the spiritual demands of consumers, improve the emotional value of cultural and creative products and arouse the resonance of consumers.

2.2 Using AHP method to determine the weight of evaluation elements

Relevant experts score n items of evaluation factors and construct a judgment matrix[9]. Suppose, $A = \left[b_{i,j} \right], b_{i,j}$ indicates the relative degree of importance among the items in the rule hierarchy that make up item A, $b_{i,j} = 1, b_{j,i} = 1 / b_{i,j}$. Suppose, $B_k = \left[c_{m,n}^k \right], c_{m,n}^k$ indicates the relative importance degree of the corresponding items in the project hierarchy that make up item B_k, $C_{m,n}^k = 1, C_{n,m}^k = 1 / C_{m,n}^k$.

Through analysis, it is known that the importance relationship among items in the rule hierarchy can be expressed by matrix A. The correlation among the items in the project hierarchy is given in the form of matrices B1 ~ B3:

$$A = \begin{bmatrix} 1 & 1/3 & 1/2 \\ 3 & 1 & 2 \\ 2 & 1/2 & 1 \end{bmatrix} \qquad B1 = \begin{bmatrix} 1 & 3 & 5 & 4 & 2 & 5 & 2 \\ 1/3 & 1 & 3 & 2 & 1/2 & 3 & 1/3 \\ 1/5 & 1/3 & 1 & 1/2 & 1/3 & 1 & 1/2 \\ 1/4 & 1/2 & 2 & 1 & 1/3 & 2 & 1/3 \\ 1/2 & 2 & 3 & 3 & 1 & 3 & 1/2 \\ 1/5 & 1/3 & 1 & 1/2 & 1/3 & 1 & 1/3 \\ 1/2 & 3 & 2 & 3 & 2 & 3 & 1 \end{bmatrix}$$

$$B2 = \begin{bmatrix} 1 & 2 & 1/4 \\ 1/2 & 1 & 1/4 \\ 4 & 4 & 1 \end{bmatrix} \qquad B3 = \begin{bmatrix} 1 & 1/4 & 1/3 & 1/5 & 1/2 & 1/5 \\ 4 & 1 & 2 & 1/2 & 3 & 1/2 \\ 3 & 1/2 & 1 & 1/4 & 2 & 1/3 \\ 5 & 2 & 4 & 1 & 3 & 1 \\ 2 & 1/3 & 1/2 & 1/3 & 1 & 1/4 \\ 5 & 2 & 3 & 1 & 4 & 1 \end{bmatrix}$$

According to the data of the judgment matrix, the software of Statistical Product Service Solutions(SPSS) is used to calculate the maximum eigenvalue $\lambda_{max} = 3.0090$ of the matrix, which determines the correlation among the rule hierarchies, and to calculate the maximum eigenvalue $\lambda_{max1\sim3}$ of matrices B1 ~ B3 determining the correlation among the various projects hierarchies, which are 7.2730、3.0540、6.1220, respectively;and then their corresponding weight vectors are calculated, that is,

$$\omega_1^A = \begin{bmatrix} 0.1638 \\ 0.5390 \\ 0.2973 \end{bmatrix} \qquad \omega_1^{B1} = \begin{bmatrix} 0.3137 \\ 0.1200 \\ 0.5730 \\ 0.7870 \\ 0.1679 \\ 0.5260 \\ 0.2099 \end{bmatrix} \qquad \omega_1^{B2} = \begin{bmatrix} 0.2114 \\ 0.1335 \\ 0.6551 \end{bmatrix}$$

$$\omega_1^{B3} = \begin{bmatrix} 0.4680 \\ 0.1793 \\ 0.1084 \\ 0.2966 \\ 0.7550 \\ 0.2935 \end{bmatrix}$$

2.3 Consistency check

The software of Statistical Product Service Solutions(SPSS) is used to conduct consistency check, and its specific results are shown in Table 1, that is,

Table 1. Results of consistency check[Self-drawn]

Category	A	B1	B2	B3
CI	0.005	0.045	0.027	0.024
RI	0.520	1.360	0.520	1.260
CR	0.009	0.033	0.052	0.019

From Table 1, it is known that the results of consistency check from each judgement matrix are CR < 0.1, which meets the consistency condition, and the weight values obtained all meet the requirements.

Table 2. Rank of comprehensive weight of various indicators[Self-drawn]

Indicator of project hierarchy	Comprehensive weight	Rank
Innovation	0.0514	12
Simplicity	0.0197	16
Texture	0.0939	6
Environmental protection	0.1289	4
Aesthetic	0.0275	15
Refining	0.0862	9
Comprehension	0.0344	13
Function	0.1139	5
Ease of use	0.0720	10
Practicality	0.1948	2
Reference	0.1391	3
Integration	0.0533	11
Inheritance	0.0322	14
Commemoration	0.0882	7
Region	0.2245	1
Resonance	0.0873	8

According to the above evaluation indexes, the ranking results of comprehensive weights are shown in Table 2: From the ranking results of each index, it can be seen that the weights of region (0.2245), practicality (0.1948), reference (0.1391) and environmental protection (0.1289) account for a high proportion, indicating that these indexes have the greatest and heaviest influence. From the perspective of comprehensive weight to analyze, it can be seen from the indicators reflecting cultural identity that emphasis should be laid upon the regional and referential

characteristics of Yan'an red cultural and creative products, and the regional and cultural characteristics of Yan'an should be highlighted, which essentially differentiates them from other ones. In terms of function selection, Yan'an red products with more practicability should be selected. In terms of constituent elements, the materials selected should be safer and more environmentally friendly.

3 Evaluation on Yan'an cultural and creative products based on TOPSIS method

3.1 Determination of Yan'an cultural and creative product sample and orientation of emotional Thinking

Through the network platform, four kinds of Yan'an red cultural and creative products popular at home and abroad are collected. There are 211 kinds of cultural and creative products in the category of home life, 100 kinds of cultural and creative products in the category of decorative ornament, 138 kinds of cultural and creative products in the category of stationery and 100 kinds of cultural and creative products in the clothing-related category. Through questionnaire survey and cluster analysis, eight representative samples of cultural and creative products in the category of home life are obtained, which are replaced by X, and each representative sample in the first row of is replaced by X1, X2, X3 and X4 respectively, and the sample in the second is replaced by X5, X6, X7 and X8, respectively; Six representative samples of and creative products in the category of decorative ornament are replaced by Y, and six representative samples of cultural and creative products in the category of stationery are replaced by Z, and six representative samples of products in the clothing-related category are replaced by W, and so on in a similar fashion. Details are shown in Tables 3 to 6.

Table 3. Various samples of cultural and creative products in the category of home life [Pictures are from the Internet]

Name	Pictures			
	X1	X2	X3	X4
X Products in the category of home life				

Table 4. Various samples of cultural and creative products in the category of decorative ornament[Pictures are from the Internet]

Name	Pictures			
	Y1	Y2	Y3	Y4
Y Products in the category of decorative ornaments				

Table 5. Various samples of cultural and creative products in the category of stationery[Pictures are from the Internet]

Name	Pictures			
	Z1	Z2	Z3	Z4
Z Products in the category of stationery				

Table 6. Various samples of clothing-related cultural and creative products[Pictures are from the Internet]

Name	Pictures			
	W1	W2	W3	W4
W Products in the clothing-				

re-lated cate-gory		

Three groups of intentional word pairs are obtained by extracting the focuses of design evaluation elements sorted out from AHP analysis and combining with three levels of emotional demands, and then SD questionnaire is used to establish a seven-order semantic scale, that is, the score of-3 to 3. Questionnaires are distributed to 61 people, and 60 valid questionnaires are received. Among them, there are 37 males and 23 females. According to statistics, the average value of perceptual evaluation data of representative samples obtained by SPSS is shown in Table 7 to 10.

Table 7. Average value of perceptual evaluation data of products in the category of home life[Self-drawn]

Sample	Artistic	Practical	Commemo-rative	Average value
X1	1.3	2.02	2.08	1.8
X2	0.88	0.72	1.23	0.94
X3	1.17	0.82	1.15	1.04
X4	0.93	1.47	1.15	1.18
X5	0.38	1.85	0.15	0.79
X6	0.43	1.38	0.23	0.68
X7	0.85	0.92	0.5	0.76
X8	0.65	1.62	0.67	0.98

Table 8. Average value of perceptual evaluation data of products in the category of decorative orna-ment[Self-drawn]

Sample	Artistic	Practical	Commemo-rative	Average value
Y1	0.93	-0.13	1.4	0.73
Y2	2.18	0.22	1.88	1.43
Y3	2.53	0.6	1.57	1.57
Y4	1	0.22	1.23	0.82
Y5	0.73	-0.15	1.88	0.82
Y6	0.75	1.15	1.17	1.02

Table 9. Average value of perceptual evaluation data of products in the category of stationery[Self-drawn]

Sample	Artistic	Practical	Commemo-rative	Average value
Z1	1.23	1.33	1.03	1.2
Z2	0.77	1.68	0.95	1.13
Z3	1.57	1.32	1.35	1.41

Z4	1.3	0.37	1.08	0.92
Z5	1.73	0.18	1.57	1.16
Z6	2.03	1.43	2.23	1.9

Table 10. Average value of perceptual evaluation data of products in the clothing-related category[Self-drawn]

Sample	Artistic	Practical	Commemo-rative	Average value
W1	0.42	1.12	1.17	0.9
W2	0.53	1.23	1.37	1.04
W3	1.77	1.6	0.87	1.41
W4	0.97	0.82	0.92	0.9
W5	0.45	0.72	1.27	0.81
W6	0.45	0.62	1.27	0.78

From Tables 7 to 10, it is known that the highest average values are X1 for cultural and creative products in the category of home life, Y3 for cultural and creative products in the category of decorative ornament, Z6 for cultural and creative products in the category of stationery and W3 for cultural and creative products in the clothing related category.

3.2 Constructing weighting matrix according to the weight of each evaluation element Countermeasure combining superiority and threat (ST)

Suppose that there are M evaluation schemes, which constitute the scheme set $D = \{X_1, Y_2, \cdots, Z_M\}$;there are N evaluative elements, which constitute element set $C = \{C_1, C_2, \cdots, C_N\}$, then the initial evaluation matrix is[10]

$$A = (a_{ij})m \cdot n \qquad (i = 1,2,\cdots, m; j = 1,2,\cdots, n) \qquad (1)$$

Seven master students studying product design, five master students studying visual communication design and three designers are selected to score 16 evaluation elements of the above four Yan'an red cultural and creative products, and the scoring range is between 0 and 10 points (0<poor≤3, 3<below the average≤5, 5<general≤6, 6<better≤8, 8<excellent≤10). SPSS is used to take the mean value as the final scores of each evaluation element, as shown in Table 11.

Table 11. Initial evaluation matrix[Self-drawn]

Evaluation Elements	Scheme scores			
	Scheme X	Scheme Y	Scheme Z	Scheme W
C1	7.4	8.67	8.13	8.2
C2	7.87	8.73	7.87	8
C3	8	8.27	8.47	8.2
C4	8.2	8	7.87	8.73
C5	7.67	8.93	8.53	8.47
C6	7.6	8.27	7.87	8
C7	8	8.07	8.47	7.93
C8	8.27	7.8	8	8.67

C9	8.53	8.33	8.33	8.6
C10	8.6	7.73	7.4	8.6
C11	8.07	8.13	8	8.2
C12	8.13	8.2	8.33	8.4
C13	8.2	7.47	8.73	7.87
C14	8.67	8.27	8.73	7.87
C15	8.2	7.93	8.4	7.53
C16	8	7.93	8.4	7.8

Table 11 is standardized to establish the standardized evaluation matrix, as shown in Table 12.

Table 12. Standardized evaluation matrix[Self-drawn]

Evaluation Elements	Scheme scores			
	Scheme X	Scheme Y	Scheme Z	Scheme W
C1	0.4561	0.5343	0.5011	0.5054
C2	0.4843	0.5372	0.4843	0.4923
C3	0.4856	0.5020	0.5142	0.4978
C4	0.4996	0.4874	0.4795	0.5319
C5	0.4559	0.5308	0.5070	0.5034
C6	0.4787	0.5209	0.4957	0.5039
C7	0.4926	0.4969	0.5215	0.4883
C8	0.5048	0.4761	0.4883	0.5292
C9	0.5048	0.4930	0.4930	0.5090
C10	0.5309	0.4772	0.4568	0.5309
C11	0.4981	0.5018	0.4938	0.5062
C12	0.4918	0.4960	0.5039	0.5081
C13	0.5074	0.4622	0.5402	0.4870
C14	0.5166	0.4927	0.5201	0.4689
C15	0.5111	0.4943	0.5236	0.4694
C16	0.4978	0.4934	0.5227	0.4853

The weighting standardized matrix is obtained by multiplying by the weights of 16 design evaluation elements obtained in Table 2, as shown in Table 13.

Table 13. Weighting standardized evaluation matrix[Self-drawn]

Evaluation Elements	Scheme scores			
	Scheme X	Scheme Y	Scheme Z	Scheme W
C1	0.0234	0.0275	0.0258	0.0260
C2	0.0095	0.0106	0.0095	0.0097
C3	0.0456	0.0471	0.0483	0.0467
C4	0.0644	0.0628	0.0618	0.0686
C5	0.0125	0.0146	0.0139	0.0138
C6	0.0413	0.0449	0.0427	0.0434
C7	0.0169	0.0171	0.0179	0.0168
C8	0.0575	0.0542	0.0556	0.0603
C9	0.0363	0.0355	0.0355	0.0366
C10	0.1034	0.0930	0.0890	0.1034
C11	0.0693	0.0698	0.0687	0.0704

C12	0.0262	0.0264	0.0269	0.0271
C13	0.0163	0.0149	0.0174	0.0157
C14	0.0456	0.0435	0.0459	0.0414
C15	0.1147	0.1110	0.1175	0.1054
C16	0.0435	0.0431	0.0456	0.0424

3.3 Calculating the Euclidean distance of four schemes and their relative closeness degree

According to Table 13, the positive ideal solution F^+ and negative ideal solution F^- are obtained[11], which are

$$F^+ = \begin{bmatrix} 0.0275, 0.0106, 0.0483, 0.0686, 0.0146, 0.0449, 0.0179, 0.0603, \\ 0.0366, 0.1034, 0.0704, 0.0271, 0.0174, 0.0459, 0.1175, 0.0456 \end{bmatrix} \tag{2}$$

$$F^- = \begin{bmatrix} 0.0234, 0.0095, 0.0456, 0.0618, 0.0125, 0.0413, 0.0168, 0.0542, \\ 0.0355, 0.0890, 0.0687, 0.0262, 0.0149, 0.0414, 0.1054, 0.0424 \end{bmatrix} \tag{3}$$

The distance of each scheme to positive ideal solution X^+ is

$$S_i^+ = \sqrt{\sum_{j=1}^{n}\left(u_{ij} - u_j^+\right)^2} \quad (i = 1,2,\cdots,m) \tag{4}$$

The distance of each scheme to negative ideal solution X^- is

$$S_i^+ = \sqrt{\sum_{j=1}^{n}\left(u_{ij} - u_j^-\right)^2} \quad (i = 1,2,\cdots,m) \tag{5}$$

The relative closeness degree of the Yan'an red cultural and creative products to the optimal solution is calculated[12], which is

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad (i = 1,2,\cdots,m) \tag{6}$$

According to formulas (4) to (6), the Euclidean distance and relative closeness degree C_i of the Yan'an red cultural and creative products are calculated, as shown in Table 14.

Table 14. Euclidean distance and relative closeness degree[Self-drawn]

Schemes	S_i^+	S_i^-	C_i	Rank
X	0.0092	0.0183	0.6668	1
Y	0.0157	0.0096	0.3794	3
Z	0.0739	0.0143	0.1626	4
W	0.0138	0.0176	0.5600	2

The larger the C_i value, the closer the distance of Yan'an red cultural and creative products to the optimal solution, the better this scheme will be. It can be found from Table 14 that the scheme X is obviously superior to the other three.

4 Conclusion

In this paper, the Analytic Hierarchy Process(AHP), combined with Technique for Order of Preference by Similarity to Ideal Solution(TOPSIS), is used to study the design process of Yan'an Red cultural and creative products. Firstly, the AHP model is established, followed by building a judgment matrix; Then, the relative weights of design evaluation elements contained in rule hierarchy and sub-rule hierarchy are figured out; Finally, four design schemes of Yan'an Red cultural and creative product are evaluated by TOPSIS, so as to avoid the influence of subjective factors on product design as much as possible and provide scientific grounds for product design and scheme selection, more scientific and rigorous. At the same time, AHP-TOPSIS evaluation system, reasonable and scientific, is easy to operate. With the continuous improvement of quantitative design evaluation system, the choice of Yan'an Red cultural and creative product design scheme will tend to be more reasonable and better serve relevant designers.

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