Perceptual Engineering and Related Research Based on the Design of Door and Window Hardware Handles

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Abstract. The main purpose of this research is to introduce the sensibility engineering to explore the relationship between the modeling style of the door and window hardware handle and the sensibility vocabulary, and through the results of this research, the design of the door and window hardware handle is more scientific. The analysis establishes a basis for its styling design and consumer perception criteria and manufacturer design. The purpose of this study is to solve the post-evaluation problem of product design. The method proposes a design evaluation method based on Analytic Hierarchy Process (AHP). Firstly, the product is decomposed into several indicators to be evaluated and scored, and the data is calculated and the weight values of each index are calculated. The overall score of the program is further ordered. The result is the accuracy of the sorting result verified by the market sales survey data of 3 door and window hardware handles, which provides a reference for the effective evaluation of product design. The conclusion is that the introduction of AHP into design evaluation can effectively reduce the disadvantages of many factors in the design evaluation, such as the factors to be evaluated, the reliance on the evaluator's experience and knowledge, and the difficulty of judging the relationship between each factor and the final solution. Influences

1. Introduction
Along with the rapid development of China's economy, people's living standards have been greatly improved, and the national audience awareness and consumption structure are simultaneously upgrading. Consumers are paying more and more for their "satisfaction", which is more inclined to the aesthetics, comfort and experience of the products. However, domestic manufacturing companies are faced with excessive production and product homogeneity caused by insufficient innovation. Serious problems, fierce competition, and other issues have caused foreign creative companies to exert great pressure on domestic enterprises. For the door and window hardware handle, it is not only important for the opening and closing of the door and window, but also for the consumer experience and the psychological satisfaction brought by the product. So with the continuous development of door and window hardware, the new design and the use of innovative materials and colors, the door and window hardware handles are constantly changing, the new hardware handles pay more attention to the consumer's human-machine experience and psychological satisfaction, greatly Breaking through the past is only the physical effect of opening and closing doors and windows. In recent years, due to the rise of consumer awareness, product styling plays an important role in conveying product imagery and communicating users [1]. Consumers have become one of the important factors leading the market trend. They also pay
more attention to the hardware handle style. The emotional demand is more and more valued for the new generation of consumers. The product shape becomes the designer in the design process. An important element that is indispensable. Research into the introduction of sensible engineering has been continuously proposed, and the influence of the morphological characteristics on the sensibility is also the main topic of discussion.

2. The literature discussion
This study explores the relationship between hardware handle modeling and sensibility, and collates relevant literature, which is discussed in the following two sections [2].

2.1. Sensible Engineering
We usually think that sensible engineering is to transform people's expectations of subjective perception into physical design elements [3], and finally become an actual design element. Japanese scholar Nagamachi defines perceptual engineering as the technique of transforming consumers' perceptions or images of products into design elements. Perceptual engineering has the following four main directions:

(1) Control the consumer's perception of the product through subjective and psychological assessment of the public.
(2) Find the design features of the product through the subjective feelings of the consumer.
(3) Establish a set of people-oriented perceptual engineering.
(4) Iteratively corrects the design direction of the product as the consumer market changes and the preferences of the audience change.

The sensible engineering technology can be divided into three types. This study adopts the type of sensible engineering-category: mainly to extend and expand a series of things, and use the hierarchical inference method to establish a correlation diagram such as a tree diagram. Get the details of the design, through the redesign and planning of these product components to express specific emotional appeals.

2.2. Analytic Hierarchy
Analytic Hierarchy Process (AHP) is a multi-objective evaluation method combining qualitative and quantitative analysis proposed by American operations researcher T.L.Saaty in the 1970s. It refers to the decomposition of relevant elements of decision-making problems into goals and criteria, a program, factors and other levels [4], based on this, a decision-making method for qualitative and quantitative analysis. The basic idea of the AHP method is to combine the hierarchical and clustering according to the nature of the problem and the goal to be achieved according to the mutual influence and membership relationship of the factors to form a hierarchical and orderly hierarchical structure. Model. Then, based on the relative importance of the same level of factors in the model, a reasonable metric scale is introduced. According to people's judgment on objective reality, the relative importance between each factor is measured by pairwise comparison, and quantitative representation is given to construct an upper element. For the weight judgment matrix of the lower layer elements, the mathematical method is used to determine the weight of the relative importance order of all factors in each layer, and the comprehensive weight of the lowest importance order of the lowest level relative to the highest layer is obtained, which is the best solution. Choose the basis for your offer [5].

3. Research methods

3.1. Construction of Evaluation Index System
After conducting design and research on the door and window hardware handles, we can understand the functions, usage scenarios, user's appeals, etc., after consulting the experts of the industry and consulting the relevant literature, from the "physical-cognitive-emotion" 3 From the perspective of the hardware handle design evaluation G is divided into function U1, appearance U2, experience U3 three aspects, build a first-level evaluation index set U = {U1, U2, U3}. Through expert interviews and user questionnaires, 9 evaluation indicators for the above three aspects were collected, and the industry
experts and professional designers were reviewed. The analysis process used the Delphi method for multiple rounds, which made the overall opinions tend to be concentrated and unified. Evaluation index set $U_1 \{V_1, V_2, V_3\}$, $U_2 = \{V_4, V_5, V_6\}$, $U_3 \{V_7, V_8, V_9\}$, and finally get the evaluation index system designed by the hardware handle, see Figure 1.

3.2. Building a judgment matrix for evaluation indicators

According to the analytic hierarchy process, in order to calculate the weight values of the indicators of each layer [6], the priority relationship matrix is constructed in the form of pairwise comparison. If there are elements $a_1, a_2, ..., a_n$, then the priority relationship matrix: $E=\{a_{ij}, i = 1, 2, ..., m; j = 1, 2, ..., n\}$. Where: $a_{ij}$ represents the contribution of the element $a_i$ and the element $a_j$ to the superior indicator, starting from the second layer of the hierarchical model, for the same layer of factors belonging to (or affecting) the upper layer, by experts, design The division and the consumer use the pairwise comparison method and the 1~9 comparison scale to construct a pairwise comparison, until the bottom layer, see Table 1.

![Figure 1. Door and window hardware handle design evaluation index system](image)

| Scaling | Meaning |
|---------|---------|
| 1       | This indicator represents the same importance as the two factors. |
| 3       | This indicator represents two factors compared to the latter, the former is slightly more important than the latter. |
| 5       | This indicator represents two factors compared to the former, which is significantly more important than the latter. |
| 7       | This indicator represents two factors compared to the latter, which is more important than the latter. |
| 9       | This indicator indicates that the former is more important than the latter compared to the two factors. |
| 2, 4, 6, 8 | This indicator represents the intermediate value of the above adjacent judgment reciprocal |

Table 1. Comparison of the meaning of the scale scale in the judgment matrix

If the importance ratio of the factor to the factor is $a_{ij}$, then the factor $j$ is proportional to the factor $i$'s importance, $a_{ji} = \frac{1}{a_{ij}}$. 

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3.3. Calculation of indicator weight value and total program ranking in 3-3 analytic model

The analytic hierarchy process is widely used in the field of industrial analysis and decision-making. It is mostly used for multi-objective and multi-attribute decision analysis of finite schemes. The weights of each target and attribute for the overall scheme are calculated. Finally, the schemes are obtained through comprehensive calculation. The total value of the program is determined by sorting to determine the pros and cons of each program, and thus assist decision makers in making judgments. When applying the AHP method for evaluation, the calculation of the weight value of each index is relatively important. Compared with the entropy method and the coefficient of variation method, the analytic hierarchy process has more advantages in solving the qualitative indicator variables. The analytic hierarchy process is used to calculate and finalize the index weight values. The specific steps are as follows.

3.3.1. Structure evaluation index feature matrix. We assume that there are M plans to be decided, then we can form a set of programs G={G_1, G_2,..., G_M}; there are N evaluation targets or attribute composition evaluation indicators set V={V_1, V_2,..., V_N }, there is an evaluation index feature matrix A:

\[ A = (a_{ij})_{mn} \quad (i = 1, 2, ..., m; \ j = 1, 2, ..., n). \]

3.3.2. Determine the weight of each indicator. We believe that the set of decision makers consisting of F-named decision makers S = {S_1, S_2,..., S_F}, and each evaluation index is compared by a scale of 1~9, and the evaluation index characteristic matrix A=(A_{ij})_{mn} constructs a fuzzy uniform matrix, and the weight values w_1, w_2, ..., w_n of the elements a_1, a_2, ..., a_n are calculated by the fuzzy consistency matrix. For the matrix A = (a_{ij})_{mn} summed by the formula (1), mathematically transformed: a_{ij} = (a_i - a_j) / 2 (n - 1) + 0.5, thus obtaining the fuzzy consistency matrix A = (a_{ij})_{Mn}, and then use the formula (2) (3) to calculate and normalize the judgment matrix, and obtain the feature vector w=(w_1, w_2,..., w_n)T, that is, U_1 ~ U_3 and V_1 ~ V_9 The weight of the indicator relative to the superior indicator G satisfies the formula (4):

\[ a_i = \sum_{k=1}^{n} e_a(i = 1, 2, ..., n) \]  
\[ a_{ij} = \frac{a_{ij}}{\sum_{k=1}^{n} a_{ij}} \quad (i = 1, 2, ..., n; \ j = 1, 2, ..., n) \]  
\[ w_i = \frac{w_j}{\sum_{j=1}^{n} w_j} \quad (i = 1, 2, ..., n; j = 1, 2, ..., n) \]  
\[ w_i = \frac{\sum_{j=1}^{n} e_{ij} + \frac{n}{2}}{n(n-1)} (i = 1, 2, ..., n) \]

3.3.3. Consistency test. After we get the weight value of each indicator, we need to check the consistency. When the consistency ratio CR is lower than 10%, the matrix is consistent. Calculate according to formula (5) (6). as follows:

\[ \lambda_{max} = \sum_{i=1}^{n} \frac{(AW)}{nw_i} \]  
\[ CI = \frac{\lambda_{max} - n}{n - 1} \]
According to Table 2, we can get the random consistency coefficient (RCI) corresponding to the data n, and calculate: CR=CI/RCI. If CR<0.1, pass the consistency test.

### Table 2. Average random consistency indicator

| N | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| RCI | 0 | 0 | 0.85 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 |

3.3.4. Comprehensive sorting calculation. After obtaining the weight value of each index for the whole, the comprehensive coefficient method is introduced, and the average value of each index obtained by the investigation is summed with the weight coefficient of the index to obtain the total score of the program, and the method is used to obtain the total score of the program. Sort the total scores of each evaluation plan, and calculate formula (1) as follows:

\[
X = w_1 \bar{V}_1 + w_2 \bar{V}_2 + \ldots + w_n \bar{V}_n
\]

Among them: the average value for the sample; the weight value of the indicator.

4. Case analysis

4.1. Selection of Scheme and Construction of Raw Data Matrix

In order to verify the effectiveness of the method, nine different styles of door and window hardware handles were selected from the market as the evaluation plan. Finally, three different styles were selected under the common screening of industry experts, designers and consumers. 2 red box selection

The above three groups of programs form a program set G. At the same time, a total of 40 decision makers M are composed of industry experts, designers and consumers. Combined with the door and window hardware handle design evaluation system of Figure 1, from U1 ~ U3 and V1 ~ V9 the Likert scale method scores 3 schemes in the interval of 0~10, and averages to establish the original data matrix. See Table 3
4.2. Calculate the weight value of each evaluation index

In this study, according to the analytic hierarchy process, each evaluation index is compared by a scale of 1~9, and the evaluation index feature matrix is constructed into a fuzzy consistent matrix. The weighted value of each evaluation index is calculated by the fuzzy consistency matrix \( w_1, w_2, \ldots, w_9 \), see Table 4.

### Table 4. Weight values of each evaluation indicator

| Evaluation index | \( w_i \) | Evaluation index | \( w_i \) |
|------------------|----------|------------------|----------|
| \( V_1 \)        | 0.0835   | \( V_6 \)        | 0.1095   |
| \( V_2 \)        | 0.0173   | \( V_7 \)        | 0.0953   |
| \( V_3 \)        | 0.0948   | \( V_8 \)        | 0.1064   |
| \( V_4 \)        | 0.0718   | \( V_9 \)        | 0.1321   |
| \( V_5 \)        | 0.0248   |                  |          |

After the weight value of each index is obtained, the consistency test is carried out on this index. After calculation, \( CR = 0.033 < 0.1 \), and the consistency test is used to prove that the judgment matrix is consistent. According to the calculation results of the total ranking weights of the above indicators, it is known that for the design evaluation of the door and window hardware handles, in terms of functions, the proportions of the swing opening and the gear reduction are in the top two; in terms of appearance, the handle material process and product styling are dominant; the experience of smooth opening and closing, durability and human-computer interaction comfort are close. After obtaining the proportion of the indicators of the door and window hardware handles in the overall design evaluation, the total scores of the three handles can be calculated and sorted by using the comprehensive coefficient method in combination with the original data matrix in Table 2.

4.3. Calculate the total score of each program by using the comprehensive coefficient method

Through the set of decision makers composed of industry experts, designers, and consumers, the weights of the three indicators of the three handles are obtained by using the Likert scale method, and the comprehensive coefficient method is used to calculate the sum of the indicators. The values obtained are as follows:

\[
X = w_1 \overline{V}_{X1} + w_2 \overline{V}_{X2} + \ldots + w_n \overline{V}_{Xn} = 7.1573 \quad (8)
\]

\[
Y = w_1 \overline{V}_{Y1} + w_2 \overline{V}_{Y2} + \ldots + w_n \overline{V}_{Yn} = 7.0347 \quad (9)
\]

\[
Z = w_1 \overline{V}_{Z1} + w_2 \overline{V}_{Z2} + \ldots + w_n \overline{V}_{Zn} = 5.3845 \quad (10)
\]
It is concluded that the comprehensive scores of the three handles are: X>Y>Z, that is, the door and window hardware handle X is optimal.

Fourth, the test results test

After obtaining the comprehensive sorting of the three handles, the sorting result needs to be verified. The verification method mainly relies on the sales of three e-commerce platforms, the popularity value and the sales volume of offline products combined with relevant comments. This online data uses Taobao Mall as the data source platform. Through the keyword "Door and Window Hardware Handle", you can find the sales volume and evaluation number of 3 products separately. The "Popularity Ranking" is obtained through the professional e-commerce data query tool "Check Ranking". The final data is summarized in the table. 5. It is verified that the ranking results in Table 5 are consistent with the evaluation results obtained by the introduction of AHP, which proves that the method has certain feasibility.

Table 5. Summary of 3 products on the online mall platform data

| Product name | Product Image | Popularity ranking | Monthly sales | Popularity |
|--------------|---------------|--------------------|---------------|------------|
|              |               | Second place       | 5819          | 18000      |
|              |               | Sixth place        | 4712          | 11500      |
|              |               | Fifteenth place    | 1081          | 8200       |

5. Conclusion
In order to reduce the difficult problems in the industrial design field, the researcher in the design evaluation process and the over-reliance on the reciprocating test in the product design evaluation process, help the designers and management to make fast, effective, scientific and objective decision-making. It was introduced into the product evaluation process, and the method was verified by three door and window hardware handles. The function, appearance and experience extended 9 secondary indicators to build an evaluation index system, and the weights of each indicator were calculated. The value, combined with the original data matrix, finally leads to the comprehensive ranking of each scheme, and the feasibility of the method is verified by the market sales survey data of the three products.

In general, the introduction of AHP can transform complex and fuzzy design evaluation into quantitative solution, which is more suitable for the accuracy and credibility of evaluation when the overall target is uncertain and the targets are small. Provide a reference for design evaluators.

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