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Industrial Housing Products Design Plans' Fuzzy Synthesis Decision Based on Customers' Fine Needs

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ABSTRACT

Different customers have different emphasis on housing products due to their differences in lifestyle. It is of great significance to design and optimize the housing products to meet the needs of specific customers. This article first subdivided the customer groups, refined and decomposed the aggregate needs and behavior habits of a subgroup, then put forward the concept of customer's need element for each requirement. Taking the internal cabinet products in the industrial housing products as an example, it established the customer's need meta-analysis model and the need weight matrix to determine the focus of product design. And then, the fuzzy comprehensive evaluation method was used to evaluate the optimal design scheme. The research shows that this method can also be applied to the related fields such as residential design and furniture product design, which has certain reference significance for the design and optimization of industrial residences and related products.

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1. Introduction

A product is anything that is manufactured or refined to meet the particular needs of people, including objects, services, places, organizations, ideas, etc.. The core measure of good or bad product is the degree to which the product meets customers' needs [1]. In many cases, designers often face challenges to understand and identify customers' needs when working on projects, which result in failed designs based on vague, emotional and incomplete design decisions. As big gaps exist between customers' actual needs and designers' decisions, it is critical for designers to understand customers' needs at the beginning of design process and to analyze customers' behaviors and lifestyles.

In this paper, customers' fine needs are mainly discussed from two aspects: customers' subgroups and the fine decomposition of action behavior in the process of using a product. Due to the wide range of products, this paper takes industrial housing products, particularly internal cabinet as an example. Industrial housing products refer to a kind of product that can meet customers' residential needs and can be installed directly in a factory without any processing on the construction site [2], it is manufactured for the purpose of residential use. Hence, all products should reflect customers' preferences and needs to become successful in market.

2. Customers' Fine needs Analysis

Customers' needs for housing product varies with their social and living conditions, and in order to further investigate the customers' real needs, it is critical to pay attention to the differences of different customer type and their preferences. On the basis of in-depth analysis of the customers' family patterns, habits, hobbies and other interests, this paper will refine the customer classification, and then establish a measurement model based on new considerations on customers' need weight distributions.

2.1 Refine the Customer Groups

First of all, this paper will take the core needs of residential product as the starting point, subdivide and consolidate the mainstream customers, the object is 22-36 years old young buyers in Xi'an, the main analysis data comes from a large amount of market data. Through the analysis of their lifestyle, behavior patterns, shopping preferences and so on, eight types of subgroups are identified, including: 1. Safety-protection type(8.8%), which the customers' background is based on low-income families focusing on children and the cost-efficiency of products; 2.Health and environmental protection type(15.5%), which the customers come from middle and high income families focusing on sustainable features of materials; 3.Simple and practical type(15.7%), which the customers' background is low income families focusing on low cost and basic function implementation; 4.Convenient and efficient type(18.4%), which the customers' background is middle-income families focusing on product performance and style; 5.Social convenience type(7.3%), which the customers' background is middle and high income families focusing on product material, design, style and brand; 6.Science and technology leading type(7.6%), which the customers' background is high-income families focusing on advanced design features of products; 7.Sensory pursuit type(14.9%), which the customers' background is middle and high income families focusing on visual effects and design styles; 8. High-grade taste type(11.7%), which the customers' background is high income families focusing on brand and high-quality [3].

2.2 Core Needs of Different Groups on Products

The obvious difference of the background of each subgroups bring different design preferences, style features and cost inputs of residential products [4]. For example, simple and practical type customers tend to pay more attention to functional features of products, as well as simple and easy usage; convenient and efficient type customers attach great importance on easy to clean and use efficiency; technology leading type customers are more concerned about whether the product design is customer-friendly, whether it has advanced technologies. Therefore, according to different customers, product designs should reflect those different values and preferences to satisfy customers' needs. Customers' core requirement point and product design focus on one-to-one correspondence, as shown in Figure 1.

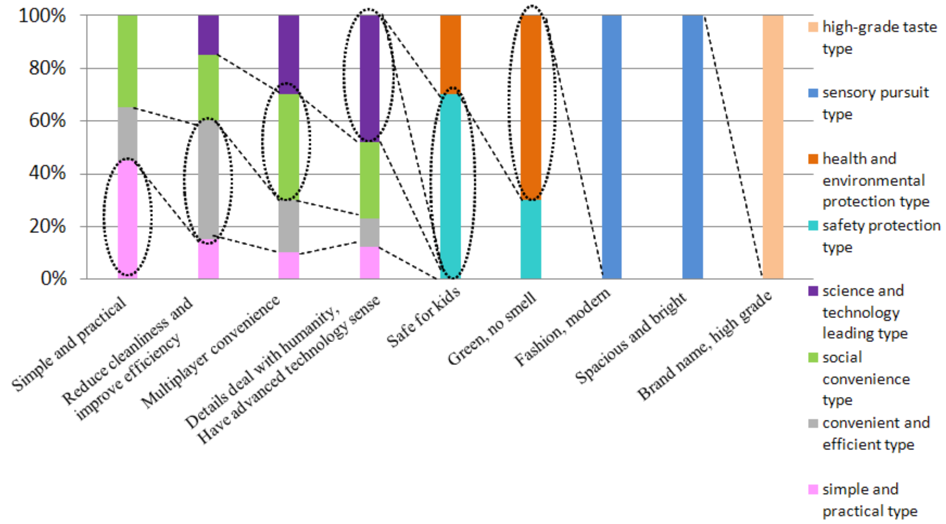

Figure 1: Customers' core requirement point.

2.3 Determining Customers' Need Weights

The concept of "Requirement Unit(RU)"is introduced here to analyze customers' needs, that is, the minimum information unit that can clearly express customers' every single basic need. There are many ways to determine the weights of customers' needs, for example, Masud put forward the fuzzy weight average method [6], Trappey used quality attribute ranking method [7], and Park et al. used analytic hierarchy process [8]. The standard weighting matrix method is adopted in this paper, supposing the aggregate requirement R=(R_1. R_2, ..., R_n), the relative importance of minimal information unit is determined according to the requirement unit, and expert scoring method is also adopted to determine the scores that represent the magnitude of the comparison between the requirement unit, as shown in Table 1.

Table 1: Magnitude of the comparison between the two requirement units

Score	Magnitude of the comparison between the two requirements
1	Equally important
2	Weakly important
3	Comparatively important
4	Obviously important

The requirement weighting matrix can be expressed as: $R_w = R \bullet R^{-1}$, R_1, R_2, … R_n is the decomposed requirement unit vector, which can be expressed as:

$$R_w = \begin{pmatrix} R_1 \\ R_2 \\ \vdots \\ R_n \end{pmatrix} \bullet (R_1, R_2, \cdots, R_n) = \begin{pmatrix} R_1R_1 & R_1R_2 & \dots & R_1R_n \\ R_2R_1 & R_2R_2 & \cdots & R_2R_n \\ \vdots & \vdots & \ddots & \vdots \\ R_nR_1 & R_nR_2 & \cdots & R_nR_n \end{pmatrix}$$

It can be simplified as:

$$R_w = \begin{pmatrix} R_1R_1 & R_1R_2 & R_1R_3 & \dots & R_1R_n \\ & R_2R_2 & R_2R_3 & \cdots & R_2R_n \\ & & R_3R_3 & \cdots & R_3R_n \\ & & & \ddots & \vdots \\ & & & & R_nR_n \end{pmatrix} \tag{1}$$

Further simplification of Equation (1), if the requirement unit R_i and R_j ($i \neq j$) are equally important, then "R_i - R_j" is used; the requirement unit on the diagonals is the same, which is 1; except that, "R_m-k"is adopted, R_m means the most important one between the two requirement unit, k is the score in the table of R_m. So a requirement weight matrix can be expressed as:

$$R^*_w = \begin{pmatrix} 1 & R_1 - R_2 & R_1 - k & \dots & R_1 - R_n \\ & 1 & R_2 - R_3 & \cdots & R_2 - k \\ & & 1 & \cdots & R_3 - R_n \\ & & & \ddots & \vdots \\ & & & & 1 \end{pmatrix} \tag{2}$$

(1) C alculate the absolute weight $A\omega_{Ri}$ of each requirement

The absolute weight $A\omega_{Ri}$ of any requirement R_i is: $A\omega_{R_i} = Row(\omega_{R_i}) + Column(\omega_{R_i})$ (3)

$Row(\omega_{R_i})$ is the sum of the weight of the row vector, $Column(\omega_{R_i})$ is the sum of the weight of the column vector.

(2) C alculate the relative weight $R\omega_{Ri}$ of each requirement

$$R\omega_{R_i} = A\omega_{R_i} / A\omega_{R_{max}} \tag{4}$$

3. Fuzzy Comprehensive Evaluation Method Based on Customers' Needs

When there are a number of alternatives, designers need to choose the most appropriate design solution. This paper puts forward a fuzzy comprehensive evaluation model based on customers' needs, which can define the following set:

(1) A collection of n candidate designs:

$$U = \{u_1, u_2, \cdots, u_n\}$$

(2) A collection of m evaluation objectives, that is, design sub objectives play a key role in decision making on product scheme, which can be expressed as:

$$V = \{v_1, v_2, \cdots, v_m\}$$

(3) The membership function and membership, the membership function of each evaluation target should reflect the design preferences, which can be given by expert evaluation, the membership degree of each design scheme corresponding to each design sub objective, expressed as:

$$R = (r_{ig})_{n \times m}$$

(4) To evaluate the importance weight of target, that is, design importance weight of sub goals, which is determined by using judgment matrix analysis:

$$W = (w_1, w_2, \cdots, w_m)^T$$

(5) To first evaluate the 3 tuples (U, V, R) according to the following three evaluation function models:

Model M(∧, ∨) ,use(∧, ∨) operator, take the maximumvalue: $B_1 = R \circ W$ (5)

Model M(^{m}, ∨) ,use(^{m}, ∨) operator, take the minimum value: $B_2 = R^* W$ (6)

Model M(, +) ,use(, +) operator, take the Weighted average: $B_3 = R W$ (7)

(6) If you take the maximum, the minimum, the weighted average, you might have a one-sidedness, so to do the second evaluation, the evaluation matrix of factor sets $U_1=\{B_1, B_2, B_3\}$ is: $R_1=(B_i)$ ($i = 1, 2, 3$)

The weights of each indicator B_i ($i = 1, 2, 3$) in U_1 are allocated to $A_1 = (1/3, 1/3, 1/3)$, use (, +)operator ,that is: $B = R_1 A_1$ (8)

(7) According to the above calculation results, the design scheme with the maximum evaluation value is the best solution [8].

4. Application Example -- Take Internal Cabinet Product as an Example

4.1 Establishment of Requirement Unit Model for Internal Cabinet Product

Taking convenient and efficient type group among mainstream customer groups as an example, we analyze their concerns and design expectations for the internal cabinet product by questionnaire, and then categorize their needs into explicit and specific requirement units, represented by R[9]. Supposing the aggregate requirement for internal cabinet use $R=(R_1,R_2, ..., R_n)$, it can be categorized into four variables: functional properties R_{w1}, safety performance R_{w2}, visual feature R_{w3} and material quality R_{w4}. Each variable can be further categorized into several smaller requirement units. Functional properties sub requirement R_{w1} can be categorized into five requirement units: storage R_1, washing R_2, food cut and preparation R_3, cooking R_4, non-cooking activities R_5; safety performance R_{w2} can be categorized into three requirement units: safety and environmental protection R_6, durability R_7, maintainability R_8; and visual features R_{w3} can be categorized into three requirement units: design style R_9, color matching R_{10}, appearance R_{11}; and material quality R_{w4} can be categorized into material brand R_{12}.

According to the score and formula (1) to (4) in Table 1, the absolute weight and relative weight of each requirement unit can be calculated. The result of solution is shown in table 2. After integration, the relative importance weight of each sub requirement can be obtained as:

$$W = (0.564, 0.159, 0.166, 0.110)^T$$

Table 2: Weight value of the requirement unit.

Requirement unit	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	R_{11}	R_{12}
R_1	1	R_1-R_2	R_1-R_3	R_1-R_4	R_1-3	R_1-R_6	R_1-2	R_1-2	R_1-2	R_1-2	R_1-2	R_1-R_{12}
R_2		1	R_2-R_3	R_2-R_4	R_2-4	R_2-2	R_2-2	R_2-4	R_2-2	R_2-2	R_2-2	R_2-2
R_3			1	R_3-R_4	R_3-4	R_3-2	R_3-2	R_3-4	R_3-2	R_3-2	R_3-2	R_3-2
R_4				1	R_4-4	R_4-2	R_4-2	R_4-3	R_4-2	R_4-2	R_4-2	R_4-2
R_5					1	R_6-3	R_7-3	R_5-R_8	R_9-2	R_{10}-2	R_{11}-2	R_{12}-4
R_6						1	R_6-R_7	R_6-3	R_6-R_9	R_6-R_{10}	R_6-R_{11}	R_{12}-3
R_7							1	R_7-2	R_7-R_9	R_7-R_{10}	R_7-2	R_{12}-3
R_8								1	R_9-2	R_{10}-2	R_8-R_{11}	R_{12}-3
R_9									1	R_9- 2	R_9-2	R_9-R_{12}
R_{10}										1	R_{10}-2	R_{12}-2
R_{11}											1	R_{11}-R_{12}
R_{12}												1
Absolute weight	19	24	24	23	2	12	11	3	12	9	6	18
Relative weight	0.117	0.147	0.147	0.141	0.012	0.074	0.067	0.018	0.074	0.055	0.037	0.110

As seen from the weight value of the requirement unit in the table, the attention to internal cabinet product of convenient and efficient customer group is R_2-R_3-R_4-R_1-R_{12}-R_6-R_9-R_7-R_{10}-R_{11}-R_8-R_5, and the weight value of the first four requirement units is 55.2%. This reminds the designer that the design should focus on such requirements units of washing, cutting, blending, cooking and storing, at the same time take full account of the capacity and location of the storage area, as well as the immediate need relationship between components of product, thus, the customers' needs will be transformed into clear design goals.

4.2 Clear Design Goals

According to above analysis, for the convenient and efficient customer group, clear design goals can be developed on core requirement units, it can be done from following specific aspects:

（1） Sort out the core areas and related issues

Customers prefer efficiency among three major areas of kitchen: storage (storage of food, cooking utensils, spices, etc.), preparation (picking, cleaning, cutting, etc.) and cooking, each of which requires sufficient spaces for different cooking related activities. In order to achieve maximal efficiency, designers need to consider "triangular working route" by creating short line spaces to improve spatial efficiency, as shown in Figure 2.

（2） Give full consideration to the immediate need relationship between the components of the product, such as the adjoining arrangement of sink and dishwasher, washing machine, and adjoining arrangement of cupboard for containing ingredients and table for preparing food, etc..

(3) Follow the ergonomic size standards.

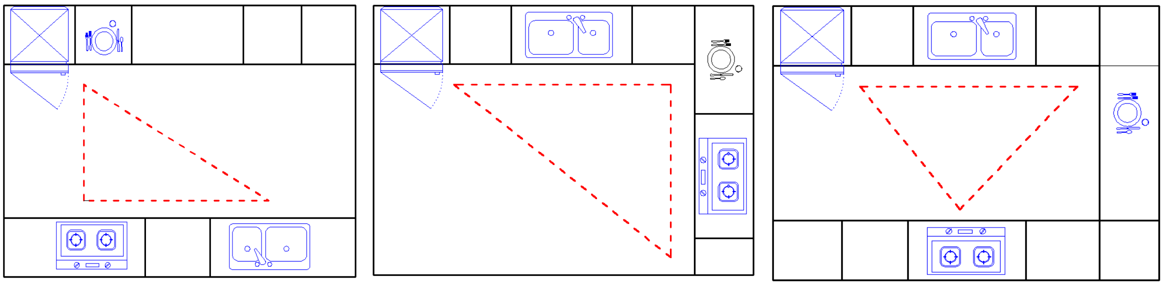

Figure 2: Triangular working route.

4.3 Decision and Optimization for Different Schemes Using Fuzzy Comprehensive Evaluation Method

Then, three design schemes of internal cabinet product are chosen as case studies: A, ZHIBANG; B, GOLDEN HOME KITCHEN; and C, JIALIAN. These three products belong to better category in the design quality fuzzy comprehensive evaluation, now, it is necessary to choose the best plan for the three programs, that is, $U=\{u_1, u_2, u_3\}$; the design criteria are 4 aspects of the product that are derived from customers' requirement analysis, that is, V={functional features, security, sensory, quality}; through consultation with experts and scoring integration, the membership matrix R' of above three cupboard design schemes to meet each design sub goal is gained, and normalization processing is made on R' to get the judgment matrix R:

$$R'=\begin{pmatrix} 0.779 & 0.677 & 0.850 & 0.606 \\ 0.785 & 0.822 & 0.661 & 0.687 \\ 0.781 & 0.806 & 0.803 & 0.679 \end{pmatrix} \qquad R=\begin{pmatrix} 0.0872 & 0.0758 & 0.0951 & 0.0678 \\ 0.0878 & 0.0920 & 0.0740 & 0.0769 \\ 0.0874 & 0.0902 & 0.0899 & 0.0760 \end{pmatrix}$$

According to formula (5) (6) (7), the first level of judgment:

$$B_1=[0.0951, 0.0920, 0.0902]^T$$

$$B_2=[0.0678, 0.0740, 0.0760]^T$$

$$B_3=[0.0833, 0.0854, 0.0871]^T$$

According to formula (8), secondary judgment is made:

$$B=\begin{pmatrix} B(u_1) \\ B(u_2) \\ B(u_3) \end{pmatrix}=\begin{pmatrix} 0.0951 & 0.0678 & 0.0833 \\ 0.0920 & 0.0740 & 0.0854 \\ 0.0902 & 0.0760 & 0.0871 \end{pmatrix}\begin{pmatrix} 1/3 \\ 1/3 \\ 1/3 \end{pmatrix}=\begin{pmatrix} 0.0821 \\ 0.0838 \\ 0.0844 \end{pmatrix}$$

According to the calculation results, the evaluation value of U_3 is 0.0844, it is the maximum evaluation value, the design scheme with the highest evaluation value is the best one, that is, among these three prefabricated cupboard products, C. JIALIAN is the relative optimum scheme.

5. Conclusion

On the basis of fine analysis on customers' needs, this paper takes the internal cabinet product as an example, and then judges the optimal scheme by establishing the analysis model on customers' requirements unit and using fuzzy comprehensive evaluation method, which provides an effective way for product optimization design and decision making. The method can also be applied to many fields such as mechanical product, electronic product, daily necessities, and so on. The further analysis and exploration of different products should be made in follow-up researches.

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