Research on influence factors of product configuration rebuilt design with demand preferences of customers

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Abstract. In order to improve the personalized demand satisfaction of customers and fully considering the demand preference characteristics of enterprise end customers, an analysis method of influence factors of product configuration rebuilt design considering customer demand preferences was proposed. Firstly, through literature analysis, market survey, questionnaire survey and other means, the demand preference characteristics of enterprise end customers are obtained and analyzed, and the influence factor set of product configuration rebuilt design considering customer demand preference is constructed. Then, the importance of influence factors is hierarchically divided by using the interpretive structural modeling method (ISM), and the key influence factors of product configuration rebuilt design considering customer demand preference are identified. On this basis, an example was given to verify the feasibility, rationality and effectiveness of proposed method.

1. Introduction

Product Configuration Rebuilt Design (PCRD) is a rapid rebuilt design mode for products under the guidance of changes in customer requirements, which has significant advantages in responding to customers' personalized, diversified and differentiated needs. At present, it has attracted extensive attention from the theoretical and academic circles, and has become an important technical means for enterprises to respond to personalized market requirements and enhance their comprehensive competitiveness.

In recent years, scholars have carried out relevant research on the issue of product configuration rebuilt design to meet customer demand preferences. For example, Wang et al. [1] transformed customer demand into input configuration demand for product configuration design by establishing a demand mapping model, thus generating a product configuration scheme; Baobei et al. [3] established a bi-level programming mathematical model for optimal allocation of product customization resources in order to realize optimal selection and allocation of various manufacturing resources under the product customization production mode. Zhan et al. [4] mined customer requirements through online reviews, designed an improved wind-driven optimization algorithm to solve the product configuration model, and then recommended product configuration according to customer preferences, thus realizing mass customization. Zhang et al. [5] used the product configuration scheme reconstruction technology of grey
correlation analysis and weight sequence crossing to configure high-grade numerical control machine tools, which improved configuration efficiency and configuration quality. Gan et al. [6] proposed a product configuration resource combination optimization technology driven by customer personalized demand, which effectively improves the income of enterprise product resource reconfiguration. Azamatov et al. [7] applied configuration generation algorithm to conceptual and preliminary stages of aircraft design and development, and proposed a product configuration design tool based on comprehensive parameters. Paparrizou et al. [8] proposed an adaptive genetic algorithm to deal with various disturbance events in product configuration resource scheduling, and then completed the reasonable allocation of product configuration design resources.

In practice, the customer demand preference shows the characteristics of individuation, diversification and differentiation. When facing the above demand characteristics, if the enterprise only aims at meeting the personalized demand preferences, the operating efficiency of company may be affected. So, subject to the production capacity or cost budget of the enterprise, it is necessary to analyze the importance and priority of customer demand preference factors and identify the key influence factors, so as to guide the product configuration rebuilt design of the enterprise.

2. Analysis of influence factors of product configuration rebuilt design with demand preferences of customers

Based on the existing research results and through a practical investigation of a refrigerator enterprise, this paper constructs a set of influence factors for product configuration rebuilt design from the perspective of customer demand preferences through operations such as factor screening, classification, etc. The specific information is shown in Table 1.

| Category | Customer preferences | Category | Description |
|----------|----------------------|----------|-------------|
| $S_1$ Appearance | $S_{11}$ Refrigerator size and LCD panel size | $S_4$ Price | $S_{41}$ Box price |
| | $S_{12}$ Panel color | | $S_{42}$ Brand price |
| | $S_{13}$ Door style | | $S_{43}$ The freight |
| | $S_{14}$ Door shell material | | $S_{44}$ Maintenance cost |
| | $S_{15}$ Transportation and inner packing | | $S_{51}$ Product rebuilt time |
| | $S_{21}$ Degree of freezing | $S_5$ Time | $S_{52}$ Purchase delivery time |
| $S_2$ Function | $S_{22}$ Compressor frequency conversion | | $S_{53}$ Maintenance time |
| | $S_{23}$ Defrosting form | | $S_{54}$ Delivery time |
| | $S_{24}$ Refrigeration form | | $S_{61}$ Sales staff attitude |
| | $S_{25}$ Energy efficiency index | $S_6$ Service | $S_{62}$ Service speed |
| | $S_{31}$ Power consumption | | $S_{63}$ After-sales service attitude |
| $S_3$ Quality | $S_{32}$ The evaporator | $S_7$ Others | $S_{71}$ brand |
| | $S_{33}$ The condenser | | $S_{72}$ noise |
| | $S_{34}$ The compressor | | $S_{73}$ security |
| | $S_{35}$ Service life | | |

3. Identification of fundamental influence factors of product configuration rebuilt design with demand preferences of customers

The Interpretative Structural Model (ISM) is a method developed by American Professor J.N. Warfield in 1973 to analyze the structural problems of complex socio-economic systems[9]. Based on the basic working principle of the interpretative structural model, this paper establishes a structural relationship
model between customer demand preferences and influence factors of product configuration rebuilt design, to identify the key influence factors. The specific steps for identifying the key influence factors of product configuration rebuilt design based on ISM are as follows:

**Step1:** Analysis of relationship between factors

Let $R_{ij}$ (abbreviated as $R$) be used to represent the relationship between the two elements $S_i$ and $S_j$. If there is a binary relationship between $S_i$ and $S_j$, the corresponding element of the system is $a_{ij} = 1$; if no binary relation, the corresponding element of the system is $a_{ij} = 0$. Specific definition is shown in formula (1).

$$a_{ij} = \begin{cases} 1, & S_i \text{ has some kind of binary relationship to } S_j \\ 0, & S_i \text{ has no binary relation to } S_j \end{cases} \quad (1)$$

$R_c$ represents the set of element pairs $(S_i, S_j)$ of elements $S_i$ and $S_j$ that satisfy a certain binary relation $R$ among system components, that is, the set of binary relation on $S$, which is denoted as the following formula (2).

$$R_c = \{(S_i, S_j) | S_i, S_j \in S, RS_i, i, j = 1, 2, \ldots, n\} \quad (2)$$

**Step2:** Establish the adjacency matrix

Adjacency matrix ($A$) is a square matrix that represents the basic binary relation or direct connection between system elements. According to step 1, the adjacency matrix ($A$) is as follows:

$$A = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} \quad (3)$$

Wherein, the element $a_{ij}$ in the adjacency matrix $A$ is defined as follows:

$$a_{ij} = \begin{cases} 1, & S_i \text{ has direct influence on } S_j \\ 0, & S_i \text{ has no direct influence on } S_j \end{cases} \quad (4)$$

Among them, $S_i$ and $S_j$ represent factors $i$ and $j$ respectively.

**Step3:** Establish accessibility matrix

Accessibility matrix ($M$) is a square matrix representing the situation that two nodes on a directed graph can reach through any long path. If $M=(m_{ij})_{n \times n}$, the maximum road length or number of passes under no loop condition is $u$, and the matrix can be defined as:

$$m_{ij} = \begin{cases} 1, & \text{There is a path from } i \text{ to } j \text{ with a maximum length of } u \\ 0, & \text{There is no path from } i \text{ to } j \end{cases} \quad (5)$$

The accessibility matrix can be obtained by Boolean algebra operation, that is, $M=(A+I)^u$, $I$ is identity matrix, and $u$ represents the maximum number of passes. According to $(A+I)^u \neq (A+I)^{u+1}$, the accessibility matrix can be obtained:

$$M = \begin{pmatrix} m_{11} & \cdots & m_{1n} \\ \vdots & \ddots & \vdots \\ m_{n1} & \cdots & m_{nn} \end{pmatrix} \quad (6)$$

**Step4:** Divide location(level)

Region division is to divide set $S$ into mutually independent regions according to the binary relation $R$, where accessible set $R(S)$, antecedent set $A(S)$ and common set $C(S)$ are specifically solved by
formulas (7), (8) and (9) respectively.

\begin{align*}
R(S) &= \{S_i | S_i \in S, m_0 = 1, j = 1,2,\ldots,n \} \quad i = 1,2,\ldots,n \\
A(S) &= \{S_i | S_i \in S, m_0 = 1, j = 1,2,\ldots,n \} \quad i = 1,2,\ldots,n \\
C(S) &= \{S_i | S_i \in S, m_0 = 1, j = 1,2,\ldots,n \} \quad i = 1,2,\ldots,n
\end{align*}

Level division is used to determine the hierarchical position of each factor in its region. Assuming that \( P \) is the factor set of a certain region and \( L_1, L_2, \ldots, L_l \) is used to represent the factor set from high to low, level division can be represented as \( \Pi(P) = L_1, L_2, \ldots \), where \( L_0 \neq \emptyset \),

\begin{align*}
L_1 &= \{S_i | S_i \in P - L_0, C(S_i) = R_0(S_i), i = 1,2,\ldots,n \} \\
L_2 &= \{S_i | S_i \in P - L_0 - L_1, C_1(S_i) = R_1(S_i), i < n \} \\
L_n &= \{S_i | S_i \in P - L_0 - L_1 - \cdots - L_{n-1}, C_{n-1}(S_i) = R_{n-1}(S_i), i < n \}
\end{align*}

**Step5:** Establish the interpretive hierarchical structure model

According to the division results of regions and levels, the interpretive hierarchical structure model of system factors can be established.

4. Case study

This paper takes the refrigerator product configuration rebuilt design of a manufacturing enterprise in reference [10] as an example. Based on the previous research and analysis on the demand of target customers in the market, it is found that customers have diversified preferences on the appearance, function, quality, cost and time of refrigerators. In order to make the design process of product configuration rebuilt fully consider the demand preference characteristics of enterprise end customers and meet the personalized and diversified demand preference of customers, the method proposed in this paper is then applied in practice. The specific analysis process is as follows:

**Step1:** Establish the set of influence factors

A set of influence factors for product configuration rebuilt design with demand preferences of customers contain 29 sub-indexes, from the appearance\((S_1)\), function\((S_2)\), quality\((S_3)\), cost\((S_4)\), time\((S_5)\), service\((S_6)\), and others\((S_7)\) of refrigerators, as shown in table 1 in Section 2.

**Step2:** Establish accessibility matrix \( M \)

According to formulas (1) to (6), the accessibility matrix \( M \) is obtained by using Boolean algebra algorithm, as shown below.
Step 3: Divide location

According to formula (7)-(12) and accessibility matrix $M$, the level division results of the influence factors can be obtained. The specific information is shown in Table 2 as below.

| NO. | $R(S)$ | $A(S)$ | $C(S)$ | Division level |
|-----|--------|--------|--------|----------------|
| 1   | 11,31,42 | 11,71  | 11     | 3              |
| 2   | 12,42   | 12,71  | 12     | 3              |
| 3   | 13,42   | 13,71  | 13     | 3              |
| 4   | 14,42   | 14,71  | 14     | 3              |
| 5   | 15,43   | 15     | 15     | 3              |
| 6   | 21,31   | 21,33  | 21     | 3              |
| 7   | 22,31   | 22,34  | 22     | 3              |
| 8   | 23,31   | 23,32  | 23     | 3              |
| 9   | 24,31   | 24,33  | 24     | 3              |
| 10  | 25,31   | 25     | 25     | 3              |
| 11  | 31,35   | 11,21,22,23,24,25,31,72 | 31 | 2 |
| 12  | 23,32,72,73 | 32 | 32 | 4 |
| 13  | 21,24,33,72,73 | 33 | 33 | 4 |
| 14  | 22,34,72,73 | 34 | 34 | 4 |
| 15  | 35      | 31,35,73 | 35 | 1 |
| 16  | 41      | 31,41,42,43 | 41 | 1 |
| 17  | 41,42   | 11,12,13,14,42 | 42 | 2 |
| 18  | 41,43   | 15,43,52 | 43 | 2 |
| 19  | 44      | 44,53  | 44     | 1              |
| 20  | 51,73   | 51     | 51     | 4              |
| 21  | 52,54   | 52     | 52     | 4              |
Step 4: Establish interpretive hierarchical structure model
Based on Table 2, the interpretive hierarchical structure model of influence factors is obtained and shown in Figure 1.

![Hierarchical structure model](image)

**Figure 1. Hierarchical structure model**

Step 5: Discussion
As can be seen from Figure 1, According to the explanation structure model, the influence factors of product configuration rebuilt design with the demand preferences of customers is a 4-level multi-level hierarchical structure: surface factors (level 1), middle factors (levels 2 and 3) and deep factors (level 4), which shows the hierarchical relationships among the influence factors. Surface factors (level 1) are the most direct factors that affect product configuration rebuilt design. The middle-level factors (levels 2 and 3) are an indirect factor, which acts on the product configuration rebuilt design by connecting the deep-level factor and the surface-level factor. The deep factors (level 4) are the fundamental and key factors affecting the product configuration rebuilt design, which have the widest influence. As is shown in Figure. 1, the key factors are evaporator (S32), condenser (S33), compressor (S34), product rebuilt time (S51), purchase and delivery time (S52) and brand (S71). In practice, only by taking these key factors into deep consideration can the problem be fundamentally solved.

5. Conclusions
Product Configuration Rebuilt Design (PCRD) is an important means to improve the competitiveness of products by quickly providing a product configuration plan to meet the personalized and differentiated needs of customers. Therefore, an analysis method of influence factors of product configuration rebuilt design with demand preferences of customers was established, and the key factors was identified, which provides an important basis for enterprises to better improve the quality of product configuration scheme and better meet customer’s demands.
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References
[1] Ardeshirilajimi, A. and Azadivar, F. (2016) Impact of incorporating customer preference in sustainable remanufacturing of commercial returns. International Journal of Sustainable Engineering, 1-11.
[2] Yuan J.J., Huang M.M., Yang H.L. and Shan M. Y. (2018) Modeling and optimization of product configuration rebuilt driven by customer requirement dynamic change. Computer Integrated Manufacturing Systems, 10: 2584-2598.
[3] Bao B.F., Yang Y., Yang T., Xue C. M. and Xie J. Z. (2014) Resource optimal allocation in product customization collaborative manufacturing. Computer Integrated Manufacturing Systems, 8: 1807-1818.
[4] Zhan J.K., Shi Y.Q. and Xia S.H. (2018) Research on Multi-objective Product Configuration Model and Configuration Optimization Based on QFD. Journal of Southwest University of Science and Technology, 3:88-94.
[5] Zhang L., Zhang S.Y., Li X.J., Wang Y. and Zhang P. (2015) Reconstruction technology of configuration design for complex product based on expanded GRA and weighted sequence cross. Computer Integrated Manufacturing Systems, 10:2564-2576.
[6] Gan H., Liu L. and Xiong F. (2016) Research on customer’s individual demand-driven product configuration technology. WIT Transactions on Engineering Sciences, 113: 328-335.
[7] Azamatov A, Lee J W and Byun Y H. (2011) Comprehensive aircraft configuration design tool for Integrated Product and Process Development. Advances in Engineering Software, 1-2:35-49.
[8] Paparrizou A. (2015) Efficient algorithms for strong local consistencies and adaptive techniques in constraint satisfaction problems. Constraints, 4:484-485.
[9] Hu G., Xu X.X. and Guo X.C. (2018) Importance calculation of complex network nodes based on interpretive structural modeling method. JOURNAL OF ZHEJIANG UNIVERSITY (ENGINEERING SCIENCE), 10:1989-1997+2022.
[10] Yang T, Yang Y, Zhang D.D. (2015) Generation of product innovation conceptual design schemes for considering the demand preferences of customers. Computer Integrated Manufacturing Systems, 4:875-884.