Research on Extension Innovation Design Method of Product Family Based on Kano Demand Model

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Abstract: By the existing innovation design methods of product family, people can get new products design effectively. However, these methods can’t make their products to meet customers’ demand completely, because they can’t help people turn customers’ demands into products characteristics using model methods. This paper uses Kano requirement model to find essential demands, clarify customers’ demands, and utilizes extension innovation methods to establish models for the products, which have different characteristics, then uses extensive analysis and extension transformations to obtained new products designs, and finally get innovation designs of product family according to superiority evaluation methods. A design for mobile phone is taken as an example to demonstrate this method.

1. Introduction

With the continuous improvement of living standards and scientific and technological standards, people's individualized demand for products is getting higher and higher. In order to improve their market competitiveness, enterprises must design individualized products from the requirement of consumers to meet the different requirement of people in today’s society. In the past, a single, large-scale and large-scale product design method was often used to meet the requirements of the market, but in the face of modern diversified and individualized competitive market, the product family or product generation design method that can meet the requirements of different markets at the same time was needed.

At present, there are several mainstream product family design methods as follows: 1. Modular design method: design each functional part of the product and then generate a brand new product through combination. However, the cost of this design method is higher in the face of small batch and personalized product customization. (2) Design method based on product platform: approximate to the collection of series products and individualized market requirement, which provides a structure and module basis for existing products. Users can also combine modules to form new products through this platform. However, the platform construction of this design method needs a relatively long time, and also needs good scalability. (3) Product family-oriented design method can also meet the market requirements for different users. However, with the increase of modular components in the product family, maintenance costs will continue to increase, and there will be some modules which are less used but need a lot of maintenance costs. (4) TRIZ innovative design method is a theory to solve the contradictions in the process of invention and creation, which has practical guiding significance for solving the problems of product creation and technology. However, there are still some deficiencies in
expressing users' requirement and related application tools.

Extension innovation design method can formally express contradictions and product design scheme in product design by constructing extension model. It makes the whole product design process more centralized and unified, and allows designers to participate more in the product design process. Kano's requirement model can comprehensively analyze the user's requirement and get the requirement model for product design according to different user's requirement. Through the combination of extension innovation design and Kano's demand model, this paper realizes the innovation design of product family from the user's demand, which provides a feasible new direction for the application of extension innovation method in product innovation design.

2. Extension Innovative Design Method Based on Kano Demand Model

2.1. Extension Design Method

Extension innovation method provides a complete set of methods of expansion, transformation and evaluation for product innovation design. From this, three creative methods are put forward to guide different types of product innovation design, including the first creative method of new product conception method based on demand and the second creative method of design and development based on existing products. And the third creative method of innovative design of new products from the defect of products.

Extension design method is a method of applying extension innovation method to product innovation design or solving contradiction problems in design field. At present, extension design has a good theoretical basis, and has achieved a lot of results in application. Among them, Professor Zhao Yanwei's mechanical product extension conceptual design is a kind of application of the formal expression and diamond thinking mode in extenics, which formally expresses the design ideas of product design, and also enables designers to better participate in it.

When applying extension design method to product innovation, according to the second creation method of product innovation, first of all, we need to formalize the design objects with primitives (including matter element, matter element and relational element) and establish the extension model of the design objects. Taking a product as an example, it can be formally expressed by matter-element. Its expression has three aspects: object, feature and the corresponding quantity value of feature. Each matter-element is represented by an orderly triple through these three parts. If the product has multiple features, it is expressed as:

\[
M = (O_m, c_m, v_m) = \begin{bmatrix}
O_m, & c_{m1}, & v_{m1} \\
& c_{m2}, & v_{m2} \\
& & \vdots \\
& & c_{mn}, & v_{mn}
\end{bmatrix}
\]

From this, the initial formal model of product is formed. In order to obtain product innovation ideas, it is necessary to expand or conjugate the initial formal model of product represented by primitives, so as to obtain a variety of possible ways to solve demand problems.

Extension transformation is to transform the initial product model into an extended new product model according to the different requirement of users in product innovation design. Their set is the product family.

Finally, the optimal solution of product design family is obtained by using the goodness evaluation method, which is a unique evaluation method in extenics.

2.2. Kano Model

Kano demand model is a user satisfaction model based on product quality characteristics proposed by Professor Noriaki Kano of Tokyo University of Science in document [10]. Kano's demand model solves the problem of the simplicity of product quality definition before, refines the quality requirement from one-dimensional model to two-dimensional model, establishes four levels of
demand, so as to more accurately grasp the different requirements of different types of users for products. Professor Yoshio Hanoi uses an orthogonal coordinate system to describe the relationship between user satisfaction and product functional characteristics, as shown in Figure 1. Kano's demand model is divided into four categories according to user's requirement:

Basic requirement are the characteristics that users think products must possess. When a product meets the requirement of users, the satisfaction of users will not increase significantly, but when the basic requirement are not met, the satisfaction of users will decrease dramatically.

Expectation demand is linearly proportional to user satisfaction, that is, with the improvement of this kind of demand, user satisfaction will increase proportionally, but with the decrease of this kind of demand, user satisfaction will also decrease proportionally.

Charm demand is a new functional feature that exceeds the value of the product itself by satisfying the potential requirement of users. Charm demand can bring great satisfaction to users, and its absence will not lead to a decrease in user satisfaction.

The irrelevant requirement is not necessary for users at present and will not cause changes in user satisfaction.

Of course, these four types of demand are only relative to the present, with the continuous development of science and technology level, users will have higher and higher requirements for product functional attributes. For example, 10 years ago, mobile Internet access was not as popular and high-speed as it is now. At that time, mobile Internet access function was the charm demand of users. Now, mobile Internet access function has become one of the essential functions of mobile phones, so it seems that mobile Internet access function belongs to the basic requirement of users. With the passage of time, users' requirement change in a life-cycle manner: insignificant requirement → charismatic requirement → expectation requirement → basic requirement.[10]

Kano requirement model can provide enough information of user requirement for enterprises. This paper applies the data obtained from Kano model to the extension innovation design, establishes the formal extension model through the user requirement, and then obtains the better solutions in all design schemes through the analysis, transformation and evaluation methods of extenics, so as to improve the customer satisfaction of products. Next, we introduce the method in detail.

2.3. Extension Innovative Design Steps Based on Kano Model

This paper combines the second creation method of the three creative methods in extenics with Kano's demand model, and extends the initial model to analyze the various requirement of users, so as to obtain a variety of possible ways to solve the contradiction between user requirement and product characteristics. In this way, we can not only give full play to the advantages of the formal expression of extension innovation design and the analysis and solution of contradictions, but also design new products according to Kano model data more in line with the market.

The steps of product family extension innovation design method based on Kano demand model are as follows:

1) Establishment of extension model for initial product. Establish an initial product extension model based on previous generation products or related products, which should contain some basic
information of products, that is, basic user requirement in Kano model.

2) Extension analysis or conjugate analysis of the initial extension model in the initial product model. According to expert opinions, consumer surveys or distributors' statistics, the initial extension model obtained from the first step is extended and conjugate analysis to generate the characteristics that many new products may need to possess, and they are expressed by extension model. After extended analysis or conjugate analysis, the preliminary results are determined. The product characteristic requirement item lays a foundation for the later Kano requirement model evaluation.

3) Determine the requirement classification and evaluation table according to Kano model. In order to accurately distinguish the four types of user's demand for products, the survey results will be defined by Kano Model Demand Classification Table\(^{[11]}\). For example, Table 1: The first alphabet of all kinds of demand is used as its symbol, while the symbol is the same as the symbol in the extension innovation design method, the others are used artificially. Letters are used to express. Among them: E represents charm demand, Q represents expectation demand, J represents basic demand and W represents insignificant demand. When the result of the survey is that the product has certain attribute and does not have certain attribute, it is called problem demand. When the result of the survey is that the product does not have certain attribute, it is called opposite demand. The letter F denotes.

4) Investigate and calculate customer satisfaction. For the product design department of an enterprise, in order to obtain products with considerable competitiveness in the market, it is necessary to obtain the requirement of users through various ways of investigation. Through the network search or questionnaire survey, the statistical results are classified and counted, so that the type of a certain demand can be determined. The proportion of different types of requirements in users' minds is also different. For each product characteristic that can satisfy users' requirement, their relative weights should be determined and used in the evaluation method of goodness. In Kano model, weight is the proportion of glamour requirement A and expectation requirement O of a certain requirement in all evaluation requirements and the maximum proportion of basic requirement M and expectation requirement O in all evaluation requirements. In the former case, \( S_i \) is used to represent the weight of a product when it has I characteristics. \( D_i \) is used to express the weight of user satisfaction when the product does not have I characteristics. The calculation formulas are as follows: (4), (5):

\[
\begin{align*}
S_i & = \frac{A_i + O_i}{A_i + O_i + M_i + I_i} \quad (2) \\
D_i & = \frac{M_i + O_i}{A_i + O_i + M_i + I_i} \quad (3)
\end{align*}
\]

Whether the user requirement can be satisfied is equally important to the user satisfaction, so the larger values in \( S_i \) and \( D_i \) are selected as the weight of the user satisfaction of the product's I characteristics, that is:

\[
w_i = \max \left\{ \frac{S_i}{\sum_{i=1}^{n} S_i}, \frac{D_i}{\sum_{i=1}^{n} D_i} \right\} \quad (4)
\]

User satisfaction weight can be used as a reference for the relevance degree of product
characteristics in goodness evaluation, and then according to other measurement indicators such as cost in product extension model to determine the specific distribution form of weight coefficient used in goodness evaluation. Generally speaking, the weight coefficient $\alpha_i$ ranges from 0 to 1 and:

$$\sum_{i=1}^{m} \alpha_i = 1$$

(5)

5) Extension model is transformed according to Kano demand table, and the transformed extension model is obtained. After ascertaining the satisfaction degree of users with various characteristics of this kind of product, the extension model of a product with certain characteristics is established by generating user groups with different requirement through extension transformation. When using extension transformation, we need to classify it according to Kano's requirement, and generate multi-level product solutions by extension transformation according to different user groups' requirements. According to users' demand for products and acceptable price range, products are divided into primary products, intermediate products and advanced products. Among them, the primary product is that the product can meet all the basic requirement of users, and attachments of some low-cost high-weight other requirement, in order to maximize the performance of the product without raising the price as far as possible. The users of intermediate products are the majority of the people in the society. Their requirements for products are not limited to basic requirement. For these users, we should add some additional attractive requirement on the basis of meeting the expected requirement, and control the price within a reasonable range. Advanced products are aimed at those who have sufficient funds and have high living standards. For such users, they should try their best to improve the performance of products, meet more attractive requirement and other requirement with great weight. Price cost is only a minor part here.

6) Recognize the measurement indicators and assign weights. Through the analysis of the definition of each product's characteristics, the measure index for the final evaluation of the product's extension model is determined, and the weight of the measure index is all ocated according to the relevant experience.

7) Establish the correlation function of the measurement index and get the final product family plan by the goodness evaluation. The above schemes are all products that can meet the requirement of different types of users. Next, we should consider the views of technicians and enterprises on new product innovation schemes. On the one hand, we need products to meet the requirement of users, on the other hand, we also need to consider design schemes from the technical and cost levels. By establishing the correlation function and calculating the correlation degree of the extension model, the situation that each product meets the corresponding requirements is determined. In the process of product design, besides considering the requirement of users, we also need to consider the feasibility and cost of technology and other factors, so the calculation of correlation degree can better grasp the satisfaction degree of generated objects. Reference [10] provides the correlation function formulas used in different situations. It has high practical application value for solving the correlation degree of product characteristics. In order to evaluate the superiority of different product schemes, Kano's demand model has been adopted to determine the user's requirement, that is to say, the designed mobile phone product family should maximize the comprehensive superiority of all key factors such as user's requirement and costs, so the superiority adopted here should be defined. In order to meet the requirements, the comprehensive correlation degree of all measurement indicators is greater than 0. That:

$$C(Z) = \sum_{i=1}^{n} \alpha_i k_i$$

(6)

8) Finally, three products with the highest degree of superiority among all the schemes are selected as the product family design schemes which are currently adapted to the market requirements. The general flow chart of product design is shown in Fig. 2.
3. case analysis

In order to better illustrate the application of the above methods in product family design, this paper takes the design of mobile phone product family as an example to verify the explanation.

3.1. Extension Model $M_0$ for Initial Products

Through the flow chart, we can see that the initial extension model is derived from the previous generation of products or related products, that is, to show the basic functional characteristics of the product, but also to express the appearance characteristics of the product. From the literature [14-15], we can see that the expected requirement of users in 2003 have become the basic functional requirements. As for the appearance of mobile phones, people have paid more attention to screen size so far. With the popularity of Android and Apple mobile phones, mobile phones mostly adopt full touch screen design, so this paper takes full touch smart phones as an example to discuss. The extension model $M_0$ of the initial product can be established as follows:
In $M_0$, besides expressing the functions of the product, it also expresses some other information such as the screen material of the product. In this way, the original model of the mobile phone product can be displayed more intuitively to the designers and users.

3.2. Expanding the Product Elements in the Initial Product Model

According to the survey of experts, consumers and distributors, the functional and physical requirement of mobile phones are obtained, and the initial extension model is extended and analyzed. In China, smartphones have become an indispensable part of people's life, learning and work. In many respects, the use of smartphone application functions by users in China is even more than that in developed countries such as the United States [17]. According to the literature [18-20] and the network survey report, it can be preliminarily determined that the user's demand for mobile phones consists of five functions: communication, entertainment, Internet access, office and learning. Now the divergence analysis of the initial product extension model is carried out:

$$
M_0 = \begin{bmatrix}
\text{mobileO}, & \text{function}_1, & \text{voice call} \\
\text{function}_2, & \text{Instant SMS} \\
\text{function}_3, & \text{Social networking} \\
\text{function}_4, & \text{Video call} \\
\text{function}_5, & \text{Multi-Media} \\
\text{function}_6, & \text{Mobile Reading} \\
\text{Screen Material}_1, & \text{Toughened glass} \\
\text{function}_8, & \text{Radio playback}
\end{bmatrix}
$$

Due to the large scale of the extension model obtained from the divergence analysis process, some of them are represented by matter-element model, and the whole product functions and user requirements are aggregated into Table 2, and all the obtained user requirements are numbered.

3.3. Determine the Demand Classification Assessment Form and Investigate and Calculate Demand Satisfaction

According to the reference information of literature and network information, the Kano requirement model classification and evaluation table is established for each user's requirement as shown in Table 1. Through observation and statistics, we can get the category of Kano requirement model that each requirement belongs to, and remove the user survey results that do not meet the requirements, and finally classify the user Kano requirement model.

In this way, we can clearly see the importance people attach to the various requirement of mobile phones. For example, many years ago, mobile phones were still quite sophisticated in technology with
cameras, and the price was very expensive. However, according to the survey results, mobile phones with cameras have become the basic requirement of users. Next, according to the network survey, the absolute weight of the product is calculated by using Kano user demand weight formula (2), (3), (4), which is used as the weight coefficient of the demand in the final optimization evaluation of the generated product scheme.

Table 2 is a table of absolute weights of users' demands for different product characteristics, which is obtained through the network questionnaire survey. According to this list, the extension models of different grades of products in product family can be constructed.

| User requirement          | ID | Kano type | Absolute weight /% |
|---------------------------|----|-----------|--------------------|
| Voice call                | 1  | J         | 70.6               |
| Instant SMS               | 2  | J         | 70.6               |
| Social networking         | 3  | Q         | 70.5               |
| Video call                | 4  | W         | 43.1               |
| Media                     | 5  | Q         | 80.4               |
| Reading                   | 6  | Q         | 81                 |
| Screen Material           | 7  | Q         | 76.5               |
| FM radio                  | 8  | W         | 41.2               |
| Shell pattern             | 9  | E         | 78.4               |
| Calculation               | 10 | Q         | 64.7               |
| Recording                 | 11 | W         | 35.3               |
| GPS Navigation            | 12 | Q         | 60.8               |
| Battery capacity          | 13 | Q         | 82.4               |
| Shell Material            | 14 | Q         | 68.6               |
| Camera                    | 15 | E         | 76.5               |
| Multi card                | 16 | E         | 76.5               |
| Screen size               | 17 | Q         | 65.8               |
| Bluetooth                 | 18 | Q         | 60.8               |
| WIFI                      | 19 | Q         | 74.5               |
| Memory capacity           | 20 | Q         | 78.4               |
| Camera                    | 21 | J         | 72.6               |
| Gravity induction         | 22 | Q         | 70.6               |
| Game                      | 23 | Q         | 60.8               |
| Anti-theft Tracking       | 24 | E         | 80.4               |
| AI controller             | 25 | E         | 76.5               |
| TV broadcasting           | 26 | W         | 35.3               |
| Office function           | 27 | Q         | 60.8               |
| light and thin            | 28 | Q         | 62.7               |
| Man-machine conversation  | 29 | W         | 43.4               |
| Mobile consumption        | 30 | E         | 80.4               |

3.4. Extension transformation of M is carried out according to Kano demand classification table, and corresponding product extension model is obtained.

Since the extended analysis is based on the opinions of experts, consumers and distributors, the Extension Model M has basically summarized all predictable product functions. Therefore, the main method of extension transformation is to add and delete the transformation, that is, on the basis of the initial model, add and delete the features and quantities to get a new extension model.

For primary products, the product is mainly to meet the basic requirement of users, and has a reasonable price range. Under the acceptable conditions of users, the desire demand and charm demand are added appropriately, so the extension transformation of the extended model is as follows:
In $T_1$ transformation, the extended model is deleted and transformed, eliminating all the charm, expectation and insignificant requirement. Only a few basic requirements with larger weights are retained. Such a product can meet the basic requirements of users for mobile phone products at a minimum, and at the same time, the price of the product can be reduced to a relatively low range. Due to space constraints, the next extension transformation will no longer be used for text description.

In the same way, the extension model of other primary products can be obtained by extension transformation.

For intermediate products, in addition to basic requirement, it should also include all expected requirement and some unrelated or attractive requirement with high weight, while ensuring that the price of the product is within the acceptable range of the vast majority of people. According to the above requirements, the extended model is transformed accordingly. The addition-deletion transformation in the extension transformation is still used here. Therefore, the extension model of intermediate products can be obtained by extension transformation as follows:

For high-end products, the weight of price is not so high. Therefore, we should try our best to
improve the functional characteristics of the product. Therefore, the design of advanced products should include all the charm requirement and the expectations, basic requirement and irrelevant requirement of some users with higher satisfaction. Therefore, the extension model of advanced products is obtained by extension transformation as follows:

$$T_{PM} = \begin{bmatrix} MobileO\alpha, \text{ Requirement type } c_{1}\nu, \{ \text{All basic requirement} \} \\ Requirement type c_{2}\nu, \{ \text{All expected requirement} \} \\ Requirement type c_{3}\nu, \{ \text{All charm requirements} \} \\ Function c_{4}\nu, \text{ Radio playback} \\ Function c_{5}\nu, \text{ Man-machine conversation} \end{bmatrix}$$

$$T_{PM} = \begin{bmatrix} MobileO\alpha, \text{ Requirement type } c_{1}\nu, \{ \text{All charm requirements} \} \\ Function c_{6}\nu, \text{ Voice call} \\ Function c_{7}\nu, \text{ Instant SMS} \\ Function c_{8}\nu, \text{ Radio playback} \\ Screen material c_{9}\nu, \text{ New Toughened Glass} \\ Battery capacity c_{10}\nu, \text{ Big} \\ Shell material c_{11}\nu, \text{ New materials} \\ Memory capacity c_{12}\nu, \text{ Big} \end{bmatrix}$$

$$T_{PM} = \begin{bmatrix} MobileO\alpha, \text{ Requirement type } c_{1}\nu, \{ \text{All Charm Requirements} \} \\ Function c_{13}\nu, \text{ Voice call} \\ Function c_{14}\nu, \text{ Instant SMS} \\ Function c_{15}\nu, \text{ Media} \\ Function c_{16}\nu, \text{ Reading} \\ Battery capacity c_{17}\nu, \text{ Big} \\ Memory capacity c_{18}\nu, \text{ Big} \end{bmatrix}$$

3.5. Selection of measurement indicators and determination of weights
Above all, according to Kano demand model of users, several extension models of three levels of products are constructed. However, it is incomplete to consider products only in terms of meeting the needs of users. In the actual design and production, we also need to consider the technical characteristics of the product cost indicators. In order to select the best scheme from the design schemes of products at different levels, it is necessary to determine the weight coefficients of technical and cost indicators for products at different levels. According to the network survey, the weights of the measurement indicators can be listed as shown in Table 3.

| Product Level     | User requirement | Technical difficulty | Cost |
|-------------------|------------------|----------------------|------|
| primary products  | 0.2              | 0.2                  | 0.6  |
| Intermediate products | 0.3          | 0.3                  | 0.4  |
| Advanced Products | 0.5              | 0.4                  | 0.1  |

3.6. Establish the correlation function of the measurement index and evaluate the goodness, and get the final product family plan.
1) The correlation function of product user demand index is determined by the absolute weight of user demand in Kano demand model. The higher the weight of user’s requirements, the better the product’s characteristics. The following formulas can be used to express the absolute weight of user needs:
Where $n$ represents the corresponding nth user requirement. But the absolute weight of user demand is not the correlation degree between product and functional demand. In this paper, the discrete correlation function is used to construct the user demand correlation degree. For the three types of product models, different value-taking methods are used. For primary products:

$$k(x_i) = \begin{cases} 
1, & x_i \in [0.73, +\infty) \\
0.5, & x_i \in (0.72, 0.73] \\
0, & x_i \in (0.71, 0.72] \\
-0.5, & x_i \in (0.7, 0.71] \\
-1, & x_i \in (-\infty, 0.7) 
\end{cases}$$

Due to space constraints, only the range of values corresponding to primary products is listed for intermediate products and advanced products. For intermediate products, the value range is: \(\langle 0.65, +\infty \rangle, \langle 0.64, 0.65 \rangle, \langle 0.63, 0.64 \rangle, \langle 0.62, 0.63 \rangle, \langle -\infty, 0.62 \rangle\). For advanced products, the corresponding value range is: \(\langle 0.75, +\infty \rangle, \langle 0.74, 0.75 \rangle, \langle 0.73, 0.74 \rangle, \langle 0.72, 0.73 \rangle, \langle -\infty, 0.72 \rangle\).

2) For designers and technicians, the lower the technological capability requirement of mobile phone product family design is, the better. On the one hand, it realizes the convenience of product design, on the other hand, it also helps to reduce the cost of consumption. According to references [7], [13], the correlation function of the technical measurement index is determined to be a simple correlation function, and the maximum value is obtained at the minimum endpoint of the interval, so that the positive domain is a finite interval \(\langle 0, 1 \rangle\):

$$k(x_i) = \begin{cases} 
x_i, & x_i < 0, \\
1 - x_i, & x_i \geq 0.
\end{cases}$$

Among them, \(I = 1, 2, 3\) represents the technical difficulty parameters of three levels of products. When the technical measurement index is \(x_i=0\), it means that the technical difficulty of product design and production is the easiest to achieve, and then the maximum value is obtained; when the value of \(X_i\) is between \(\langle 0, 1 \rangle\), with the increase of the value, it is considered that the technical difficulty is increasing; when \(X_i\) is not in the X range, it is considered that it is very difficult to achieve or even impossible to achieve.

3) The cost of product design is also a factor that must be taken into account. Except for the high-level products which pay less attention to the price, the price weight coefficients of the low-level products and the intermediate products are all higher. Therefore, in the process of considering product design, it is of great significance to determine the cost weight coefficient. Generally speaking, the price should be controlled within a reasonable range. At the same time, when the price of the product is higher or lower than the user's satisfaction range, there is also a price range that users can tolerate. So the three-interval nested correlation function is used to calculate the correlation degree of product design cost.

$$k(x_i) = \begin{cases} 
\rho(x_j, x_{a_j}, X_j), & x_j \in X_j \\
\frac{D(x_j, X_{a_j}, X_j)}{D(x_j, X_j, \hat{X}_j)}, & x_j \not\in X_j
\end{cases}$$

Among them: \(j = 1, 2, 3\), respectively, representing the corresponding cost parameters \(X_{a_j} = \langle a_{0j}, b_{0j} \rangle, X_j = \langle a_j, b_j \rangle, \hat{X} = \langle c_j, d_j \rangle, x_{a_j} \in \langle a_{0j}, b_{0j} \rangle, X_{a_j} \subset X_j \subset \hat{X}_j\) for three categories of
products. There is no common endpoint for \( X_0, X \) and \( \hat{X} \), and the maximum value is taken at \( x_{0j} = a_{0j} \). The formulas for calculating the left distance \( \rho(x_j, a_j, X_j) \) and the position values \( D(x_j, X_{0j}, X_j) \) and \( D(x_j, X_j, \hat{X}_j) \) are given in reference [7].

Next in this paragraph, according to the results of market research, we give the arbitrage results of price intervals of various products. For primary products: \( X_{01} = \{300, 500\}, X_1 = \{100, 1000\}, \hat{X}_1 = \{0, 1200\} \); for intermediate products: \( X_{02} = \{1500, 2000\}, X_2 = \{1200, 3000\}, \hat{X}_2 = \{1000, 3200\} \); for advanced products: \( X_{03} = \{4000, 5000\}, X_3 = \{3500, 10000\}, \hat{X}_3 = \{3200, 12000\} \).

Based on the above formulas and information, the correlation degree of products corresponding to extension models with respect to each evaluation index can be calculated. The results are shown in Table 4.

According to the goodness evaluation information shown in table 4, scheme \( M_{011}, M_{022}, M_{033} \) can be selected as the final product family design scheme.

**Table 4**

| Object Model | Relevance Degree of User Requirements | Technical Relevance Degree | Cost Relevance Degree | Goodness degree \( C(Z) \) |
|--------------|--------------------------------------|---------------------------|-----------------------|-----------------------------|
| M011         | 0                                    | 0.1                       | 3.25                  | 1.97                        |
| M012         | 1                                    | 0.2                       | 1.444                 | 1.106                       |
| M013         | 0.5                                  | 0.2                       | 1.833                 | 1.2398                      |
| M021         | 1                                    | 0.3                       | 0.8                   | 0.71                        |
| M022         | 0                                    | 0.4                       | 2.8                   | 1.24                        |
| M023         | 0                                    | 0.5                       | 1.375                 | 0.7                         |
| M031         | 0                                    | 0.9                       | 0.6                   | 0.42                        |
| M032         | 0                                    | 0.8                       | 11                    | 1.42                        |
| M033         | 1                                    | 0.7                       | 11.6                  | 1.94                        |

4. Discussion and conclusion

This paper analyses the application and shortcomings of various methods of product family design in practice, and proposes an innovative design method of extension product family based on Kano demand model. The formal model of prototype product is established by extension model. The types of user's demand for the product are obtained through investigation and analysis. According to the results of Kano's demand model, the user's demand and weight are re-classified. Then a new product family creative scheme is generated by extension transformation and degree evaluation. Through the case study of mobile phone product family design, it is proved that this method has a very broad prospect in practical application, and has guiding significance for the application of synchronous multi-product design and the combination of extension and innovation methods and practice.

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**Project information:**

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References

[1] Nie Daan, Li Yan, Ma GuangLin, et al. Simultaneous multi product design method based on customer requirements classification[J]. Computer Integrated Manufacturing Systems, 2010,16(6):1131-1137.

[2] Liao Fei, Jia Weiying. The research of listed companies’ financial crisis forewarning based on cash flow. Commercial Accounting, 2014(82):80-82.

[3] Zhang Mier, Wu Chunyou. Product innovation model based on product platform[J]. R&D Management, 2000, 12(5):10-11.

[4] Zhu Bin, Jiang Pinyu. Methodology of design for product family[J]. Chinese Journal of Mechanical Engineering, 2006, 42(3):1-8.

[5] Tian Runhua, Wang Qingyu, Yuan Caiyun, et al. Theory for solving the inventive problems (TRIZ)—the process tools and developing trends of TRIZ[J]. Mechanical Engineering, 2001(7):7-12.

[6] Ma Yongzhi, Ding Yi, Gao Hong, Liu Wei. Logistics market segmentation based on extension classification[C] // Proceeding of International Conference on Information Management, Innovation Management and Industrial Engineering. Xi’an, China: IEEE press, 2013 (2): 216-219.

[7] Yang Chunyan, Cai Wen. Extenics Theory, Method and Application[M]. Beijing: Science Press, 2013.

[8] Ding Yi, Gao Hong, Liu Wei. A personalized recommendation algorithm based on Extenics[C] // Proceedings of The International Symposium on Extenics and Innovation Methods. Beijing: CRC press, 2013:101-107.

[9] REN Shuai, ZHANG Tao, XU Zhenchao, WANG Zhen, HE Yuan, LIU Yunong. Information hiding algorithm for 3D models based on feature point labeling and clustering[J]. Journal of Computer Applications, 2018, 38(4): 1017-1022.

[10] QI K, ZHANG D F, XIE D Q. Steganography for 3D model based on frame transform and HMM model in wavelet domain[J]. Journal of Computer-Aided Design & Computer Graphics, 2010, 22(8):1406-1411.

[11] HUA S G, ZHONG Q, LI S S. 3D shape deformation based on edge collapse mesh simplification[J]. Journal of Dalian University of Technology, 2011, 51(3):363-367.

[12] Sheng Chuanxin. Research on the method of appearance design based on 3g mobile phone. Wuhan: The study of Art, WuHan university of technology, 2008.