Innovative Design of Household Body Composition Analyzer Based on INPD and QFD

Huan Jia-mei 1, Chen Yang 1,*, and Luo Fei 2

1School of Mechanical Engineering, Guizhou University, Huaxi District, Guiyang City, Guizhou Province, 550025, China
2AECC Guizhou Liyang Aero-engine, Co., Ltd., Baiyun District, Guiyang City, Guizhou Province, 550014, China

* E-mail: 892168711@qq.com

Abstract. In order to solve the problems that the household body composition analyzer has not yet established a good experience relationship with users and the diversity of user needs, a new design method is proposed to get a more complete solution. Taking INPD as a research framework, re-examining the changes of SET factors can create new product opportunities and find product opportunity gaps; Through market surveys and user surveys, in-depth digging into the needs, preferences and expectations of target user groups, understanding product opportunity; Combining QFD models quantitatively analyze user needs and refine design requirements, establish a mapping relationship between user needs and design requirements, and quantify key design requirements. Through the combination of INPD and QFD, a design scheme driven by customer needs is given, which solves user needs to a certain extent, and its feasibility provides a reference for the innovative design of such products.

1. Introduction

With the improvement of people's awareness about health and the popularization of smart health care products, household body composition analyzer has become a research hotspot. However, the current trend of homogenization of household body composition analyzers on the market is obvious, lack of pertinence, and non-professionals are not easy to recognize, resulting in low user satisfaction. Therefore, developing products driven by customer needs is an urgent problem to be solved. According to the data, there are few studies on this product, mainly focusing on function and technology. Li Zhao [1] and others designed a body composition analyzer based on the data analysis technology of the Android platform, which improved the human-computer interaction of the product; Xiao Xiao-ming [2] and others studied the software and hardware system of the body composition analyzer, which improved the accuracy and reliability of the measurement results; Sung-Hoon Bae [3] and others introduced a chip design of the body composition analyzer based on the BIA method technology. It can be seen that these studies tend to be guided by the realization of functional technology, lacking in-depth analysis of the needs of consumer groups, and user-centric product development ideas. This article proposes a design method based on the combination of INPD development method and QFD model. Through systematic qualitative and quantitative analysis, users' needs are sorted out accurately, the importance of needs and key design requirements are quantified, and the design scheme that meets users' needs are put forward according to the quantitative results.
2. Design methods and procedures

2.1. INPD
INPD (Integrated New Product Development) is a development method proposed by Professor Cagan J and Vogel C M of Carnegie University, which is suitable for the early stage of product development ambiguity. It emphasizes the multi-professional combination of the development team based on the needs, requirements and wishes of users and the interests of other stakeholders. User-centered INPD includes four stages: identifying product opportunity, understanding product opportunity, product concepts formed by product opportunity, and Realization of opportunity [4].

2.2 QFD
QFD (Quality Function Deployment) is a quantitative analysis method that transforms user needs into design requirements. Its core content is to create products based on customer needs, and truly implement user needs into design practice [5]. As a scientific method for analyzing user needs, its key role is to correlate customer needs with product engineering requirements, construct a relationship matrix between the customer needs and product engineering requirements, and effectively convert the user's demand language into the technical language of development personnel [6]. To reduce the repeated changes and development of cycles in the design process, improve product quality.

2.3 Integration of INPD and QFD
Both INPD and QFD are user demand-oriented design methods. The advantage of the former is that it can accurately reflect the needs of users, but it can only achieve the effect of qualitative analysis, which has a certain subjective color. The latter uses matrix calculation to quantify the importance of user needs and calculate the key design requirements. Therefore, the combination of INPD and QFD can combine the common advantages of the two methods and give full play to their respective advantages to improve the design efficiency and product quality. Taking the design of the household body composition analyzer as an example, discussed the application of INPD and QFD in household body composition analyzer, so as to solve the shortcomings of the existing household body composition analyzer.

The four stages of INPD are used as the theoretical framework for research, which analyzes the early stage of product design fuzzy, identifies and understands product opportunities, comprehensively obtains user needs; In the conceptual opportunity stage, use QFD to determine the mapping between user needs and design requirements, quantify key design requirements and prioritization, and accordingly transform the product concept formed by the opportunity into a concrete design plan, and then guide the innovative design of the body composition analyzer. The application process of the design methods of INPD and QFD as shown in Figure 1.

![INPD and QFD design method application process](image)

3. Identify opportunity gaps
When the existing products are difficult to meet the needs of users under the new trend, the
re-examination of changes in social factors, economic factors and technological factors can create new product opportunities [7]. By reviewing books, news and online literature, the product opportunity gaps of body composition analyzer were identified by using the SET factor analysis method, as shown in Figure 2.

Through the analysis of SET factors, the potential needs of users under the new trend are found: In the aspect of social factors, according to the concerns and physiological characteristics of different groups, different display modes are designed and switchable data display modes are designed; In terms of economy, the household body composition analyzer can be used as a health investment in spare time. The middle-aged and elderly people can pay attention to the health indicators and warning signs, while young people can pay attention to body shape, image and health. As far as technology is concerned, there are problems in data reading of body composition analyzer, which leads to poor user experience and insufficient intelligence information. Internet, Internet of Things and other intelligent technologies can be applied to the products of body composition analyzer to enhance the user's Experience and convenience.

4. Understand product opportunity
At this stage, through market and user research, in-depth understanding of the needs of the target user, to understand the use and experience of the existing body composition analyzer, as well as potential users' lifestyle and preferences needs. The previous market research will be combined with questionnaires and user interviews to collect users' needs for body composition analyzers. This questionnaire designed 10 questions around the use of the body composition analyzer, and 76 valid questionnaires were collected. According to the questionnaire survey, interviews were set up. At the same time, we interviewed 12 consumers in the school and the community. The age range is mainly 18-65 years old, with a certain proportion of each. Collect and collate the user's demand for household body composition analyzer, as shown in Table 1.

| Number | User needs          | Number | User needs          |
|--------|---------------------|--------|---------------------|
| R1     | Easy to store       | R6     | Easy operation      |
| R2     | Easy interaction    | R7     | Beautiful shape     |
| R3     | Accurately measure  | R8     | Affordable          |
| R4     | Security            | R9     | Small size          |
| R5     | Feedback of data    | R10    | Durable             |

5. Establish a mapping relationship between user needs and design requirements
For design and development, determining the importance of needs in the minds of users is the key to guiding innovative design in the later period [8]. To meet the needs of the user group for household body composition analyzers to the maximum extent, 20 users are invited to participate in the important
assessment of household body composition analyzers according to 1—5 points. The records of demands that have no impact on the function realization are 1, those that have no impact on the main function realization are 2, those that have a great impact on the function realization are 3, those that have an important impact on the function realization are 4, and those that are basic, safety-related and particularly important are 5 [9]. By collecting the user's evaluation and analysis, the importance of the user's demand for household body composition analyzer is obtained, as shown in Table 2.

| Demand No. | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 |
|-----------|----|----|----|----|----|----|----|----|----|-----|
| Importance I | 3  | 4  | 5  | 5  | 5  | 4  | 2  | 3  | 4  | 2   |

Based on the important results given in Table 2, calculate the relative weight of user needs according to formula (1) [10].

$$w_i = \frac{I_i}{\sum_{i=1}^{n} I_i}$$  \hspace{1cm} (1)

After calculation, the relevant weight matrix of demand is:

$$W = \begin{bmatrix}
0.0811 & 0.1081 & 0.1351 & 0.1351 & 0.1351 & 0.1351 & 0.1081 & 0.0541 & 0.0811 & 0.1351 \\
0.1351 & 0.0811 & 0.1081 & 0.1351 & 0.1081 & 0.1351 & 0.1081 & 0.1351 & 0.0541 & 0.1081 \\
0.0541 & 0.0541 & 0.0541 & 0.0541 & 0.0541 & 0.0541 & 0.0541 & 0.0541 & 0.0541 & 0.0541
\end{bmatrix}$$

In order to implement the needs of household body composition analyzers and integrate them into every design detail, these needs should be translated into design requirements. Using the KJ method to sort out the design requirements according to the relevant design requirements that the product discussion may have a certain impact on customer needs. The KJ method can effectively organize the survey data and the qualitative ideas of the participants according to the similarity between user needs and design requirements, and unify the opinions of the participants [11]. Through analysis and sorting out the design requirements, as shown in Table 3.

| Number | Design requirements                        | Number | Design requirements                        |
|--------|-------------------------------------------|--------|-------------------------------------------|
| D1     | Can be stored                              | D7     | Product structure                         |
| D2     | Provides multiple display modes            | D8     | Measurement method                        |
| D3     | Provides data analysis and recording       | D9     | Comfortable grip                          |
| D4     | Voice broadcast data                       | D10    | Product form                              |
| D5     | Key data are clear                         | D11    | Man-machine size                          |
| D6     | Stable to prevent rollover                 | D12    | Material selection                        |

Construct the relationship between the user needs and the design requirements of the body composition analyzer. According to the correlation between them, the relationship values are given in the range of [-2, 2], which corresponds to strong positive correlation, positive correlation, irrelevance, negative correlation, strong negative correlation. And adding the relevant weight matrix of the above user needs to the relationship matrix table, as shown in Table 4.

| Number | $w_i$ | D1  | D2  | D3  | D4  | D5  | D6  | D7  | D8  | D9  | D10 | D11 | D12 |
|--------|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| R1     | 0.0811| 2   | 0   | 0   | 0   | 0   | 1   | 0   | 0   | 1   | 0   | 0   | 1   |
| R2     | 0.1081| 1   | 2   | 1   | 2   | 2   | 0   | 0   | 1   | 0   | 2   | 0   | 0   |
| R3     | 0.1351| 0   | 2   | 0   | 0   | 0   | 0   | 0   | 2   | 0   | 0   | 0   | 0   |
| R4     | 0.1351| 0   | 0   | 0   | 0   | 0   | 2   | 1   | 0   | 0   | 1   | 0   | 1   |
| R5     | 0.1351| 0   | 2   | 2   | 1   | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| R6     | 0.1081| 0   | 1   | 1   | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 1   | 0   |
| R7     | 0.0541| 1   | 0   | 0   | 0   | 0   | 1   | 0   | 2   | 0   | 0   | 0   | 0   |
| R8     | 0.0811| -1  | -1  | -2  | -1  | 0   | 0   | -1  | -1  | 0   | -2  | 0   | -2  |
| R9     | 0.1081| 2   | 0   | 0   | 0   | 0   | 0   | 1   | 0   | 0   | 2   | 0   | 0   |
| R10    | 0.0541| 1   | 0   | 0   | 0   | 0   | 1   | 0   | 0   | 1   | 1   | 1   | 2   |

According to the relationship matrix in Table 4, the user demand weight matrix and the design
requirement matrix are quantified by the matrix calculation method to quantify the key design requirements, and the overall evaluation degree and preferred ranking results of the household body composition analyzer are obtained, as shown in Table 5.

**Table 5. Evaluation degree and optimal ranking of household body composition analyzer.**

| Design requirements(D) | D1    | D2    | D3    | D4    | D5    | D6    | D7    | D8    | D9    | D10   | D11   | D12   |
|------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Rating                 | 0.5136| 0.7836| 0.3242| 0.3783| 0.4594| 0.2702| 0.4595| 0.4053| 0.01081| 0.7568| 0.0541| 0.1622|
| Prioritization         | 3     | 1     | 8     | 7     | 5     | 9     | 4     | 6     | 11    | 2     | 12    | 10    |

6. Scheme design

According to the ranking results in Table 5, the design requirement D2 "provides multiple display modes" is the most important thing for the user community. Because different people have different data and information, satisfaction of the product is not high at present. Therefore, product design should aim at user groups and meet the needs of people with different attributes to the maximum extent. The target population is mainly divided into three categories: the first category, body fat measurement is irregular, focusing on simple weight. For this group of people, a simple reading mode should be set. When it is necessary to measure the whole body fat, you can set it yourself, as shown in Figure 3 (a); The second and third categories are middle-aged and elderly, respectively, while focusing on the health index, each has its focus. The middle-aged and elderly people pay more attention to disease prevention, and their body functions decline, and their eyesight is poor. It is necessary to consider the display font size; Young people pay more attention to the body shape and body fat rate direction, but the product display function area is limited, and it does not cover all the data well. According to the data which they are most concerned about, different display modes are presented to reduce the complexity of the interface and make it easier to recognize, as shown in figure 3 (b) and (c).

The design requirement D10 "product form" is second only to D2. The use of body composition analyzer is irregular, and users will use it more in their spare time. Good product shapes can give users a beautiful visual sense. Current product shapes are mostly rectangular and round, which lack interesting shapes. Extracting the relevant elements of such products for the morphological design of the body composition analyzer can increase the popularity of the product. This design is mainly extracted as a human body curve, using it as a modeling element, as shown in figure 4.

The design requirement D1 "can be stored" is the third most important. The frequency of use of the body composition analyzer is relatively low. When people use it, they hope it can be stored reasonably and save space. Therefore, the storage method of figure 5 can not only satisfy the different properties measured by different people, but also store the line reasonably.

![Figure 3](image-url)  (a) and (b) (c) three display modes.
Based on the ranking results and in-depth analysis, the design requirements are implemented into the product design, the key design requirements of the household body composition analyzer are optimized, and the design expectations that are closer to the user's needs are proposed.

7. Conclusion
The INPD and QFD models are combined to fully analyze the user needs, which can not only ensure effective investment in the analysis of user needs in the early stage of development, but also quantify the importance and key design requirements through the QFD model. It avoids the subjective deviation of the analysis of user needs causing by the INPD carding requirements. Through qualitative and quantitative analysis in different stages, the key design requirements of the body composition analyzer are obtained, and the key development direction is pointed out for the designers and developers. According to the key design requirements, a brand-new design scheme was put forward, and the design of the household body composition analyzer for users' needs was finally completed, which provides new ideas for the innovation of related products.

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