Design and Evaluation of Scene-Based Product Device

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Abstract. The production of persimmon has a long history, however, the traditional production of persimmon depends mainly on manpower and is greatly affected by the natural weather. The yield and quality cannot be guaranteed which affects the taste, sales and word of mouth. According to the scenario design program, four kinds of user requirement models are constructed. After systematic analysis, four functional principle schemes are obtained, and five evaluation indexes are summarized. Finally, scheme 4 is selected as the most ideal scheme. Through the research and application of scenario design method in the process of product design, this paper provides an evaluation method for the evaluation of the product design, which helps designers to determine the direction of product development effectively.

1. Introduction

1.1. For Scenario design
In the product design, the user’s experience is difficult to quantify by the statistical method, therefore, it is usually done by building a user scenario. Scenario construction can help the designer to take into account the different state of the product in different scenarios, and understand the way of life and behaviour of the user deeply [1]. In this paper, Scenario story method is used to analyze the storyboard and the user demand model. Through the combination of analytic hierarchy process and triangular fuzzy number method, optimum scheme can be selected, meanwhile, the innovative design method of the user's personalized needs is explored.

A scenario is a description of the actual situation of the past or the future. It is a collection of expected scenarios [2]. The paper uses the first three steps of raising questions, scenario segmentation, and scenario construction in scenario design program. Because of the research of persimmon suspension drying device, so "putting forward questions" is to solve the related problems of persimmon hanging drying. The factors of the scene model include the interaction among the environment, the user, the product and the three.

According to the design procedure of scenario story and the results of market investigation, the production of persimmon can be divided into four first-class scenarios, namely, persimmon drying is shown in figure 1, persimmon hanging is shown in figure 2, persimmon suspension is shown in figure 3, manual drying is shown in figure 4. The four first-class scenarios are divided into a number of secondary scenarios such as cleaning, staging, placing, and so on. Through on-site investigation, analysis, data inspection and so on, scenario of persimmon production have been constructed. namely, persimmon drying, persimmon hanging, persimmon suspension, manual drying. The traditional production of the artificial persimmon depends on the non-stable nature. The quality of the high-quality products is low, however, the artificial drying method can overcome the drawbacks of the
natural drying system. After analysis, the present situation of persimmon cake can be obtained as follows: (1) environmental factors: drying and hanging the natural environment, weather and air cannot be effectively controlled, however, the drying environment is opposite, but the cost is higher; (2) user factors: consuming a lot of manpower, repetitive work, high physical requirements, etc., but less drying workload; (3) Product factors: drying only the baking yield and quality are guaranteed; the cycle is short; the equipment covers a small area; and the degree of mechanization is high.

1.2. User requirement model extraction

There are many decisive factors in product design, such as product function, style and so on. The user's demand for the product usually includes material, psychological and social needs. According to the story board analysis, we can get the needs of agricultural users, detailed user requirements as shown in Table 1.

Figure 1. Persimmon drying story board

Figure 2. Persimmon hanging story board.

Figure 3. Persimmon hanging story board

Figure 4. Manual drying story board

Figure 5. The whole structure of persimmon baking

Figure 6. Automatic kneading machine for persimmon
2. Systematic Analysis of existing products

2.1. Total function analysis
Functional Analysis is a commonly used method in Product systematic Analysis when we adopt the function analysis method to carry on the scheme design, the step is to first determine the total function, abstract its design problem. Secondly, the total function of the system was decomposed into Sub-function. Finally, the combination of principle solution of general function was form a variety of principle design scheme.

The main structure of the connecting rod-conveying chain combined persimmon cake baking device [3] comprises a shell, a rotating device, a persimmon rack, a hot air device and an air guide device. As shown in figure 5, the front door 3 and the side door 7 is arranged on the shell 4, the rotation device 1 and the hanging frame 2 is arranged in the shell 4, the air outlet 8 is arranged at the top of the shell 4, the heating device 6 is arranged at the bottom of the shell 4, and the receiving box 5 is connected with the shell 4. A number of hangers 2 are connected to the rotation device 1. The function and layout of this device provide an effective reference value for the device designed in this paper.

The persimmon cake automatic kneading machine[4] is composed of a power device 1, a bracket 2, a grid device 3, a driving rod 4 and a rolling wheel device 5, the support 2 is used for supporting the rest of the structure and the grid device 3 is used for containing the persimmon, the driving rod is used for driving the kneading wheel device 5 to knead the persimmon 6. The device integrates the principle of shape change in the process of transformation between quadrilateral and rhomboid into the kneading design of persimmon cake so that the kneading device is combined with the oven tray, and the whole structure of the persimmon cake kneading device is shown in figure 6.

![Table 1. User demand.](attachment:image)

2.2. Morphological matrix calculation
The morphological synthesis method is based on the morphological matrix and finds out all kinds of answers through the decomposition and combination of the system [5]. According to the functional decomposition diagram and scenario map of persimmon making device, the functional elements of persimmon baking device are solved by the method of design catalogue. The morphological matrix of functional elements of persimmon baking device is constructed by means of morphological analysis[6]. The morphological matrix of the main functional elements is shown in figure 7.

According to the above principles and the user's demand model, the following several suitable schemes can be obtained. Scheme 1: semi-automatic persimmon hanging drying device (A1+B2+C2+D2+E2+F2+G1). Scheme 2: self-rotating kneading and kneading persimmon baking
device (A1+B4+C4+D1+E2+G1) Scheme 3: drive type persimmon cake baking device (A2+B3+C4+D1+E1+G2) Scheme 4 (A2+B1+C3+D2+E2+F3+G1).

Table 2. Evaluation Index of persimmon hanging drying device

| Classification | Primary indicator | Secondary indicator |
|----------------|-------------------|---------------------|
| Technical index of persimmon suspension device | Temperature rise rate A1 | Floor area B1 |
| | | Persimmon space area B2 |
| | | Observable area B4 |
| Human-machine relationship A2 | Color B5 | Modelling B6 |
| Practicability index A3 | Security B8 | Operational ease B9 |
| | | Degree of automation B10 |
| | | Maintainability B11 |

| Economic index of persimmon suspension device | Economic index A4 | Device cost B12 | Work cost B13 | Work period B14 | Product period B15 |
| Society Index of persimmon suspension device | Green index A5 | Pollution level B16 | Fuel B17 | Security B18 | Retrievability B19 |

Table 3. The first level index matrix and weight of the device.

| A   | A1  | A2  | A3   | A4    | A5    | W    |
|-----|-----|-----|------|-------|-------|------|
| A1  | 1   | 5   | 2    | 1/7   | 1/2   | 0.151|
| A2  | 1/5 | 1   | 1/5  | 1/6   | 1/6   | 0.037|
| A3  | 1/2 | 5   | 1    | 1/2   | 1     | 0.157|
| A4  | 7   | 6   | 2    | 1     | 1     | 0.409|
| A5  | 2   | 6   | 1    | 1     | 1     | 0.243|

Table 4. The assembly matrix of the evaluator’s opinions.

|    | U1       | U2       | U3       | U4       | U5       |
|----|----------|----------|----------|----------|----------|
| X1 | (0.21,0.27,0.32) | (0.16,0.20,0.28) | (0.20,0.22,0.25) | (0.25,0.29,0.33) | (0.32,0.37,0.42) |
| X2 | (0.23,0.26,0.31) | (0.08,0.14,0.22) | (0.26,0.29,0.33) | (0.22,0.25,0.29) | (0.08,0.11,0.14) |
| X3 | (0.16,0.20,0.25) | (0.14,0.18,0.24) | (0.19,0.22,0.26) | (0.18,0.21,0.24) | (0.22,0.24,0.27) |
| X4 | (0.22,0.25,0.30) | (0.37,0.46,0.55) | (0.19,0.23,0.26) | (0.21,0.23,0.26) | (0.24,0.25,0.29) |

3. Scheme Optimization based on the functional principle of user satisfaction

3.1. Determination of evaluation index system of product function principle scheme

The evaluation index system refers to the framework and system for the evaluation of industrial products. Because of its wide range and complexity, we should first establish an evaluation system to measure the comprehensive performance of products [6]. So we can get the evaluation index of persimmon hanging drying device. Which is shown in Table 2.
The analytic hierarchy process (AHP) is mainly to compare the elements in pairs, and then to sort and judge the overall weights of these elements, and finally to establish the weights of each element [7]. Through the expert consultation method, we compare the importance of the first-level index of the 1-9 scale method, and calculate the evaluation index of the judgment matrix. In order to achieve satisfactory consistency [8], we get the weight of the influencing factors, and the random consistency of the hierarchy total order order (CR=0 < 0.1, P < 0.01). Therefore, the matrix is effective, and the weights of the first-order indexes and the synthetic evaluation indexes are obtained, as shown in Table 3.

According to the final comprehensive evaluation of weight, five evaluation indexes of persimmon hanging drying device can be selected, including the work cycle, safety, device cost, persimmon space area and automation degree.

| Functional element unnumbering | Functional element |
|-----------------------------|------------------|
|                            | A    | B    | C     | D     | E      | F    | G      |
| Barbecue                   | Placing | kneading | Observe the interior | Operation panel | Storage | Destroy |
| Fuel                        | Tray            | Open-air drying | Glass type | Touch screen | Manual acceptance | Ultraviolet rays |
| Electrical heating          | Hang            | Manual kneading | Window type | Press key | Drop acceptance | Spray drugs |
| Link mechanism              |                |                |                |                | Device acceptance |                |
| Mechanical kneading        |                |                |                |                |                |                |

**Figure 7.** Morphology matrix of persimmon baking device

3.2. **Determined by the group multi-evaluation index decision-making method of the triangular fuzzy number**

Firstly, the fuzzy decision matrix of the Kth expert is constructed

\[ \tilde{A} = [a_{ij}]_{m \times n}, \quad a_{ij} = (a_{ij}^L, a_{ij}^M, a_{ij}^U) \]

 Represents the value of the K evaluator's evaluation of the scheme \( X_i \) under the target \( U_j \), which In order to eliminate the influence of different physical dimensions on decision-making results. The normalized formula is as follows[8].

\[
\begin{align*}
    b_{ij}^{KL} &= \frac{a_{ij}^{KL}}{\sum_{i,j} a_{ij}^{KL}} , \\
    b_{ij}^{KM} &= \frac{a_{ij}^{KM}}{\sum_{i,j} a_{ij}^{KM}} , \\
    b_{ij}^{LU} &= \frac{a_{ij}^{LU}}{\sum_{i,j} a_{ij}^{LU}} \\
\end{align*}
\]

(1)

The aggregation of the evaluator's opinions is to aggregate the individual evaluation value of each evaluator under the subjective evaluation index. The evaluation value of the evaluator \( e^k \) under the evaluation index \( u_j \) is set as the evaluation value of the evaluation index \( u_j \) \( \tilde{b}_{ij} = (b_{ij}^{KL}, b_{ij}^{KM}, b_{ij}^{LU}) \).
This paper holds that the weights of the three experts are the same, that is, \( \omega_k = (1/3, 1/3, 1/3) \). Therefore, the assembly matrix of evaluators’ opinions can be obtained, as shown in Table 4.

The \( U^* = (u_1, u_2, \ldots, u_n) \) is ideal Schema. We are based on the distance between the two triangular fuzzy numbers, that is, the average value of the alternative scheme evaluation to the evaluation value of the positive ideal scheme and the negative. The European distance of the evaluation value of ideal scheme and the European distance are shown in the formulas.

\[
\begin{align*}
d_i^+ &= \sqrt{(d_{i1}^+)^2 + (d_{i2}^+)^2 + \ldots + (d_{in}^+)^2} \\
d_i^- &= \sqrt{(d_{i1}^-)^2 + (d_{i2}^-)^2 + \ldots + (d_{in}^-)^2} \\
L(X_i) &= \frac{d_i^+}{d_i^+ + d_i^-} \\
L(X_*) &= 0.781
\end{align*}
\]

4. Conclusion

In this paper, he first three steps of scenario design program can be used to construct the feature model of product user group effectively. The scheme of constructing innovative product can be determined by the method of systematic product analysis. Comprehensive analytic hierarchy process (AHP) and trigonometric fuzzy number (TFA) re used to evaluate the product scheme the innovative design of persimmon hanging drying device, it shows that the innovative design of mechanical and electrical products based on theory and technology is effective, which provides an innovative approach.

References

[1] Liu Lanlan, “Application of situational storytelling in Product Design and Development.” Journal of Packaging Engineering, 2007(9).

[2] Hu Kang, “Design of Fire helmet based on situational Construction.” Journal of Packaging Engineering, 2018(6).

[3] Liu Jianhua, “Connecting rod conveyor chain combined persimmon baking device.” Chinese patent: 201612173U, 2017(11).

[4] Li Ke, “Automatic kneading and kneading machine of cam-connecting rod persimmon.” Chinese patent: 201612173U, 2017(11).

[5] Li Yao, “Research on customer-oriented Collaborative Evaluation system for Industrial Design products.” Degree of — Shaanxi University of Technologym, 2007(6)

[6] Liu Yuan, “Research on Advertising originality based on morphological Matrix decomposition elements.” Degree of Hubei University Of Technology, 2009(6).

[7] Hong Zhiguo “Calculation of higher-order average Stochastic consistency Index (ri) in Analytic hierarchy process.” Journal of Computer engineering and application, 2002(6)

[8] Zhang Zhina, “Research on driving School selection based on Fuzzy Analytic hierarchy process.” Journal of Shangqiu Vocational and Technical College2015(4).