Research on fire and explosion-proof elevator design based on RAHP-QFD

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ABSTRACT

In the current society, the application of fire-fighting explosion-proof elevators is reflected in more and more scenarios, indicating that fire-fighting explosion-proof elevators have great development potential. In this paper, the rough analytic hierarchy process (RAHP) and the mass function development method (QFD) are used to study and analyze the design of large-load and low-energy fire-fighting explosion-proof elevators, and put forward design suggestions. Firstly, the user demand index was obtained through market research and other methods, and the weight value of each demand was calculated by using the RAHP method, and then the user demand was transformed into technical indicators and the quality house was established, and finally the quality house was analyzed and conclusions. The RAHP-QFD method can well combine the user's needs with the technical indicators, and can more intuitively reflect the relationship between the user's needs and the technical indicators. At the same time, the combination of the two methods can complement the shortcomings of the two methods as a strong basis for conclusions.

Keywords: Rough analytic hierarchy process, QFD, fire explosion-proof elevator, user demand

1. INTRODUCTION

Fire and explosion-proof elevator, as an important disaster relief and life-saving equipment, can be used for firefighters to rescue the complete safety protection in case of fire, and it is the key for firefighters to be able to go to the floor of the fire in time to effectively extinguish the fire and reduce the loss. Current research on fire and explosion-proof elevators primarily focuses on improving its fire and explosion-proof performance, as well as enhancing the evacuation efficiency and safety. The application of new materials and the introduction of advanced technology have further improved the performance of fire and explosion-proof elevators. However, there is little research on the overall design planning of fire and explosion-proof elevators, resulting in incomplete design considerations for fire and explosion-proof elevators, repeated modification of design requirements, and low development efficiency.

Currently, the design of explosion-proof elevator mainly considers customer needs and elevator installation environment, therefore, obtaining user needs and transforming them into accomplishable indexes according to the needs is the key to the design process of explosion-proof elevator. Quality Function Deployment (QFD, Quality Function Deployment), as a user demand-oriented product design method, provides a model for transforming from user demand to technical requirements. The AHP method has been widely used in multi-attribute decision making since it was proposed in 1980 [1-3], and the combination of AHP and QFD can effectively solve the problem of the problem of transforming customer needs into technical objectives. Shi Hailin[4] and others used AHP-QFD to study the identification of industrial competitive intelligence needs, and transformed customer intelligence needs into key intelligence tasks through standardized and process-oriented methods to provide effective identification methods for intelligence needs identification; Zhang Yang[5] and others collated customer needs related to the packaging project of maintenance equipment, and weighted and quantitatively evaluated the needs using AHP-QFD methods to The index system of customer demand is obtained; Wang Jun[6] et al. constructed a theoretical model of the quality design of the elderly bathroom cabinet with the quality function development (QFD) theory and hierarchical analysis method (AHP) as the theoretical support, and used it as the basis for the design practice of the elderly bathroom cabinet; Wang Qiuhu[7] et al. explored the human-machine system design method of the restaurant service robots based on the quality function development (QFD) theory, citing the rough hierarchical analysis method (RAA) and

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the rough hierarchical analysis method (RAA). The rough set theory is applied to the hierarchical analysis method to obtain the passenger demand hierarchy table and transform it into evaluation indexes to construct a two-stage QFD model; Zheng Yifeng[8] and others explored the QFD-based human-robot system design method for restaurant service robots, citing the rough set theory in the rough hierarchical analysis method to calculate the weights occupied by the demand characteristics, and then analyzed the key design objectives in the QFD-based restaurant service robots design method. model; Zheng Yifeng[9] and others introduced rough hierarchical analysis (RAHP) to obtain the initial importance of user requirements for intelligent air purifiers, used the fuzzy Kano model (FKM) to determine the categories of each requirement, and utilized the quality function development (QFD) to transform the user requirements into design elements.

However, the combination of AHP and QFD also has the defect of strong subjectivity[10], this paper uses rough hierarchical analysis to analyze and calculate the weights of the user demand indicators of fire and explosion-proof elevators in order to reduce the subjectivity of the hierarchical analysis method, and adopts the QFD method to transform the user demand into the technical objectives of fire and explosion-proof elevators, and through the hierarchical analysis of the RAHP to quantify the importance of each factor Through the hierarchical analysis of RAHP, the importance of each factor is quantified and evaluated to improve the systematic and scientific nature of the design process of the fire and explosion-proof elevator, and to ensure that the product meets the user's needs and at the same time, it has good technical realization and market competitiveness.

2. RAHP-QFD DESIGN MODEL

2.1 Quality house construction and design planning based on QFD methodology

QFD is a quality function development (QFD) methodology used to translate customer needs into specific requirements in the product design and production process[11,12]. QFD helps enterprises to better understand and satisfy customer needs, improve product quality and market competitiveness by systematically linking customer needs, product characteristics and production processe[13]. The method usually includes demand analysis at the strategic level, product characteristic development at the design level, and process development at the production level, to ensure that the product can fully take into account the customer demand in the design and production process, improve product quality and meet market demand, the specific model is shown in Figure 1.

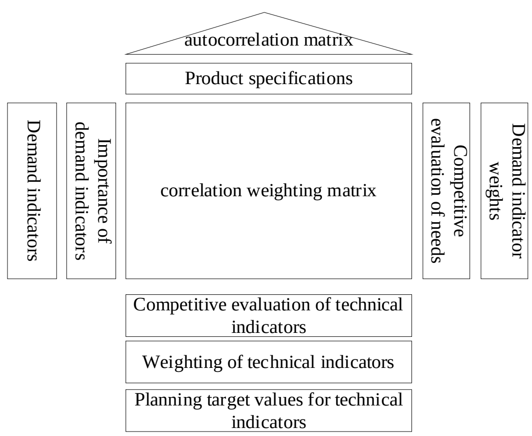

Figure 1. Masterplan Quality House Structure Plan

In the quality house, the left wall of the quality house consists of the extreme importance of the demand indicators, which can be collected through market research and other methods, and their importance can be derived from the evaluation of experts or target customers, or based on the statistical frequency of the demand indicators during the collection process; The ceiling of the quality house consists of the product's technical indicators, which are selected by the expert panel in conjunction with the evaluation of the product's actual situation; The room of the quality house consists of the relevance weighting The room of the quality house is the correlation weight matrix, which represents the relationship between each technical indicator and each demand indicator and is determined by the expert panel; The roof of the quality house is the autocorrelation matrix of the technical indicators, which represents the positive or negative correlation between each technical indicator; The right wall of the quality house includes the competitive evaluation of the demand indicators and their weights, and it can display the information of the demand indicators' current level, target value, level improvement rate, absolute weight and relative weight, etc.; The floor of the quality house includes the technical indicators and their weights. The floor of the quality house includes the competitive evaluation, absolute weight and relative weight of technical indicators, which indicates the relative importance of each technical indicator; the basement of the quality house is the planning target value of technical indicators, which indicates the target of design planning for each technical indicator. QFD method can help enterprises to better meet customer needs in the product design and production process, improve product quality and market competitiveness[14-16].

2.2 Calculation of demand indicator weights based on RAHP methodology

RAHP (Rough Analytic Hierarchy Process) is a multi-criteria decision-making method designed to solve prioritization and decision-making problems in complex decision making environments[17]. AHP helps decision makers by firstly decomposing the problem into structural hierarchies, and then using expert judgement and mathematical calculations to determine the relative importance between the factors to help them make trade-offs and decision-making[18].

The basic steps for calculating the weight of demand indicators using the RAHP method are shown in Figure 2.

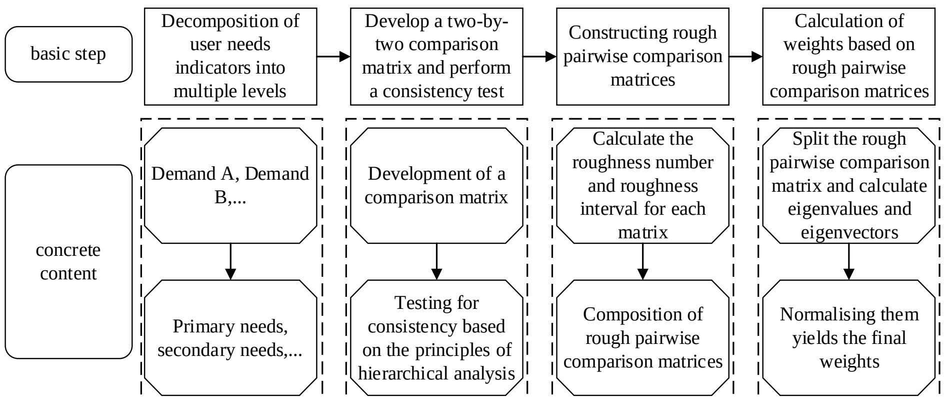

Figure 2. RAHP Basic Steps

1. Hierarchical structure: Decision-making problems are decomposed into multiple levels, including the objective, criterion and program levels, in order to better understand the complexity of the problem and the hierarchical relationships.

2. Developing a two-by-two comparison matrix and conducting consistency tests: factors at each level are compared two-by-two to determine their relative importance, which usually requires expert judgment and subjective evaluation. The form of the judgment matrix developed is shown below:

$$P_i = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \tag{1}$$

Where i is the number of experts, a_{ij} is the comparison coefficient assessed by the experts, and n is the number of factors. of which, i is the number of experts, a_{ij} is the comparison coefficient assessed by the experts, and n is the number of factors. Afterwards, the consistency test was performed on each matrix. Afterwards the consistency test is performed on each matrix.

First calculate the geometric mean of each matrix t:

$$t_i = \sqrt[n]{\prod_{j}^{n} Y_{ij}} = [t_i^1 \quad t_i^2 \quad \cdots \quad t_i^n]^T \tag{2}$$

Normalize all results to obtain relative weights W:

$$W_i = t_i / \sum_{i=1}^{n} t_i = [w_i^1 \quad w_i^2 \quad \cdots \quad w_i^n]^T \tag{3}$$

Calculate the largest characteristic root λ_{max}:

$$ZW_i = [zw_i^1 \quad zw_i^2 \quad zw_i^3]^T \tag{4}$$

Where Z is the judgment matrix P_i, then:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{ZW_i}{W_i} = \frac{1}{n} \times \left(\frac{zw_i^1}{w_i^1} + \frac{zw_i^2}{w_i^2} + \cdots + \frac{zw_i^n}{w_i^n}\right) \tag{5}$$

Finally, the results were tested for consistency:

$$CI = \frac{\lambda_{max} - n}{n-1}$$
$$CR = \frac{CI}{RI} \tag{6}$$

The value of RI in the formula is shown in Table 1, when $CR \leq 0.1$, it means that the decision maker's judgment of the elements is reasonable, on the contrary, it is necessary to recalculate the value of each demand indicator in the matrix until $CR \leq 0.1$.

Table 1. Table of RI values

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

3. Finding the rough pairwise comparison matrix: combining all the evaluation matrices into one sum matrix, i.e.

$$P^* = \begin{bmatrix} 1 & \cdots & P_{1f}^* \\ \vdots & \ddots & \vdots \\ P_{e1}^* & \cdots & P_{ff}^* \end{bmatrix} \tag{7}$$

Where $P_{ef}^{*n} = \{P_1^n, P_2^n, \cdots, P_i^n\}$ i.e., the set of elements at the corresponding positions in each judgment matrix.

After that, the roughness of each element of P^* is calculated., Take p_{12}^* as an example, the roughness of "division p_i" is calculated for $p_{12}^* = \{p_1, p_2, p_3, p_4\}$:

$$\underline{Lim}(p_i) = \frac{[\sum_1^m p^{\geq}]}{m} \quad , \quad \overline{Lim}(p_i) = \frac{[\sum_1^m p^{\leq}]}{m} \tag{8}$$

Where $p^{\geq}$ denotes an element in P^* that is greater than or equal to p_i and $p^{\leq}$ denotes an element in P^* that is less than or equal to p_i.

Then its rough boundary interval is:

$$RBnd(p_i) = \overline{Lim}(p_i) - \underline{Lim}(p_i) \tag{9}$$

Therefore, the roughness of "division p_i" is:

$$RN(p_i) = \left[\underline{Lim}(p_i), \overline{Lim}(p_i)\right] \tag{10}$$

After calculating the amount of roughness's for each element, the rough set of p_{12}^* can be derived:

$$RN(p_{12}^*) = \left\{\left[\underline{Lim}(p_1), \overline{Lim}(p_1)\right], \ldots, \left[\underline{Lim}(p_i), \overline{Lim}(p_i)\right]\right\} \tag{11}$$

Define rough number algorithm. Let $RN_i = [L_i, U_i]$ and $RN_j = [L_j, U_j]$ be two rough numbers, where L_i and L_j are the lower bounds of RN_i and RN_j,respectively, and U_i and U_j are the upper bounds of RN_i and RN_j,respectively, and $L_i, L_j, U_i, U_j \in R^+$,and k is a nonzero constant, then we have:

$$RN_i + RN_j = [L_i, U_i] + [L_j, U_j] = [L_i + L_j, U_i + U_j] \tag{12}$$
$$RN_i - RN_j = [L_i, U_i] - [L_j, U_j] = [L_i - L_j, U_i - U_j] \tag{13}$$
$$RN_i \times RN_j = [L_i, U_i] \times [L_j, U_j] = [L_i \times L_j, U_i \times U_j] \tag{14}$$
$$k \times RN_i = k \times [L_i, U_i] = [kL_i + kL_j] \tag{15}$$

According to the algorithm, the average roughness interval of p_{12}^* can be derived:

$$RN(p_{12}) = \left[\frac{\sum \underline{Lim}(p_i)}{n}, \frac{\overline{Lim}(p_i)}{n}\right] \tag{16}$$

Similarly, the roughness numbers and average roughness intervals of all the elements in the group decision matrix can be found according to the above principle to obtain the roughness pairwise comparison matrix P:

$$P = \begin{bmatrix} [1,1] & \cdots & [P_{1n}^-, P_{1n}^+] \\ \vdots & \ddots & \vdots \\ [P_{n1}^-, P_{n1}^+] & \cdots & [1,1] \end{bmatrix} \tag{17}$$

4. Calculate the weights: split the rough pairwise comparison matrix into two upper and lower bounding matrices, i.e.

$$P^- = \begin{bmatrix} 1 & \cdots & P_{1n}^- \\ \vdots & \ddots & \vdots \\ P_{n1}^- & \cdots & 1 \end{bmatrix}, \quad P^+ = \begin{bmatrix} 1 & \cdots & P_{1n}^+ \\ \vdots & \ddots & \vdots \\ P_{n1}^+ & \cdots & 1 \end{bmatrix} \tag{18}$$

The eigenvalues and eigenvectors are calculated respectively, and finally the importance of the indicators can be derived by normalizing the eigenvectors and taking the average.

The RAHP method can be applied to decision-making problems in various fields, such as project selection, supplier evaluation, product design, etc., to help decision-makers conduct systematic multi-criteria decision analysis and improve the scientific and accuracy of decision-making.

3. FIRE AND EXPLOSION ELEVATOR DESIGN PLANNING

3.1 Design planning process

RAHP-QFD-based design planning for fire and explosion-proof elevator primarily consists of the steps of obtaining user requirements, converting the initial user requirements into demand indicators, calculating the importance of the demand indicators using RAHP method, converting the demand indicators into technical indicators, determining the parameters of the quality house, constructing the quality house and analyzing it. The overall design planning process is shown in Figure 3.

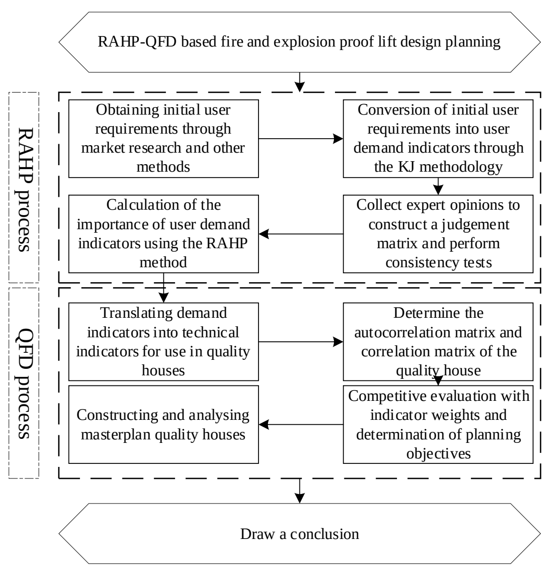

Figure 3. Technology Roadmap

3.2 User requirements identification

According to the current technological development and market demand, for explosion-proof elevator manufacturers to carry out research work. First of all, after obtaining the demand indicators, the affinity diagram (KJ method) is used to organize and screen the user's original demand and divide the demand level; secondly, the questionnaire survey is carried out from the explosion-proof performance and fire performance of the fire protection elevator, and the degree of influence of the user's demand on the user's satisfaction is investigated; lastly, the type of the user's demand is analyzed and summarized, and feasible demand indicators and their degree of importance are determined.

This study mainly obtains user demand indicators through the method of market research. Through the questionnaire survey, on-site investigation and other ways of fire and explosion-proof elevator user enterprises on the fire and explosion-proof elevator specific needs of the survey, the results of the survey are shown in Table 2.

Table 2. Demand statistics of target users for fire and explosion-proof lifts

Targets	Serial number	Details of requirements
Lift performance	1	Maximum load capacity 5000kg
	2	Running speed meets the requirements of national standards
	3	Energy consumption as low as possible
	4	High security level
	5	Good pressure resistance of the carriages
Explosion-proof performance	1	The explosion-proof rating of the whole machine should be high
	2	Explosion-proof motors are explosion-proof.
	3	Explosion-proof control cabinets with good explosion-proof performance
	4	Good anti-electronic spark performance
	5	Good anti-static properties
Fire performance	1	Ventilation system is working well
	2	Fire alarm system can detect danger and alarm in time

When using the KJ method for hierarchical expansion of user requirements, it is necessary to reasonably screen out the inefficient requirement vocabulary in order to avoid the overlap and proximity of the selected words, and finally construct a scientific and comprehensive hierarchical expansion table of user requirements, as shown in Table 3.

Table 3. Fire and Explosion-proof Elevator Demand Level Development and Importance Degree

The first level of needs A	The second level of needs B	The third of needs C
Fire and explosion proof lift design A	Lift performance requirements B_1	Maximum load C_1
Fire and explosion proof lift design A	Lift performance requirements B_1	running speed C_2
Fire and explosion proof lift design A	Lift performance requirements B_1	power consumption C_3
Fire and explosion proof lift design A	Lift performance requirements B_1	Safety and security facilities C_4
Fire and explosion proof lift design A	Lift performance requirements B_1	Car wall strength C_5
Fire and explosion proof lift design A	Explosion-proof performance requirements B_2	Explosion-proof control cabinet explosion-proof requirements C_6
Fire and explosion proof lift design A	Explosion-proof performance requirements B_2	Explosion-proof requirements for trolling motors C_7

The first level of needs A	The second level of needs B	The third of needs C
Fire and explosion proof lift design A	Fire performance requirements B_3	Fire performance C_8
Fire and explosion proof lift design A	Fire performance requirements B_3	Antistatic properties C_9

3.3 RAHP-based user requirement weighting analysis

Hierarchical analysis is a method with very strong logical decision-making, which can hierarchically and systematically use qualitative and quantitative methods to solve multi-objective complex problems. In the first demand level A of the design of fire and explosion-proof elevator with large load and low energy consumption, take the elevator performance B_1, explosion-proof performance B_2, fire performance B_3 as an example, and invite three experts and one target user to use the 1~9 judging scale method, based on the fire and explosion-proof elevator for the importance of each second level of the demand level indicators of the two comparisons and transformed into a judgment index W_{ij}, the judgment matrix scales and meanings are shown in Table 4. The judgment matrix scales and meanings are shown in Table 4.

Table 4. Judgement matrix scaling and its meaning

Importance judgement level	Hidden meaning
1	i is as important as j
3	i is slightly more important than j.
5	i is more important than j
7	i is more strongly important than j
9	i is more important than j.
1/3，1/5，1/7，1/9	Results of inverted comparisons of i and j 2 comparison terms

The judgement matrix is as follows:

$$P_{11}=\begin{bmatrix}1&3&5\\ \frac{1}{3}&1&3\\ \frac{1}{5}&\frac{1}{3}&1\end{bmatrix},P_{12}=\begin{bmatrix}1&5&7\\ \frac{1}{5}&1&3\\ \frac{1}{7}&\frac{1}{3}&1\end{bmatrix},P_{13}=\begin{bmatrix}1&5&7\\ \frac{1}{5}&1&3\\ \frac{1}{7}&\frac{1}{3}&1\end{bmatrix},P_{14}=\begin{bmatrix}1&3&7\\ \frac{1}{3}&1&5\\ \frac{1}{7}&\frac{1}{5}&1\end{bmatrix} \tag{19}$$

The CR values of P_{11},P_{12},P_{13},and P_{14} can be derived from equations (1) to (7) as 0.0322, 0.0559, 0.0060, and 0.0559, respectively, and the results are less than 0.1, and the consistency test is passed.

Create a rough decision matrix to find the rough pairwise comparison matrix. Represent the above four AHP judgement matrices as rough group decision matrix in the form of:

$$P_1^*=\begin{bmatrix}1,1,1,1&3,5,5,3&5,7,9,7\\ \frac{1}{3},\frac{1}{5},\frac{1}{5},\frac{1}{3}&1,1,1,1&3,3,5,5\\ \frac{1}{5},\frac{1}{7},\frac{1}{9},\frac{1}{7}&\frac{1}{3},\frac{1}{3},\frac{1}{5},\frac{1}{5}&1,1,1,1\end{bmatrix} \tag{20}$$

Afterwards, according to equations (9) to (18) can be derived to find the roughness number and average roughness interval of all the elements in the group decision matrix to get the roughness pairwise comparison matrix:

$$P_1=\begin{bmatrix}[1,1]&[3.500,4.500]&[6.150,7.835]\\ [0.233,0.300]&[1,1]&[3.500,4.500]\\ [0.128,0.168]&[0.233,0.300]&[1,1]\end{bmatrix} \tag{21}$$

Obtain the importance of the second level of need hierarchy. Split the above rough pairwise comparison matrix P_1 into a rough lower bound matrix P^- and a rough upper bound matrix P^+:

$$P^{-}=\begin{bmatrix}1 & 3.500 & 6.150\\ 0.233 & 1 & 3.500\\ 0.128 & 0.233 & 1\end{bmatrix} \quad (22)$$

$$P^{+}=\begin{bmatrix}1 & 4.500 & 7.835\\ 0.300 & 1 & 4.500\\ 0.168 & 0.300 & 1\end{bmatrix} \quad (23)$$

The maximum eigenvalues and eigenvectors corresponding to the rough lower boundary matrix P^{-} and rough upper boundary matrix P^{+} are further derived.

The maximum eigenvalues and eigenvectors of the rough lower boundary matrix P^{-} are $\lambda^{-}=2.856$ and $L^{-}=(0.943,0.316,0.105)$,and the maximum eigenvalues and eigenvectors of the rough upper boundary matrix P^{+} are $\lambda^{+}=3.394$ and $L^{+}=(0.942,0.317,0.106)$,respectively.

The feature vectors L^{-} and L^{+} are normalised to obtain, respectively:

$$[l_1^-,l_2^-,l_3^-]=[0.691,0.232,0.077] \quad (24)$$

$$[l_1^+,l_2^+,l_3^+]=[0.690,0.232,0.078] \quad (25)$$

Obtain the importance of secondary demand indicators B_1,$B_2$and B_3:

$$l(B_i)=\frac{|l_i^-|+|l_i^+|}{2} \quad (26)$$

The importance of the secondary demand indicators B_1,$B_2$and B_3 is obtained:

$$(l_1,l_2,l_3)=(0.6905,0.2320,0.0775) \quad (27)$$

Similarly, the weights of the three levels of demand indicators can be obtained as shown in Table 5.

Table 5. Calculation of user requirement weights

Second demand levelB	Weights	Third demand level C	Weights	Final demand weights	Sequence
B_1	B_1	Maximum load C_1	0.3156	0.2179	1
B_1	B_1	running speed C_2	0.2714	0.1874	2
B_1	B_1	power consumption C_3	0.1856	0.1282	3
B_1	B_1	Safety and security facilities C_4	0.1355	0.0936	6
		Car wall strength C_5	0.0919	0.0635	7
B_2	0.2320	Explosion-proof control cabinet explosion-proof requirements C_6	0.4500	0.1044	5
		Explosion-proof requirements for trolling motors C_7	0.5500	0.1276	4
B_3	0.0775	Fire performance C_8	0.7500	0.0581	8
		Antistatic properties C_9	0.2500	0.0194	9

3.4 Construction of a quality house for fire and explosion proof elevator design

3.4.1 Construction of autocorrelation matrix for quality house. The group discussion method is used to analyze and categorize the user demand indicators and propose reasonable design technical indicators to meet these demands. Second, the degree of autocorrelation of technical indicators is studied, and the correlation between technical characteristics can be categorized into strong positive correlation, positive correlation, negative correlation, strong negative correlation and no correlation. For any two technical indicators, it is necessary to clarify whether the realization of one of them has the role of mutual promotion, mutual obstruction or no effect on the realization of the other, and analyze in-depth the repetitive, uncoordinated, or even mutually exclusive engineering technology in the design process of the fire and explosion-proof elevator, and make timely adjustments to the program[19].In the process of constructing the relevance weight matrix, expert opinions were used to quantify the degree of relevance between the demand indicators and technical indicators. In order to ensure the accuracy of the established quality house, senior engineers specialized in machinery and special equipment were invited to carry out the assessment.

3.4.2 Competitive evaluation and determination of indicator weights. Through the market survey to understand the user cluster demand information and development, from the user's point of view on the fire and explosion-proof elevator equipment in meeting the user's needs to assess the competitiveness of the relevant indicators. Afterwards, the collected information is organized and summarized, the competitive evaluation matrix is established, and the corresponding weights of the indicators are calculated[20].

For the demand indicators, from the perspective of user experience, the product in the same type of product demand competitiveness evaluation. According to the degree of fire and explosion-proof elevator design for the various demand indicators, the degree of user satisfaction and the current level of research technology, the numbers 1~5 are used to indicate the existing level of demand indicators and the corresponding planning quality target value, 1 means the worst, 5 means the best. Combined with the ranking of the importance of the demand in Table 5, so that the value of the product characteristics of 1.0, 1.2 and 1.5, respectively, indicating that there is no obvious point of product characteristics, the product characteristics of the point of the general and product characteristics of the point of the prominent[21].

Assuming that P_i denotes the existing level of fire and explosion−proof lift equipment to meet the ith demand indicator, and Q_i denotes the planning quality target value of the ith demand indicator, the level improvement rate R_i can be expressed as:

$$R_i = \frac{P_i}{Q_i} \tag{28}$$

Let W_i and $W_i^{'}$ denote the absolute and relative weights of the ith demand indicator, W_j and $W_j^{'}$ denote the absolute and relative weights of the jth technical indicator, I_i denote the importance of the ith demand indicator, i.e., the final demand weight, C_i denote the value of the product characteristics of the ith demand indicator, and R_{ij} denote the correlation between the ith demand indicator and the jth technical indicator weight coefficients, then there are:

$$W_i = I_i \times R_i \times C_i \tag{29}$$

$$W_i' = \frac{W_i}{\sum_{i=1}^{n} W_i} \tag{30}$$

$$W_j = \sum_{i=1}^{n} W_i' R_{ij} \tag{31}$$

$$W_j' = \frac{W_j}{\sum_{i=1}^{n} W_j} \tag{32}$$

The weights of the demand indicators can be calculated according to equations (22) to (26).

In view of the technical indicators, from the perspective of technology, the technical competitiveness of this product is evaluated in the same type of products, and the main competitive items are fully understood to determine the direction of technical improvement of the fire and explosion-proof elevator with large load and low energy consumption. According to the senior engineer's competitive evaluation of technical indicators, the numbers 1~5 are used to indicate the technical competitiveness from weak to strong.

3.4.3 Technical indicator planning target setting. After calculating the weights of the technical indicators, it is necessary to set a specific planning target value for each technical indicator according to the development of market demand and the existing technical level, which intuitively reflects the output results of the demand transformation process. Among the ten technical indicators extracted, “explosion-proof level”, “electrical safety”, “applicable environment”, “safety device” and “anti-explosion level”, “electrical safety”, “safety device” and “anti-explosion level”. The five technical indicators of “explosion-proof level”, “electrical safety”, “applicable environment”, “safety device” and “anti-mechanical spark material” are combined with “GB T 3836.28-2021 Explosive Environment Part 28: Non-electrical Equipment for Explosive Environments Basic Methods and Requirements”, “GB/T 3836.1-2021 Explosive Environment Part 1: GB/T 3836.1-2021 Explosive Environment Part 1: General Requirements for Equipment, GB/T 3836.2-2021 Explosive Environments Part 2: Equipment Protected by Explosion-proof Shell “d”, GB-T 3836.29-2021 Explosive Environments Part 29: Non-electrical Equipment for Explosive Environments, Structurally Safe Type GB-T 3836.29-2021 Explosive atmospheres Part 29: Non-electrical equipment for use in explosive atmospheres Structural safety type “c”, control of ignition sources type “b”, liquid-immersed type “k” and GB-T 3836.35-2021 Explosive atmospheres Part 35: Places in explosive dust environments. Part: Classification of explosive dust environment places" and other relevant standards, giving the corresponding planning target value[22-26]. It is now required that the five technical indicators should meet the following requirements:

Explosion-proof type: explosion-proof intrinsically safe composite type.

Explosion-proof grade: ≤ gas IICT4/Gb, ≤ dust III135°C/Db.

Motor casing must have a certain degree of explosion-proof and explosion-resistant, in the explosion of combustible gases inside the motor, the motor casing can withstand the explosion pressure, and block the internal flame through the joints to the outside.

When there is an unexpected situation, there should be appropriate safety devices for emergency braking, including safety clamps, buffers, brakes and other devices.

Anti-mechanical sparking materials shall be made of copper or nickel plated.

Among the remaining technical indicators, the target values of "rated load", "rated speed" and "energy consumption level" are formulated by combining the users' demands with the current technical level. The rated load is not less than 5000kg, the rated speed is not less than 0.5m/s, and the energy consumption level is Grade 2; the target value of "Fire Alarm System" is set by the requirements of "GB 26465-2011 Safety Code for the Manufacture and Installation of Fire Service Elevators", which requires that the sensors, controllers, and alarm equipment's conforming to the requirements should be selected, and connected to the network. Connection. The target value of "cost" needs to be discussed with users.

An analysis of the quality house leads to the following conclusions:

(1) According to the competitive evaluation of user demand in the quality house, it can be seen that users pay more attention to the fire and explosion-proof elevator's own performance, the relative weight of the ratio and more than 50%, followed by the fire and explosion-proof elevator's explosion-proof performance, the relative weight of the ratio and reached 23.6%, and these demand indicators of the product to improve the rate of higher, and the demand for the importance of the research is consistent with the situation.

(2) Combined with the current level of research, it is difficult to simultaneously achieve the rated load, rated speed, energy consumption level explosion-proof performance and other indicators. Therefore, in the design phase of the fire and explosion-proof elevator need to strengthen the market competitiveness in the relevant demand indicators, as far as possible to invest resources in meeting the demand indicators.

(3) From the evaluation of the competitiveness of technical indicators and correlation matrix can be seen, both "cost" of the competitiveness of "cost" and "cost" and demand for indicators of the correlation is very high, that is to say, reduce the cost of fire and explosion-proof elevator can greatly improve the degree of market competitiveness of the elevator. That is to say, cost reduction can greatly improve the market competitiveness of fire and explosion-proof elevator. Therefore, in the design process of fire and explosion-proof elevator, must meet the elevator performance, to ensure safety and reliability of the premise, try to reduce costs, you can improve their own advantages.

4. CONCLUSION

Because there will be corresponding products only if there is demand, at the same time, demand is also the basis of product design, how to identify which demand is more important from the many demands, and transformed into technical requirements can be realized for the design of R & D to provide guidance, is to improve the competitiveness of the product as well as user satisfaction is a key step. Therefore, this paper uses RAHP method and QFD method to analyze the design of fire and explosion-proof elevator, first of all, through market research and other ways to collect statistics of user needs and organize them into user demand indicators, and then organize the scoring of experts for the importance of demand indicators into a judgment matrix and consistency test, and then form it into a rough decision-making matrix, combining with the basic principles of rough number theory to derive a rough pairwise comparison matrix, and through calculation to get each pairwise comparison matrix, which is the basis for the design and development of the product. Matrix, and through the calculation of the importance of each demand indicator, and then each demand indicator through group discussion into technical indicators, and through the analysis and calculation of the competitive evaluation of technical indicators and their weights, the construction of the overall design and planning of the quality of the house, and finally analyze the quality of the house to draw the following conclusions:

(1) In the design of the fire and explosion-proof elevator, attention should be paid to the elevator's own performance, especially in terms of the maximum load. The design needs to comprehensively consider the car volume, traction motor specifications, the number of traction sheaves, traction rope strength and other factors, and determine the optimal parameters through fine calculations to meet the user's needs.

(2) Cost is one of the factors that users are very concerned about, and whether the price is reasonable or not directly affects the choice of users. Under the premise of ensuring that the elevator performance meets the demand, the cost can be reduced through the use of new technology, new materials and other ways to improve the market competitiveness of the product.

(3) The adoption of RAHP-QFD method can more effectively consider user needs, directly transform user needs into technical elements, ensure that the product design is more in line with the market demand, and improve the competitiveness of the product. This method not only helps to ensure that the product design meets the market demand, but also provides a useful reference for the design of similar products.

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