Study on Comprehensive Evaluation of Elevator Door System Based on AHP-CRTIC

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Abstract: The elevator door system is affected by the physical structure, external factors and geographical location and other factors, and has become the most prone to failure and accident components in the eight elevator systems. Select 15 evaluation factors including speed, acceleration, operating noise, vibration frequency and response time in the transmission system; voltage, current, corrosive gas, conductive dust in the safety protection system, engagement depth, leveling accuracy, temperature, humidity, balance coefficient and load weight in the stripping system, calculate the subjective and objective weight of each evaluation factor by AHP and CRTIC evaluation method, establish the AHP-CRTIC comprehensive evaluation model. Compared with the evaluation results of AHP, C RTIC and AHP-CRITIC models in the actual elevator system, the results show that the evaluation accuracy of combined empowerment is the highest, which provides a new idea and method for the safety performance evaluation of the elevator door system.

Keywords: Elevator Door System; Evaluation Factor; AHP Hierarchy Analysis Method; CRTIC Objective Empowerment Method; Comprehensive Evaluation

1. Foreword

With the development of economic globalization and the rapid progress of urbanization in the world, the elevator has become the most important mode of transportation in high-rise buildings. Due to the particularity of the elevator structure and working environment, coupled with the wrong operation of passengers in the use of the elevator, the elevator falls, shear, top, trapped, impact, electrical and other elevator safety accidents, seriously affecting the safety of the elevator passengers[1].

According to statistics, among the 232 traction drive elevator accidents, the accidents related to the elevator "door" ranked the first, reaching 87 cases, among which 77 accidents were killed. The elevator door system is particularly important in the operation process of the elevator. Each operation has to go through the opening and closing action, which causes slight wear on the door guide rail, door slide, door block and door lock. If the use or maintenance is improper, the elevator accident is easy to occur[2].

At present, domestic scholars pay attention to the comparison of the threshold indicators of the elevator safety research, and use the elevator monitoring system to monitor the specific value of the elevator indicators, but they do not focus on the specific research of the elevator door system[3]. AHP hierarchy analysis is often used in the state evaluation of mechanical equipment, which is a subjective evaluation method; C RITIC evaluation method is to compare the strength and conflict between indicators, which is an objective evaluation method. In view of the elevator door system as a complex mechanical structure, its overall state is affected by various factors, some of these effects can be tested by specific data, and the other part of the effects can only be summarized by the vague expression of daily work experience. Therefore, this study proposed a comprehensive evaluation method combining AHP hierarchical analysis with objective empowerment of CRITIC.

1. Construct the evaluation index system of the elevator door system

1.1 Selection of evaluation indicators

According to the main component system of the elevator door system, and the working principle, influencing factors

and characteristic indicators of each system are analyzed, the evaluation indicators related to the safety of the elevator door system are screened out, and the common components between the indicators form the criterion layer of the evaluation system. The subsystem of the elevator door system is divided into transmission system, safety protection system and anti-stripping system:

(1) Transmission system. The transmission device of the elevator door system includes linkage mechanism, automatic door opening mechanism, layer door self-closing device, door knife and lock hook[4]. The door motor provides the power source for the door system. The car door begins to move under the power provided by the door motor, and drives the layer door to move at the same time through the transmission mechanism. The transmission system mainly controls the movement of the door system, and its characteristic indexes are related to the physical movement, so the speed, acceleration, running noise, vibration frequency and response time are taken as the evaluation indexes.

(2) Anti-stripping system. The anti-stripping system is mainly when the elevator door is closed when someone scraping the door can not hurt the passengers[5]. When the door is closed, the controller can provide power at small speed and small torque. In the special case of detecting someone in the door, the power can ensure that the door is closed as soon as possible, and restore the original state after the end of the door event. The engagement depth between the doors reflects whether the door is safely closed, and ensures that passengers cannot open the car door under normal closure. The accuracy of the flat floor reflects whether the elevator is parked at the accurate position, so the engagement depth and floor accuracy are taken as the evaluation index of the flat floor shutdown of the elevator door system.

Safety protection system. The purpose in the safety protection system is to prevent safety accidents when the door is open and close[6].

The safety protection system is generally composed of the electrical components in the elevator door system, which reflects the operation mode of the elevator door system under the signal control. In addition to the characteristic indexes in the molecular system, there are two indexes related to the design structure of the elevator door system and the load weight in the elevator operation.

1.2 Evaluation index system

The structure and working principle of each subsystem of the elevator and door system are analyzed to obtain 15 evaluation indexes of the elevator door system. Due to the different influence modes of evaluation indexes and different characteristics, the study is divided into three criterion layers: physical characteristics, chemical characteristics and structural state characteristics.

2. Evaluation model of the elevator door system

This paper will hierarchy analysis and C RITIC objective empowerment method, combined with the hierarchy analysis of subjective advantages and the objective advantage of C RITIC method, respectively calculate the index weight of two evaluation methods and through the combination empowerment model index weight, establish the elevator door model evaluation system, using the model of the elevator door system overall safety state analysis.

2.1 The AHP hierarchy analysis method

AHP hierarchical analysis is an analysis method for multi-objective decision making. This method combines quantitative and qualitative analysis and subjectively judges the relative importance between the target according to expert experience, and finally gets the weight of each index. The specific process is as follows:

1） Build a judgment matrix. The commonly used levels from 1 to 9 are used to analyze the importance between the indicators to build a judgment matrix:

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

2） Calculate the subjective weight of each index.

$$\boldsymbol{W}_i = \frac{\sqrt[n]{\prod_{j=1}^{n} a_{ij}}}{\sum_{j=1}^{n} \sqrt[n]{\prod_{j=1}^{n} a_{ij}}} \quad (2)$$

$a_{ij}\boldsymbol{W}_i$ Where: it is the indicator element, and it is the eigenvector corresponding to the indicator.

3) Conformance test. To verify the rationality of the weight index, a consistency test of the matrix is required. C*I*The consistency index is calculated from formula (3).

$$C_I = \frac{\lambda_{max} - n}{n-1} \lambda_{max} \quad (3)$$

the maximum eigenvalue of matrix A, is the average random consistency index,R_I

2.2 The CRITIC method to calculate the objective weight

In terms of calculation weight, CRITIC method calculates the conflict and variability of each index. It is the weight obtained from the connection between the calculation indicators, and it is an objective evaluation method. CRITIC The calculated objective weights are as follows:

1） The conflict amount and information amount in the calculation index, the calculation formula is:

$$t_i = \sqrt{\frac{1}{n} \sum_{j=0}^{n} (X_{ij} - \overline{X}_{ij})^2} \quad （4）$$

$$\rho_{ij} = \operatorname{cov}(x_i^{'}, x_j^{'}) / (t_i, t_j) \quad (5)$$

iWhere: After standardizing the index, the correlation coefficient between the index and the index.$t_i \rho_{ij} ij$

2） jTo calculate the amount of information contained in the first index, the calculation formula is:E_j

$$E_j = \xi_j \sum_{i=1}^{n} (1 - \rho_{ij}) \quad (6)$$

3） According to the ratio of the index information and the total information, the calculation formula is:σ_j

$$\sigma_j = E_j / \sum_{j=1}^{n} E_j \quad （7）$$

2.3 Comprehensive weight of combination empowerment calculation

The subjective weight calculated by the AHP hierarchy analysis method and the objective weight calculated by the C RITIC method can reach a dynamic balance through the combined empowerment. The calculation formula is:

$$\omega_i = \alpha a_i + (1 - \alpha) b_i \quad （8）$$

$\omega_i a_i b_i i$ Formula: for the obtained comprehensive weight, it is divided into the subjective weight and the objective weight of the first index, and it is the dynamic combination factorα

3. Evaluation results and analysis

The elevator selected in this study is located in the passenger elevator of Yipin Dongfu Community, Dazhu County, Sichuan Province. The data comes from the data during the elevator operation in the second half of 2022. The elevator model is CAR-2006-001, using W INONE series elevator operation box; the system adopts 32-bit microprocessor; CAN network bus for data communication and management, and its signal transmission speed can reach 78 kbits / sec.

3.1 Analysis of the AHP evaluation results

In the hierarchical analysis method, the importance of each layer is different. Twenty experts who have long been engaged in elevator related standards, research and development, manufacturing, inspection, elevator measurement, elevator operation and maintenance are selected to quantify the weight of the evaluation model indicators. According to the different fields, form the expert collection 1 to the expert collection 5,

The maximum feature root, consistency index and consistency ratio obtained by the judgment matrix constructed by each layer index meet the requirements.

3.2 CRITIC, evaluation results analysis and combination weight

According to the C RITIC formula, the variability and conflict of each index in the elevator door system are calculated,

and the information quantity and objective weight of the index are finally obtained. $E_j\sigma_j$ .1163.1264.1146.1807.1007 By combined weight analysis, In the elevator door system, the operation speed, acceleration, operating voltage, operating temperature, humidity five attributes of the weight proportion of the highest, , 0,0,0,0,0, Represents the main movement state and external environmental factors in the process of elevator operation; Response time, operating noise, vibration frequency, operating current on the elevator door system, These five parameters mainly show the physical characteristics of the elevator derived in the process of operation; Flat layer accuracy, corrosive gas, conductive dust, balance coefficient and load weight have the least impact on the operation safety of the elevator door system.

4. Conclusion

Through the analysis of elevator safety accidents in recent years, it is found that the elevator door system accounts for the largest proportion of elevator accidents, with about 40%, so the elevator door system is selected as the research object of this paper. On this basis, the mechanical structure and working principle of each subsystem of the elevator door system are analyzed, and 15 indexes are determined as the evaluation indexes of the elevator door system.

AHP hierarchy analysis focuses on the subjective evaluation of each index. Compared with AHP hierarchy analysis, C RITIC objective empowerment method considers the information and objective weight of the index; combine AHP hierarchy analysis and C RITIC objective empowerment method as the evaluation model of the elevator door system, so as to judge the relative importance of each index to the elevator door system.

The weight calculation of various indicators in the elevator door system is conducted through the AHP-CRITIC model. The operating speed, acceleration, operating voltage, operating temperature, humidity and external environment factors affect the elevator door system; the response time, operating noise, vibration frequency, operating current affect the elevator door system; the rare environmental factors and structural characteristics such as flat accuracy, corrosive gas, conductive dust, balance coefficient and load weight have the least impact on the elevator door system.

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