Research on health evaluation model for elevator based on analytic hierarchy process

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Abstract. Elevator safety has been widely concerned by the society. In order to evaluate the health of elevator visually, a quantitative evaluation model based on analytic hierarchy process is proposed. The value of elevator health is determined according to the failure frequency, inspection result, maintenance etc. The weight value of each factor is calculated by analytic hierarchy process which based on two level index system. Besides, the subtraction method was added to the analytic hierarchy process for improving its operability. The practice is conducted to verify the evaluation method is feasible which is applied to risk warning for elevator.

Keywords: Elevator; health evaluation; analytic hierarchy process; weighted value

1. Introduction

China is the largest elevator country in the world, with more than 7.86 million elevators in use by the end of 2020 year. With the increasing installation of new elevators and the aging of old elevators, the safety of elevators cannot be ignored. For a long time, the elevator adopts the way of regular maintenance to ensure the security, and when the elevator is in a dangerous state, it will cause the maintenance is not timely. Therefore, it is very important to evaluate health condition of elevator.

Traditional risk evaluate is characterized by scoring and judging on the basis of experienced field operators and expert opinions, and its accuracy is greatly limited. As one of the most popular methods for multi-criteria decision-making, the analytic hierarchy process(AHP) has been successfully used in a variety of fields，including weapon system evaluation, comprehensive evaluation and many other applications.

Therefore, a quantitative evaluation model based on analytic hierarchy process is proposed in this paper. The value of elevator health is determined according to the failure frequency, inspection result, maintenance etc. The weight value of each factor is calculated by analytic hierarchy process which based on two level index system. Besides, the subtraction method was added to the analytic hierarchy process for improving its operability.

2. Modeling

AHP can be used in any situation where the presence of multiple influencing factors and decision criteria make it difficult to understand the interactions among them intuitively. In such cases AHP offers a structured approach to reduce the complexity and help us in making a decision objectively. AHP is a complicated multi-objective decision-making problem as a system, the target is decomposed into multiple objectives or principles, or rules, constraints, and multiple index of several levels.

In order to accurately evaluate the elevator health status, comprehensively consider the frequency of failure, inspection, maintenance, supervision and spot check, and combine the multi-source heterogeneous data in Chongqing Elevator intelligent supervision platform, the elevator health value index system has been established. Drawing on the evaluation factors in elevator, seven second-level factors has been considered as shown in figure 1 and table 1.

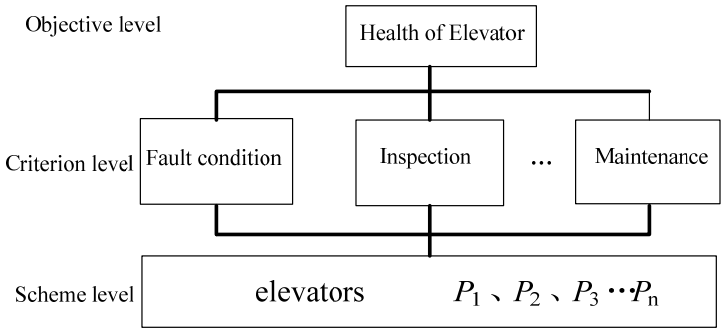


Figure 1. Hierarchy figure

Table 1. Index system of health evaluation for elevator

First-level index	Second-level index
Fault condition from internet of things	Numbers of fault
	Frequency of fault
Maintenance	Whether the maintenance contract is valid
	Whether it is maintained on time
	Maintenance quality
Inspection	Whether there are serious risks
	Whether there are general risks
	Whether the inspection is conducted on time
Supervision	Whether there are serious risks
	Whether there are general risks
Internet of things terminal disconnection situation	Length of offline time
Elevator emergency from 96333	Someone is trapped in elevator
Year of the elevator	Year of the elevator

The weight of the index reflects the importance of the index to the object. The weight directly determines the relative position of each index in the evaluation of elevator health value. Therefore, it is necessary to allocate the weight reasonably and relatively scientifically. In order to improve the scientific weight distribution, the AHP method is used to determine the weight.

Build judgment matrix *A*

The scaling method of its elements is detailed in analytic hierarchy process, and the following judgment matrix is obtained through questionnaire survey and data analysis as follows.

$$A=\begin{bmatrix} c_{11} & c_{12} & c_{13} & c_{14} & c_{15} & c_{16} & c_{17} \\ c_{21} & c_{22} & c_{23} & c_{24} & c_{25} & c_{26} & c_{27} \\ c_{31} & c_{32} & c_{33} & c_{34} & c_{35} & c_{36} & c_{37} \\ c_{41} & c_{42} & c_{43} & c_{44} & c_{45} & c_{46} & c_{47} \\ c_{51} & c_{52} & c_{53} & c_{54} & c_{55} & c_{56} & c_{57} \\ c_{61} & c_{62} & c_{63} & c_{64} & c_{65} & c_{66} & c_{67} \\ c_{71} & c_{72} & c_{73} & c_{74} & c_{75} & c_{76} & c_{77} \end{bmatrix}=\begin{bmatrix} 1 & 1/2 & 1/2 & 1 & 3/2 & 3/5 & 3/2 \\ 2 & 1 & 2/3 & 1 & 2 & 1/2 & 3/2 \\ 2 & 3/2 & 1 & 1 & 5/2 & 1 & 5/2 \\ 1 & 1 & 1 & 1 & 2 & 3/5 & 2 \\ 2/3 & 1/2 & 2/5 & 1/2 & 1 & 2/5 & 1 \\ 5/3 & 2 & 1 & 5/3 & 5/2 & 1 & 5/2 \\ 2/3 & 2/3 & 2/5 & 1/2 & 1 & 2/5 & 1 \end{bmatrix} \quad (1)$$

Where Cij meet the following rules：c_{ij} =1(when i=j)，$c_{ij}=1/c_{ji}$。

Slove maximal eigenvalue λ_{max}

The maximal eigenvalue λ_{max} of matrix *A* can be obtained by matrix operation.

$$\lambda_{max}=7.0842 \quad (2)$$

And the corresponding eigenvector is W=[0.2870 0.3716 0.5031 0.3770 0.1959 0.5513 0.2047]^T。

3)Conduct consistency checks and calculate combined weight

Calculate the consistency index *CI*,the average consistency index *RI*, calculate the consistency ratio *CR*

$$CR = \frac{CI}{RI} = \frac{\lambda_{max}-n}{(n-1)\ RI} = \frac{7.0842-7}{(7-1)\times 1.36} = \frac{0.0842}{8.16} = 0.01 < 0.1 \quad (3)$$

The consistency of judgement matrix is acceptable.

3. Application of Evaluation

Since the elevator health value evaluation is automatically calculated according to the platform data through the big-data system, in order to intuitively describe the elevator health status, the health evaluation adopts the scoring system of subtraction method.

We set the initial score of each elevator to 100 points, and those who violate the corresponding index will be deducted the corresponding score according to the corresponding weight.

The final weight vector W_0 can be obtained by normalization of the eigenvector W.

$$W_0=[0.12\ 0.15\ 0.20\ 0.15\ 0.08\ 0.22\ 0.08]^T \quad (4)$$

The deduction points of each index are determined according to the relative weight of W_0, and the final health value quantitative scoring system is shown in table 2.

Table 2. Quantitative scoring system of health evaluation for elevator

Second-level index	Quantitative impairment
Numbers of fault	-3
Frequency of fault	-10
Whether the maintenance contract is valid	-10
Whether it is maintained on time	-10
Maintenance quality	-5
Whether there are serious risks	-10
Whether there are general risks	-3
Whether the inspection is conducted on time	-20
Whether there are serious risks	-20
Whether there are general risks	-5
Length of offline time	-2
Someone is trapped in elevator	-15
Year of the elevator	If the elevator is more than 6 years old, one point will be deducted for each additional year

In this paper, 500 samples of elevators are randomly selected from elevator big-data supervision platform, and the health value evaluation model constructed above is used to obtain the statistical table of the health value of selected samples, as shown in figure 2.

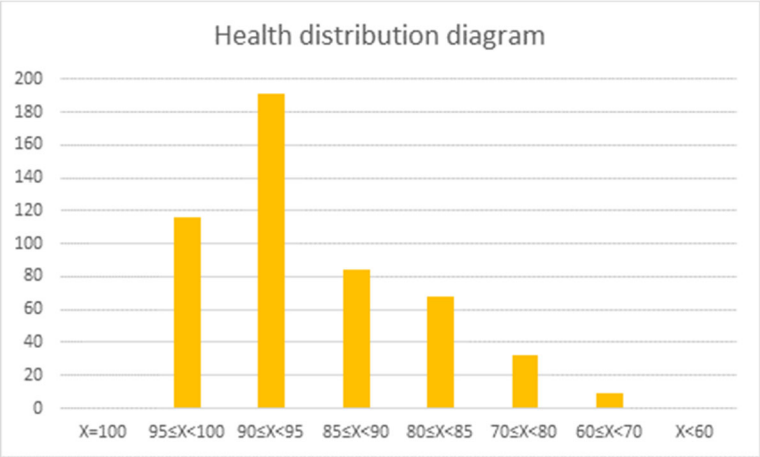


Figure 2. Distribution diagram of Health value for elevator

It can be seen from the figure 2 that the evaluation results of elevator health value basically accord with normal distribution law, indicating that the model is scientific.

4. Conclusion

In this paper, the elevator health value evaluation model oriented to intelligent supervision is constructed, which provides connotation support and new ideas for intelligent supervision construction of elevator, is conducive to more intuitive and scientific risk investigation and management. The model provides technical support for accurate supervision of elevator. As the measured data in this paper are not enough, the next step is to further improve and optimize the evaluation model by combining more massive measured data results in practice, with the purpose of better playing the role of risk early warning.

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