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Design Performance Assessment of Fire Alarm System based on Principal Components Analysis

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Key words: fire alarm system; design performance assessment; principal components analysis

Abstract. Design performance assessment of fire alarm system is to test the design scheme of large complex fire alarm system and determine the degree of satisfaction of the system design objective. The second-grade indexes of design performance assessment of fire alarm system are extracted by principal components analysis. The paper uses SPSS16.0 and Microsoft Excel to complete the data statistics and analysis process.

Introduction

If the performance of fire alarm system is excellent, the loss of life and property caused by fire can be minimized. The performance of fire alarm system mainly includes design performance, product performance and running performance. Design performance evaluation is a large complex fire automatic alarm system design program to determine to meet the system design goals. The principal component analysis method is used to evaluate the design performance of automatic fire alarm system, which can promote the scientific and standardization of the automatic fire alarm system evaluation.

In 2011, Liu concluded that the detection time of the fire detection system under the longitudinal air condition depends on the fuel type, the size and location of the fire, the velocity of the air flow and the detection method [1]. Marty Ahrens counts the performance of the American home smoke alarm system [2]. In 2012, Zhang Z. analyzed the response performance of the fire detector, predicted the response time of the ASD system by numerical calculation, and could guide the design and installation of the ASD system of the large space building, and did not establish the effectiveness evaluation model of the automatic fire alarm system [3]. Zhang L. uses the analytic hierarchy process to determine the comprehensive weight of the third-level index of multi-criteria and constructs the effectiveness evaluation model of fire command automation system [4]. In 2014, G. Santha established a tumor analysis model using the combination of PNN and PCA[5].

Evaluation Algorithm Design. According to GB / Z24978-2010 of fire automatic alarm system performance evaluation, design performance evaluation indexes of fire alarm system include7 first-level evaluation indicators and 21secondary evaluation indicators. The evaluation method can be used to simplify the evaluation model by using the principal component analysis method to evaluate the secondary evaluation index after compression extraction.

Design Performance Evaluation Indicators. Design performance evaluation indexes of fire alarm system are shown in Table 1.

Secondary Evaluation Index Compression Extraction. ***Principal Component Analysis.*** Principal component analysis is a multivariate statistical method that examines the correlation between multiple variables. It examines how a few principal components can be used to reveal the internal structure between multiple variables, that is, a few principal components are derived from the original variables, As much as possible to retain the original variable information, and each other between each other. The specific steps are as follows:

①Column matrix Y, and the data is normalized matrix X;

②Establish the relevant matrix: $C=\frac{1}{m-1}*X'*X$;

③Calculate the correlation coefficient matrix: $R=\left[r_{ij}\right]_{p*p}=\frac{X'*X}{m-1}$;

④Find eigenvalues and eigenvectors: $[V, D] = eig(C)$;

⑤From large to small eigenvalues: $\lambda_1 > \lambda_2 > \cdots > \lambda_m$;

⑥Calculate variance contribution rate (greater than 90%): $K = \sum_{i=1}^{r} K_i = \sum_{i=1}^{r} |\lambda_i / \sum_{i=1}^{n} \lambda_i| * 100\%$;

⑦For each one $\lambda_j, j = 1,2 \cdots r$,Solution of equations $R * b = \lambda_j * b$ unit vector $b_j^0 = \frac{b_j}{\|b_j\|}$;

⑧Calculate the principal component.

Table 1. Design performance evaluation index system

First level index	Two level index	First level index	Two level index
System integrity	Basic technical requirements of the system	Fire separation	Fire extinguishing separation
	System network constitution and management mode		Fire control equipment linkage control logic relationship
	System compatible	Facilities monitoring	Smoke control threshold monitoring
	Redundancy and extension of controller capacity		Evacuation door monitoring
Fire detection	Selection and selection of fire detectors		Fire extinguishing facilities monitoring
	Fire trigger device setting		Field fire power monitoring
Evacuation security	Selection of evacuation linkage	External help	Fire danger spot indication
	Fire alarm and emergency broadcast design		Fire procedure and range information indication
	Equipment integrated linkage control logic relationship		Fire elevator linkage control
	Complex area evacuation off - line guidance instructions		
Fire extinguishing linkage control	Fire extinguishing system linkage control equipment selection		
	Fire control system linkage control logic relationship		

Comprehensive Evaluation of Design Performance of Automatic Fire Alarm System

This paper evaluates the design performance of a university automatic fire alarm system and uses SPSS16.0 and Microsoft Excel to complete the data statistics and analysis process.

Expert Scoring. In the quantitative process of the indicators used in the expert scoring method.

The evaluation process used the five-point principle to score the actual performance of the 21 indicators by four experts. The meanings of the individual values are as follows.

Table 2. Expert scoring table

Fraction	1	2	3	4	5
Implication	Not good	Just so	Commonly	Better	Splendidly

Index Data Operation. In SPSS16.0, enter the expert scoring data, and standardize the data of each index, the results shown in Table 3.

Table 3. Data standardization

Zx1	Zx2	Zx3	Zx4	Zx5	Zx6	Zx7	Zx8	Zx9	Zx10	Zx11
0.000	1.225	1.095	0.000	1.500	0.993	1.225	1.391	0.500	0.500	1.391
0.000	-1.225	0.548	1.225	-0.500	0.199	0.000	-0.199	0.500	0.500	-0.993
1.225	0.000	-0.548	0.000	-0.500	-1.391	0.000	-0.993	0.500	-1.500	-0.199
-1.225	0.000	-1.095	-1.225	-0.500	0.199	-1.225	-0.199	-1.500	0.500	-0.199
Zx12	Zx13	Zx14	Zx15	Zx16	Zx17	Zx18	Zx19	Zx20	Zx21	
-0.500	-0.866	-0.866	0.000	-1.225	0.866	-0.783	-1.225	1.225	-0.866	
1.500	-0.866	-0.866	1.225	1.225	0.866	0.261	1.225	0.000	0.866	
-0.500	0.866	0.866	0.000	0.000	-0.866	-0.783	0.000	-1.255	-0.866	
-0.500	0.866	0.866	1.225	0.000	-0.866	1.306	0.000	0.000	0.866	

X1 is the system basic technical requirements, X2 for the system network configuration and management mode, X3 is system compatible, X4 for the controller capacity redundancy and expansion, X5 for the fire detector selection and selection, X6 for the fire trigger device settings, X8 for the evacuation linkage control equipment selection, X8 for the fire alarm and emergency broadcast design, X9 for the evacuation channel equipment integrated linkage control logic, X10 for the personnel-intensive complex regional evacuation route guidance instructions, X11 fire extinguishing system linkage control equipment selection, X12 Fire protection system linkage control logic, X13 for the fire separation control equipment selection, X14 for the fire separation equipment linkage control relationship, X15 for the smoke control and smoke control valve monitoring, X16 for the evacuation channel fire door monitoring, X17 for the fire extinguishing equipment Monitoring, X18 for the scene fire power monitoring, X19 fire process and scope information instructions, X20 for the fire danger parts instructions, X21 for the fire elevator linkage control.

It is possible to judge whether the research project is suitable for principal component analysis by analyzing the correlation coefficient matrix. If there is a strong correlation between the variables (correlation coefficient greater than 0.5 that there is a strong correlation), you can analyze the main data, as shown in Table 4.

As can be seen from Table 5, x3 system compatibility, x5 fire detector selection and selection, x7 evacuation linkage control equipment selection, x8 fire alarm and emergency broadcast design, x17 fire protection facility monitoring, x20 fire hazard location indication and There is a large positive correlation between the main components, x13 fire separation control equipment selection, x14 fire separation equipment linkage control logic relationship and the first principal component has a greater negative correlation. X4 fire capacity and expansion of the controller, x12 fire control system linkage control logic relationship, x15 smoke exhaust fan and smoke control valve monitoring, x16 evacuation channel fire door monitoring, x19 fire process and range information indication and the second main component Big positive correlation. X2 system network composition and management mode and the second principal component has a greater negative correlation. X10 staff-intensive complex regional evacuation route guidance instructions, x18 field fire power monitoring and the third principal component has a greater positive correlation, x1 system basic technical requirements and the third principal component has a greater negative correlation.

Table 4. Correlation coefficient matrix

	x1	x2	x3	x4	x5	x6	x7	x8	x9
x1	1.000	.000	.224	.500	.000	-.649	.500	-.324	.816
x2	.000	1.000	.224	-.500	.816	.324	.500	.649	.000
x3	.224	.224	1.000	.671	.730	.580	.894	.725	.730
x4	.500	-.500	.671	1.000	.000	.000	.500	.000	.816
x5	.000	.816	.730	.000	1.000	.662	.816	.927	.333
x6	-.649	.324	.580	.000	.662	1.000	.324	.895	-.132
x7	.500	.500	.894	.500	.816	.324	1.000	.649	.816
x8	-.324	.649	.725	.000	.927	.895	.649	1.000	.132
x9	.816	.000	.730	.816	.333	-.132	.816	.132	1.000
x10	-.816	.000	.365	.000	.333	.927	.000	.662	-.333
x11	.000	.973	.435	-.324	.927	.474	.649	.789	.132
x12	.000	-.816	.365	.816	-.333	.132	.000	-.132	.333
x13	.000	.000	-.949	-.707	-.577	-.688	-.707	-.688	-.577
x14	.000	.000	-.949	-.707	-.577	-.688	-.707	-.688	-.577
x15	.500	-.500	.671	1.000	.000	.000	.500	.000	.816
x16	.000	-1.000	-.224	.500	-.816	-.324	-.500	-.649	.000
x17	.000	.000	.949	.707	.577	.688	.707	.688	.577
x18	-.853	-.426	-.572	-.426	-.522	.208	-.853	-.208	-.870
x19	.000	-1.000	-.224	.500	-.816	-.324	-.500	-.649	.000
x20	-.500	.500	.671	.000	.816	.973	.500	.973	.000
x21	-.707	-.707	-.316	.000	-.577	.229	-.707	-.229	-.577

Table 5. Load table

x1	.011	.028	-.194
x2	.062	-.121	-.019
x3	.099	.058	-.013
x4	.036	.133	-.061
x5	.101	-.051	.006
x6	.074	.000	.145
x7	.098	.012	-.080
x8	.097	-.030	.076
x9	.059	.070	-.137
x10	.042	.025	.180
x11	.081	-.099	-.010
x12	.000	.147	.037
x13	-.087	-.083	-.037
x14	-.087	-.083	-.037
x15	.036	.133	-.061
x16	-.062	.121	.019
x17	.087	.083	.037
x18	-.062	.003	.162
x19	-.062	.121	.019
x20	.088	-.016	.114
x21	-.052	.066	.151

In Figure 1, each axis represents a principal component, each indicator in this three-dimensional space has a certain location, according to the indicators in the three-dimensional map of the location can clearly see the importance of the indicators. If an indicator has no effect on the three principal components, it is at the origin of the coordinates; if an indicator has a large negative impact on the three principal components, it is far from the origin; if one Indicators have a positive effect on the three principal components, and it is far from the origin.

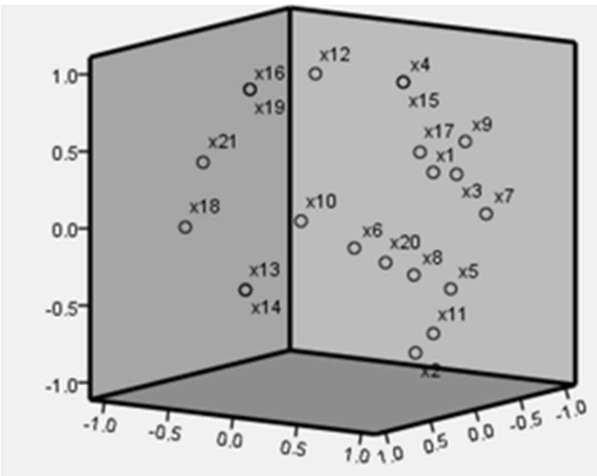

Figure 1. Component diagram

Design Performance Evaluation. After the analysis of the selection of the three principal components, the main component of the score can represent the entire system score. The linear combination of the three principal component coefficients is shown in equations (1), (2) and (3), and the principal component is shown in equation (4).

$$F1=0.098*Zx1+0.578*Zx2+0.920*Zx3+0.333*Zx4+0.940*Zx5+0.681*Zx6+0.911*Zx7+0.901*Zx8+0.548*Zx9+0.387*Zx10+0.749*Zx11+(-0.04)*Zx12+(-0.810)*Zx13+(-0.810)*Zx14+0.333*Zx15+(-0.578)*Zx16+0.810*Zx17+(-0.575)*Zx18+(-0.578)*Zx19+0.813)*Zx20+(-0.478)*Zx21 \quad (1)$$

$$F2=0.185*Zx1+(-0.810)*Zx2+0.388*Zx3+0.891*Zx4+(-0.341)*Zx5+0.000*Zx6+0.080*Zx7+(-0.203)*Zx8+0.472*Zx9+0.170*Zx10+(-0.661)*Zx11+0.983*Zx12+(-0.556)*Zx13+(-0.556)*Zx14+0.891*Zx15+0.810*Zx16+0.556*Zx17+0.020*Zx18+0.810*Zx19+(-0.104)*Zx20+0.442*Zx21 \quad (2)$$

$$F3=(-0.978)*Zx1+(-0.095)*Zx2+(-0.063)Zx3+(-0.310)*Zx4+0.030*Zx5+0.732*Zx6+(-0.405)*Zx7+0.384*Zx8+(-0.691)*Zx9+0.906*Zx10+(-0.050)*Zx11+0.185*Zx12+(-0.186)*Zx13(-0.186)*Zx14+(-0.310)*Zx15+0.095*Zx16+0.186*Zx17+0.818*Zx18+0.095*Zx19+0.573*Zx20+0.759*Zx21 \quad (3)$$

$$F=9.266/(9.266+6.694+5.04)*F1+6.694/(9.266+6.694+5.04)*F2+5.04/(9.266+6.694+5.04)*F3 \quad (4)$$

Through the calculation of the four experts for the three main components of the score, and then through the three principal component score obtained a comprehensive score, four experts get the final score is the final result of the final evaluation of the system, combined with four experts Comments, the final score was 3.15 points. Then the expert evaluation of the fire automatic alarm system design performance is excellent.

Conclusion

This paper analyzes the evaluation indexes of system design performance comprehensively and quantifies and standardizes them. And then the principal component analysis, the three principal components F1, F2, F3, the three principal components through the index of the score matrix distribution, the three main components of the score, and calculated a comprehensive score, automatic fire alarm system Design performance is excellent.

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