Aviation Safety Management Decision Based on HFACS-GRA-MFR Method

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Abstract. A novel method named HFACS-GRA-MFR is proposed to solve the problems of aviation safety management decision-making. First, HFACS model is established based on the actual aviation safety accidents. Furthermore, grey correlation analysis is used to analysis the influence degree of accident cause on aviation accidents, and five preventive measures are proposed. Finally, the optimal measures are obtained through multi-level fuzzy decision analysis. This paper provides a feasible solution for the follow-up study of aviation safety management decision.

Keywords: HFACS-GRA-MFR · aviation safety accident · security management decisions

1 Introduction

REcently, the development of aviation safety is becoming increasingly mature, and the overall accident rate is on the decline. Usually, the incidence of aviation accidents is very low, but once it happens, the national economic loss and social impact is huge. Therefore, it is necessary to analyse the causes of aviation safety accidents and formulate relevant preventive measures and management systems to reduce or avoid aviation safety accidents, so as to control aviation safety risks more effectively.

At present, studies on aviation safety accidents have been relatively mature, mainly including SHELL model, Reason model, HFACS model and so on [1][3] [7]. Besides, Mogles et al. proved the effectiveness of Agent-based modelling and Systems Theoretic Accident Modelling and Processes in solving aviation safety problems [6]. Gao et al. analyses a typical aviation security incidents of unsafe behavior based on OHFAM, and Put forward targeted measures [4]. Overall, the researches of domestic and foreign scholars on aviation safety mainly focus on the analysis of the cause of accidents and the prevention and treatment of accidents, and there are few researches on the decision-making methods of accident prevention measures.

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Based on the above analysis, this paper proposes an HFACS-GRA-MFR method on the basis of in-depth study of aviation safety accidents. The HFACS model is established and grey correlation analysis is used for quantitative analysis. The main causes of accidents are explored, preventive measures are proposed and measures are sorted by multi-level fuzzy decision analysis. To find the best measures to improve the scientific, rational and economic decision-making.

Generally speaking, aviation safety accidents are divided into human factors, mechanical flight accidents and maintenance ground accidents. Considering that human factor flight accidents account for 70%-80% of them, this paper selects human flight accidents from 2013 to 2016 for analysis. (In this paper, aviation safety accidents refer to aviation safety accidents and accident symptoms).

2 Model of HFACS

2.1 Model Introduction

Human factor analysis and classification system is an analysis model established by Wiegmann et al. on the basis of Reason accident causation model to solve aviation safety accidents, which solves the problem of long-term separation between human error theory and time application. HFACS (Human Factor Analysis and Classification System Analysis) model divides human error into unsafe behaviour (directly leading to the occurrence of the accident), preconditions of unsafe behaviour (subjective and objective conditions of the accident), unsafe supervision and command management (potential causes of the accident) from four aspects of human, machine, environment and management. This paper makes up for the shortcomings of accident analysis theories such as trajectory crossing theory and Heinrich causal linkage theory in analysing the causes of accidents, and introduces the "loopholes" in Reason model in detail. Compared with other theories and models, HFACS model not only makes up for defects but also makes improvements, which can analyse accidents in more detail and accurately and put forward more targeted measures [5][8][9].

2.2 Cause Identification of Accident

Based on relevant theoretical study and characteristics of flight accidents, 22 accident causes are analysed from four aspects: unsafe behaviours, preconditions of unsafe behaviours, unsafe supervision and command management. The results are shown in Fig. 1.

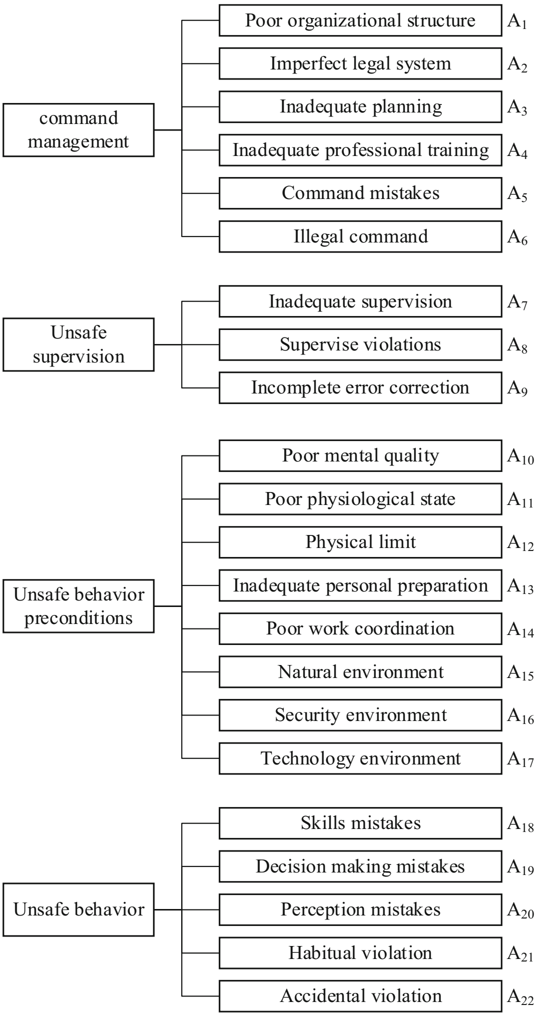

Fig. 1. Identification of human cause of aviation safety accidents based on HFACS model.

3 Grey Correlation Analysis of Accident Cause

Many factors, such as economy and safety, should be considered in the formulation of aviation safety accident prevention measures, but these factors are often difficult to grasp completely. It can be seen that aviation safety accidents have gray characteristics. Therefore, this paper uses grey correlation analysis to quantitatively calculate the correlation degree ranking between aviation safety accidents and their causes, and find out the main causes of accidents, so as to make targeted preventive measures in the next step.

3.1 Method Introduction

Grey relational analysis is to use grey relational analysis to determine the influence degree of factors on the overall system [2][10]. The main idea is to pre-process the reference sequence and comparison sequence to calculate the correlation degree of each factor according to the correlation degree calculation formula. It should be further pointed out that factors with a high degree of correlation have a great impact on the system and need to be focused on.

Step1: determine the analysis sequence.

The reference sequence $Y_0 = \{Y_0(1), Y_0(2), \ldots, Y_0(n)\}$ (n is the length of reference sequence).

The compare sequence $Y_i = \{Y_i(1), Y_i(2), \ldots, Y_i(n)\} i = 1, 2, \ldots, m$ (m is the number of causative factors).

Step2: Analyse sequence normalization.

Considering the physical significance of different physical quantities and the dimension of data are different, dimensionless processing of data is carried out to ensure the accuracy of the results. The calculation formula is

$$X_i(k) = \frac{X_i(k)}{X_i(1)}, (k = 1, 2, \ldots, n;\;\; i = 1, 2, \ldots, m) \tag{1}$$

Step3: Calculate the correlation coefficient.

The calculation formula of the correlation coefficient is

$$\varepsilon(k) = \frac{(minmin|X_0(k) - X_i(k)| + \rho maxmax|X_0(k) - X_i(k)|)}{(|X_0(k) - X_i(k)| + \rho maxmax|X_0(k) - X_i(k)|)} \tag{2}$$

Among them, distinguish coefficient $\rho \in (0, 1)$.

Step4: Calculate the correlation degree.

The average value of each correlation coefficient is the correlation degree value, and the formula is

$$r_i = \frac{1}{n}\sum_{k=1}^{n}\varepsilon(k) \tag{3}$$

Step5: Sorting of correlation degree.

Rank the correlation degree of all the calculated factors according to the numerical value.

3.2 Cause Analysis of Accident

Combined with the data of aviation safety accidents during the four-year period from 2013 to 2016, the annual total number of accidents is set as the reference sequence, and the number of accidents caused by each cause in the HFACS model is set as the comparison sequence. Based on this, the gray correlation analysis is carried out, and the order of the correlation degree was obtained as shown in Table 1.

Table 1. Correlation degree values and order of each cause.

Factor	Correlation	Sorting	Factor	Correlation	Sorting	Factor	Correlation	Sorting
A_{15}	0.9505	1	A_{22}	0.8430	9	A_3	0.7148	17
A_4	0.9160	2	A_6	0.8096	10	A_{11}	0.6058	18
A_{16}	0.9061	3	A_5	0.8053	11	A_{12}	0.5842	19
A_{21}	0.8855	4	A_{10}	0.8033	12	A_{13}	0.5756	20
A_7	0.8720	5	A_8	0.7808	13	A_{14}	0.5637	21
A_{19}	0.8697	6	A_{20}	0.7790	14	A_{17}	0.5115	22
A_1	0.8516	7	A_{18}	0.7587	15			
A_9	0.8439	8	A_2	0.7165	16			

As can be seen from Table 1, natural environment A_{15}, inadequate professional training A_4, security environment A_{16}, habitual violation A_{21}, inadequate supervision A_7 are the main causes of aviation safety accidents, among which natural environment A_{15} is the most important cause. Based on this, this paper proposes the following measures to reduce the incidence of aviation safety accidents:

(1) Conduct business skills training for relevant personnel to strengthen personal ability.
(2) Adopt text hints and other auxiliary means to carry out aviation safety management. The probability of maintenance errors can be reduced by marking key parts and error-prone parts of the aircraft and drawing lines in the tool room.
(3) Strengthen education and raise awareness. Through strengthening all kinds of personnel education, strengthen their safety awareness, awareness of danger, vigilance, so as to reduce the accident rate.
(4) Improve the working environment. Through the improvement of the working environment to enhance the comfort of the staff, the sense of superiority, enhance their work enthusiasm, so as to reduce the accident rate.
(5) Strengthen on-site management. Through the implementation of 6S management on the work site, the regular work order, from formulating relevant laws and regulations to their active compliance with the regulations, to achieve passive management to active management.

4 Multi-level Fuzzy Decision Making

4.1 Method Introduction

Fuzzy decision is to use fuzzy mathematics theory and method to make decision to the decision target quantitatively. Because of the complexity and variability of the external environment, most decisions are fuzzy ones. At present, fuzzy sorting, fuzzy optimization, fuzzy comprehensive decision making and other methods are commonly used for fuzzy decision making. The mathematical model of fuzzy comprehensive decision making is introduced below.

Fuzzy decision making consists of three elements and five steps:

The three elements are factor set U, evaluation set V and single factor R evaluation matrix. The five steps are as follows:

Step1: find out the influencing factors of the problem to be solved and establish the factor set U, $U = \{u_1, u_2, u_3, \cdots\}$.

Step2: Establish evaluation criteria and evaluation set V, $V = \{v_1, v_2, v_3, \cdots\}$.

Step3: Find professionals to establish single-factor evaluation for the research questions u_i, $u_i \rightarrow (a_i, b_i, c_i, \ldots)$.

Step4: Single factor evaluation matrix can be obtained by single factor evaluation R in step 3.

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} \tag{4}$$

Step5: Conduct comprehensive evaluation, input weight $A = (r_1, r_2, r_3, \cdots)$, perform synthetic operation on A and R according to the $max - min$ rules, and obtain comprehensive evaluation $K = A \circ R$ according to the principle of maximum membership degree.

4.2 Construction of Evaluation System

According to the principles of objectivity, comprehensiveness, quantification and dynamics, and in combination with the five measures obtained in Sect. 2.2, feasibility, benefit, time cost and work intensity are selected as evaluation indexes, and the quantification principles are shown in Table 2.

4.3 Optimal Measure Decision

Based on the theory of multi-level fuzzy decision making and combined with the practice in this paper, the algorithm flow chart is shown in Fig. 2.

Based on expert experience and investigation and visits to relevant units, the actual values $C(Y_{ji})$, weights among indicators W_i (first-level weights) and weights among measures k_j (second-level weights) corresponding to the five measures were collected and counted, as shown in Table 3.

Based on this, this paper uses multi-level fuzzy decision theory for further analysis. The first-level fuzzy decision value, second-level fuzzy decision value and maximum benefit function are calculated as

$$r_j = \sum_{i=1}^{4} W_i \times C(Y_{ji}) \tag{5}$$

$$R_j = r_j \times k_j \tag{6}$$

$$R = \max_j (R_j) \tag{7}$$

Table 2. Indicator meaning and quantification principle.

Serial number	Evaluation index	Meaning	Quantitative values			
			Poor	General	Good	Very good
			[0,0.25)	[0.25,0.5)	[0.5,0.75)	[0.75,1)
1	Feasibility	The simple level of action implement	Small feasibility	Feasibility generally	Good feasibility	Very good feasibility
2	Benefit	The sum of the benefits generated by the measures taken	Almost no effect	Effect generally	Good effect	Very good effect
3	Time cost	The time cost of taking action	Duration very long	Duration long	Duration short	Duration very short
4	Working strength	The amount of work done	Workload very large	Workload large	Workload small	Workload very small

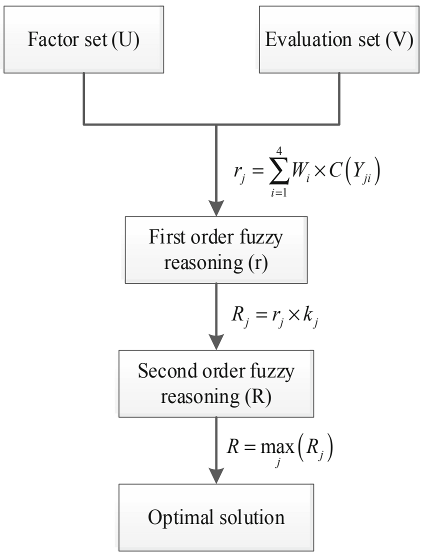

Fig. 2. Flow chart of fuzzy decision algorithm.

Table 3. Weights between evaluation indicators and measures.

	Feasibility	Benefit	Time cost	Working strength	2^{nd}-level weight
Measure 1	0.5	1	0.3	0.7	0.4
Measure 2	0.75	0.65	0.9	0.35	0.25
Measure 3	0.8	0.7	0.1	0.75	0.2
Measure 4	0.4	0.5	0.6	0	0.1
Measure 5	0.5	0.45	0.35	0.3	0.15
1^{st}-level weight	0.2	0.4	0.25	0.15	

(1) First-level fuzzy decision making
Obtained by formula (5), $r_1 = \sum_{i=1}^{4} W_i \times C(Y_{ji}) = 0.2 \times 0.5 + 0.4 \times 1 + 0.3 \times 0.25 + 0.7 \times 0.15 = 0.68$. Similarly, $r_2 = 0.6875$, $r_3 = 0.5775$, $r_4 = 0.43$, $r_5 = 0.4325$.
(2) Second-level fuzzy decision making
Obtained by formula (6), $R_1 = r_1 \times k_1 = 0.68 \times 0.4 = 0.272$. Similarly, $R_2 = 0.172$, $R_3 = 0.116$, $R_4 = 0.043$, $R_5 = 0.065$.
(3) Decision making

According to Formula (7) and Fig. 2, measure 1 is the best measure, and the ranking of measures is "business skills training of relevant personnel to strengthen personal ability", "aviation safety management by auxiliary means such as text hints", "Strengthening safety education to improve safety awareness", "strengthening on-site management", "improving the working environment".

5 Conclusion

Based on the HFACS model, 22 causes of aviation safety accidents are obtained in combination with the characteristics of flight accidents. Grey correlation analysis is used to analyse the man-made flight accidents from 2013 to 2016, and the main causes of accidents are obtained and corresponding preventive measures are proposed. Multilevel fuzzy decision making is used to analyse the order of measures. The results show that the most important causes of aviation safety accidents are natural factors, and the best preventive measures are "training relevant personnel in business skills and strengthening personal ability". The aviation safety management decision made in this paper only considers a single preventive measure. However, in the real society, to do aviation safety management well, it is not enough to rely on the prevention of a single measure. In practical work, two or more measures can be selected based on the model and combined with their own reality for collaborative prevention, so as to greatly improve the efficiency of aviation safety management. The research results of this paper provide a feasible management decision-making idea for aviation safety managers, and further improve the practicality, economy and science of relevant measures, and have a certain reference significance for the development of aviation safety management decision-making field.

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