Research on airline operational risk management and control method

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Abstract. Starting from the reality of airlines, this paper studies the operational risk and control methods of airlines, establishes relevant risk index system, and formulates corresponding control methods. Based on the four aspects of human, aircraft, environment and management, the risk index system is established. The weight of the index and the score of each system are determined by using the analytic hierarchy process and the fuzzy comprehensive evaluation respectively, and the airline risk evaluation model is established. In the formulation of airline management and control methods, genetic algorithm is used to compare different flight task combinations, and the advantages of this method are obtained.

1. Introduction
In recent years, with the vigorous development of civil aviation, the demand of customers for civil aviation transportation is growing, and the demand is getting higher and higher. The daily operation of airlines involves many factors and is a complex large-scale system. Therefore, it is difficult to evaluate the operational risk of airlines, and it is even more difficult to formulate corresponding control methods for the operational risk of airlines. These two problems are becoming increasingly prominent and need to be solved urgently.

Y.T. Wang et al.[1] established a flight risk assessment system from the operational point of view based on flights, and then Y.T. Wang[2] revised the degree of mutual influence of various indicators in airline safety risk assessment. In order to analyze the influence of operational risk factors, Y.T. Wang[3] systematically analyzed and calculated the coupling situation of flight operational risk. Literature[4] analyzed the fatigue degree of crew members and the risk value of experience. D.L. Li[5] pioneered the airline safety risk assessment based on dispatch release. T. Liu[6] combines the theory of organizational behavior and risk management to explore effective measures of risk management and control from the perspective of organization, and elaborates the existing operational system of airlines in an all-round way. Z.W. Ji[7] evaluates airline safety risk based on Bayesian network.

Beyond seas, Experts such as M. Bineid[8] focus on the development of reliability methods for civil aircraft dispatching, starting from the feasibility of airline flight dispatching. M. Janic[9] based on the airline database for many years, programmed by himself, and studied the risk and safety assessment of civil aviation. R.E. Braithwaite[10] carries out risk assessment and control for local airlines based on Australian airline database and related information.
The above research lacks unified evaluation criteria. This paper evaluates the operational risk of airlines by combining qualitative and quantitative analysis around the four systems of human, aircraft, ring and management, and puts forward corresponding control strategies.

2. Airline operational risk assessment

2.1. Analytic hierarchy process
(1) Constructing judgment matrix
Taking the subsystem of human factors as an example, the judgment matrix of the two comparisons of the subsystem of human factors is established.

\[ F = (f_{ij})_{nm}, i, j = 1, 2, \ldots, n \] (1)

The judgment matrix of human factor subsystem is as follows:

\[
C = \begin{pmatrix}
1 & 2 & 3 & 4 & 4 \\
1/2 & 1 & 2 & 3 & 3 \\
1/3 & 1/2 & 1 & 2 & 2 \\
1/4 & 1/3 & 1/2 & 1 & 1 \\
1/5 & 1/4 & 1/3 & 1/2 & 1 \\
\end{pmatrix}
\] (2)

(2) The weight of each index can be obtained by AHP method, As shown in table 1:

| First level index | weight | Second level index | weight |
|-------------------|--------|--------------------|--------|
| Human factors C   | 0.394  | Fatigue degree(C1) | 0.414  |
| C                 |        | Skill level(C2)    | 0.257  |
|                   |        | Tacit understanding degree(C3) | 0.153 |
|                   |        | English ability (C4) | 0.088 |
|                   |        | Psychological quality (C5) | 0.088 |
|                   |        | Aircraft properties (M1) | 0.311 |
|                   |        | Maintenance (M2) | 0.019 |
|                   | 0.258  | Communication navigation | 0.111 |
| Machine factors M |        | Aircraft MEL term (M4) | 0.298 |
|                   |        | Insecurity incidents (M5) | 0.261 |
|                   |        | Airspace condition of route (E1) | 0.034 |
|                   | 0.213  | Weather condition(E2) | 0.299 |
| environmental factors E | | Airport condition (E3) | 0.317 |
|                   |        | Communication coordination(E4) | 0.195 |
|                   |        | Response status (E5) | 0.155 |
|                   |        | Relevant system(P1) | 0.332 |
|                   | 0.135  | Training status(P2) | 0.233 |
| Management factors P | | Organization structure(P3) | 0.241 |
|                   |        | Departmental cooperation(P4) | 0.098 |
|                   |        | Emergency plan(P5) | 0.096 |

2.2. Fuzzy comprehensive evaluation
Taking the subsystem of human factors as an example, the safety level of each risk index is defined as:

\[ H = \{1 \text{(Extremely poor)}, 2 \text{(Poor)}, 3 \text{(Medium)}, 4 \text{(Good)}, 5 \text{(Excellent)} \} \]

Applying expert scoring method to obtain evaluation matrix:
Therefore, the fuzzy comprehensive evaluation matrix is:

\[
A = \begin{bmatrix}
0.3 & 0.4 & 0.4 & 0.6 & 0.3 \\
0.7 & 0.2 & 0.5 & 0.1 & 0.5 \\
0.6 & 0.4 & 0.3 & 0.2 & 0.5 \\
0.1 & 0.8 & 0.3 & 0.3 & 0.5 \\
0.6 & 0.6 & 0.6 & 0.1 & 0.1
\end{bmatrix}
\]

The risk assessment grade is calculated:

\[
C_i = \frac{\sum_{j=1}^{n} b_i^j \cdot j}{\sum_{j=1}^{n} b_i^j} = 3.09
\]

Therefore, the anthropogenic factors in the operational risk of airlines belong to level 3, that is, the degree of risk is moderate. Similarly, \( M_i = 2.42, E_i = 2.92, P_i = 3.44 \), then it can form a general secondary evaluation matrix: 

\[
[0.3002 \ 0.2843 \ 0.2673 \ 0.1492 \ ]
\]

Finally, the overall airline operational risk score can be obtained:

\[
C = \frac{\sum_{j=1}^{n} b_i^j \cdot j}{\sum_{j=1}^{n} b_i^j} = 2.906
\]

That is to say, the operational risk of the whole airline is close to the medium level.

3. Genetic algorithms

3.1. Mathematical model

In the calculation of airline operational risk evaluation model, the lowest risk index is used to calculate. The first-level fuzzy comprehensive evaluation formula is as follows:

\[
B_i = W^T \cdot R_i
\]

For the weight of each risk index, the relationship between each risk index and the score set.

Similarly, two-level fuzzy comprehensive evaluation:

\[
B_i = W^T \cdot R_i = (b_1, b_2, \ldots, b_n)
\]

For each subsystem corresponding weight, for each subsystem corresponding to the relationship between scoring set. So the objective function is:

\[
MAX(F(C)) = \frac{\sum_{j=1}^{n} b_i^j \cdot j}{\sum_{j=1}^{n} b_i^j}
\]

The total score representing a group of flight tasks depends on the score of the person, the machine, the loop and the management in the task. Firstly, the risk scores of human, aircraft, loop and tube are obtained by using the fuzzy comprehensive evaluation. Then, according to the task combination, the risk scores of a group of tasks are obtained by using the fuzzy comprehensive evaluation again. Finally, the total risk scores of N groups of missions are obtained. The fitness function is chosen as (penalty function):

\[
Fit(F(C)) = \frac{10000}{(1-c + F(C)) \cdot \delta}
\]

3.2. Selection operator
Roulette betting is used for selection, and the generation gap is 0.8, which means that 80% of the excellent groups will be selected to replicate. Next, the operation steps of roulette are introduced.

Firstly, the individual fitness of each individual is calculated, and then the overall fitness of the population is calculated. Then, the probability of each individual being selected is calculated.

\[ P_i = \frac{\text{per}(i)}{\sum_{j=1}^{n} \text{per}(i)} \]  

(9)

In this paper, the single-point crossover method is adopted, and the crossover probability is set to 0.7. According to the principle of single-point crossover, if an individual's coding length is V, there are V-1 points to be selected as crossover points, and then V-1 new individuals are generated by single-point crossover.

3.3. Variant operator

The mutation operation is an important operation in the later stage of genetic algorithm. Genes of organisms will mutate in the genetic evolution of successive generations, and the new generation of chromosomes that are likely to mutate has a better advantage than the previous generation of chromosomes. The mutation operation minimizes the possibility of destroying the better patterns that have been formed in the population, and generates the more excellent patterns as much as possible. Therefore, the setting of mutation probability is particularly important, assuming that the mutation probability is constant, 0.001.

Mutation operation: firstly, the numbering codes of the four subsystems of human, machine, loop and tube are generated, and the gene numbers at this position are mutated. The gene values of the mutated individuals are replaced by other alleles, and a new generation of individuals is generated.

The whole algorithm flow is shown in figure 1:

![Algorithm procedure](image)

**Figure 1.** Algorithm procedure.

4. Examples verification

In this paper, the data of auspicious airlines to develop flight plans and corresponding flight tasks, the existing personnel, aircraft, flight environment, management departments are 10. This paper tries to search for a better control scheme by genetic algorithm.

The default chromosome 1 is the initial feasible solution, which is calculated from the initial feasible solution.

\[ F(C) = \sum_{i=1}^{10} f(C_i) = 23.323 \]  

(10)

The concrete calculation results are shown in table 2:
Table 2. Primary chromosome scoring.

| Serial number | 1   | 2   | 3   | 4   | 5   |
|--------------|-----|-----|-----|-----|-----|
| Systematic   | 2.901 | 2.683 | 3.983 | 1.981 | 2.947 |
| Serial number | 6   | 7   | 8   | 9   | 10  |
| Systematic   | 3.401 | 1.713 | 1.819 | 3.926 | 3.482 |

According to the data in the table, the operational risk score of the combination of serial number 4, 7 and 8 is less than 2. If these three combinations want to fly, they will not only cause great potential safety hazards, but also cause considerable losses to the interests of airlines.

In the algorithm, the number of individuals is set to 100, the maximum genetic algebra is 200, the chromosome length is 4, the generation gap is 0.8, the crossover probability is 0.7, and the mutation probability is 0.001.

By calculating, the model is solved as a new flight task group, i.e. the combination of human, aircraft, loop and management after adjustment. The trend of optimal individual fitness is as follows in: figure 2 and figure 3.

Figure 2. The solution is related to the population. Figure 3. Compare flight mission ratings.

As shown in figure 2, about the 50th generation of solutions began to converge, and now the 80th and 140th generation solutions are used to calculate the new flight task scores by using the fuzzy comprehensive evaluation in the previous section. The new flight task scores are drawn together with the initial solutions, as shown in figure 3.

By comparison, only task 3 did not reach score 2 in the 80th Generation Solution, and the rest exceeded score 2. The overall trend tended to be stable, but there was no obvious advantage. It only increased the number of flights that exceeded score 2, and the effect was not satisfactory.

In the 140th generation solution, all tasks have been fulfilled with more than 2 points, and the airline's benefits have been maximized. According to the trend of the image, the flight task score of the 140th generation solution is not only higher than that of the 80th generation solution and the initial solution, but also more stable and concentrated, and the fluctuation is significantly reduced, which means that the flight task score has been improved and maintained at a relatively safe level. This also proves that the risk of airline operation control is further reduced, and the effect of control strategy is more intuitive. The total score of airline operational risk management and control method can be obtained by further calculation, The comparison of results is given in table 3.

Table 3. Comparison of results.

|                  | Initial solution | The 80th generation | The 140th generation |
|------------------|------------------|---------------------|---------------------|
| Fitness value    | 435.144          | 365.296             | 339.536             |
| Risk score       | 23.323           | 27.875              | 29.951              |

Through the above examples, it can be seen that three flight task groups in the initial feasible solution can not reach 2 points, and one flight task group in the eightieth generation solution can not reach 2 points. These flight tasks pose a great threat to the operation safety of the entire airline. In the
optimized results, all flight tasks in the 140th generation have reached 2 points, which achieves the desired results.

5. Conclusion
This paper actively searches for the risk indicators under the subsystem, and then establishes the airline operational risk index system and the airline operational risk evaluation model. The genetic algorithm is used to optimize the airline risk management and control strategy and search for the optimal solution, which provides support for the safe and efficient operation of airlines. However, genetic algorithm has a general problem, the stability of its operation results is poor, and it is difficult to get the optimal solution, which is also the direction of later research to provide more stable and accurate algorithm and conclusions.

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