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Research on Risk Evaluation Using RNP Technology for Operation into High Elevation Airports with Critical Terrain

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Abstract

On the basis of the preceding risk identification and the risk evaluation index systems, this paper applied AHP to determine the weight of risk evaluation indexes and fuzzy comprehensive evaluation to obtain the risk level under the condition of RNP technology operation into Nyingchi airport from the four aspects of human risk factor, equipment risk factor, environment risk factor and management risk factor. In order to improve the plateau flight safety, it made further efforts to put forward measures of risk control and prevention for plateau flight based on the risk evaluation results.

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1. INTRODUCTION

It keeps good flight safety records over several years at the high elevation airports. Never happened serious flight accidents, but slight events or accidents happened at the high elevation airports are much more than at the plain airports. There were several events, such as landing short of runway, tire burst and so on, happened at Jiuzhai, Nyingchi, Lhasa and Lijiang airports, which happened under the case of

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meeting the regulatory requirements. The root of the problem lies in insufficient understanding of the manual and data formulated in accordance with the regulations and lack of understanding of the law of the risks existing at the plateau flight. Therefore, it is urgent to build a set of safety assessment methods and standards to ensure the safety operation at the high elevation airports.

There have been not safety assessment methods and standards suitable for plateau flight at home and abroad. Indeed, risk evaluation matrix was always applied in the risk assessment in civil aviation, which is a qualitative evaluation method. The evaluation personnel make a judgment to the risk possibility level and severity rating subjectively on their own experience, and then the risk level is concluded through the risk evaluation matrix. Though this method is simple and easy to operate, it is so subjective and qualitative that its evaluation result has a low accuracy. So it is only suitable for the slight risk, while not for the big risk with severe loss existing in the plateau flight. Therefore, it is quite necessary to explore and establish a set of risk evaluation method combining with quantitative and qualitative for plateau flight.

2. RISK EVALUATION INDEX SYSTEM UNDER THE CONDITION OF RNP OPERATION AT THE HIGH ELEVATION AIRPORTS

The proceeding work of this paper had been done, which finished the risk factor analysis under the condition of RNP operation at the high elevation airports and formed a risk source list. The index system is divided into general layer, factors layer and index layer under the guidance of the construction principles of scientific, systematic, applicability, comparability and sensitivity in strict accordance with the index system design steps and process. The 36 risk evaluation index was selected separately from the four aspects of personnel, equipment, environment and management, see Fig 1~5[1].

![Risk Evaluation Index System](image-url)
## Human Risk Factor
- Physiological disability
- Stress out
- Mood disorder
- Loss of decision-making ability
- Improper distribution of attention
- Loss of situation awareness
- Lack of expertise and experience
- Unreasonable cockpit resources management
- ATC staff lacked skill training of RNP
- Dispatcher lacked skill training of plateau flight
- Maintenance lacked skill training of plateau flight
- Cabin passenger factors

## Equipment Risk Factor
- Decline of navigation performance and precision
- Satellite navigation signal loss or relegation
- Navigation database error
- RNP System component failure
- Aircraft engine failure
- Aircraft oxygen system failure
- The cabin air-conditioning system failure
- Brake system failure
- Weather radar failure
- Power failure
- Not equipped with emergency procedures

Fig. 2. Risk Evaluation Index Systems (Human risk factor index layer 1)

Fig. 3. Risk Evaluation Index Systems (Equipment risk factor index layer 2)
3. RISK EVALUATION UNDER THE CONDITION OF RNP OPERATION AT THE HIGH ELEVATION AIRPORTS

3.1. Risk Evaluation Methods

3.1.1 Analytical Hierarchy Process

AHP (Analytical Hierarchy Process) is a method combined with qualitative and quantitative analysis, which was presented by a famous American operational research experts T.L.Saaty. It is a simple method combining with qualitative and quantitative analysis for decision-making to the relatively obscure and complicated problem. Especially it quantifies the decision-maker's experience and judgment. It makes people's thinking process hierarchical, compares the relevant factor and check out the comparison results layer by layer and which provides persuasive evidence [2-3].

The basic steps of AHP:
1. Establish the hierarchical structure model
Firstly, it needs to build a hierarchical structure figure of the evaluation system according to the specific circumstances, which is convenient for hierarchy analysis of the evaluation object and to establish clear grading index system, usually the first layer for target strata, other levels for index level.

(2) Tectonic judgment matrix

Supposed there are \( n \) elements \((X_1, \cdots, X_n)\) on each layer with impacts on the target of the upper layer. And then compare two elements \( X_i \) and \( X_j \), \( a_{ij} \) was used to indicate the importance ratio to the upper target between \( X_i \) and \( X_j \), and matrix \( A = (a_{ij})_{mn\times n} \) was used to indicate the full result as the judgment matrix. In order to determine the value of \( a_{ij} \), it quoted a common 1~9 scale method, as shown in the following tables.

Table 1. The scale method of judgment matrix element \( a_{ij} \)

| Scale | Implication                                      |
|-------|--------------------------------------------------|
| 1     | Two elements with the same importance            |
| 3     | A factor is slightly more important than the other one |
| 5     | A factor is obviously more important than the other one |
| 7     | A factor is much more important than the other one |
| 9     | A factor is extremely more important than the other one |
| 2, 4, 6, 8 | The mid-value of the two adjacent judgments above |
| Reciprocal | The judgment of the comparison between I and j is \( a_{ij} \), while |
|          | the judgment between j and I is \( a_{ji} = 1/a_{ij} \) |

Table 2. The scale and its implication of the judgment matrix

| No. | Importance rating                        | Scale \( a_{ij} \) |
|-----|------------------------------------------|-------------------|
| 1   | i and j are equally important            | 1                 |
| 2   | i is slightly more important than j      | 3                 |
| 3   | i is obviously more important than j     | 5                 |
| 4   | i is much more important than j          | 7                 |
| 5   | i is extremely more important than j     | 9                 |
| 6   | i is slightly less important than j      | \( 1/3 \)         |
| 7   | i is obviously less important than j     | \( 1/5 \)         |
| 8   | i is much less important than j          | \( 1/7 \)         |
| 9   | i is extremely less important than j     | \( 1/9 \)         |

Note: \( a_{ij} = \{2, 4, 6, 8, 1/2, 1/4, 1/6, 1/8\} \) indicate their importance rating are between \( a_{ij} = \{1, 3, 5, 7, 9, 1/3, 1/5, 1/7, 1/9\} \), which are determined according to the intuition and judgment of experts' qualitative analysis.

(3) Solving judgment matrix

There are a variety of ways to solve judgment matrix, but join-quadrate method was applied to solve the judgment matrix here.

1) To standardize each column of the judgment matrix to get matrix \( \bar{A} = [\bar{a}_{ij}] \),

\[
\bar{a}_{ij} = \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}} = (i, j, k = 1, 2, 3, \cdots, n)
\]
2) To add each element in judgment matrix $\overline{A}$ together by row to get vector $\overline{W} = [W_i]_r$

Among them, $W_i = \sum_{j=1}^{n} a_{ij} (i, j = 1, 2, 3, \cdots, n)$

3) To normalize $\overline{W}$ to get the weight of the relevant elements of layer $M_i$ relative to $M$ layer.

4) To calculate the biggest characteristic root of the judgment matrix $\lambda_{max} = \sum_{i=1}^{n} (AW)_i / nW_i$

Among them, $(AW)_i$ indicates element $i$ of the vector $AW$.

(4) Level single sorting and consistency test

Judgment matrix is a matrix result from binary comparison between complicated things. So it's difficult to get a completely consistent judgment and we allow a certain range inconsistencies. Professor Saaty presented the following methods:

If $CR < 0.1$, then the inconsistency of $A$ is in the allowable range. It's allowable to use the standardization characteristic vector as weight vector, or it needs to readjust $A$. $CR$ is consistency ratio and $CR = \frac{CI}{RI}$. $CI$ is the consistency index of $A$ and $CI = \frac{\lambda_{max} - n}{n - 1}$. $RI$ is the random consistency index of $A$ and its value are shown in table 3.

Table 3. Judgment matrix RI value

| n  | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| RI | 0.00| 0.00| 0.58| 0.90| 1.12| 1.24| 1.32| 1.41| 1.45| 1.49| 1.51| 1.54|

### 3.1.2 Analytical Hierarchy Process

Fuzzy comprehensive evaluation is method combining with fuzzy mathematics and fuzzy statistic, which considers each element with impact on some thing comprehensively to make a scientific evaluation on the quality of it. Fuzzy comprehensive evaluation begins from the bottom layer to the top layer to the evaluation result of the target layer. It needs to make secondary comprehensive evaluation to criterion strata and target layer[4].

Its steps are shown as following:

1) To establish evaluation index set $M = \{M_1, M_2, \cdots, M_k\}$, $M_i = \{M_{i1}, M_{i2}, \cdots, M_{ik}\}$.

To determine index weight set, each index’s impact on $M_i$ is $B_i = \{W_{i1}, W_{i2}, \cdots, W_{ik}\}$, similarly, the weight distribution set of $M_i$ to $M$ is $D = \{W_1, W_2, \cdots, W_k\}$.

2) To select evaluation sets: To establish suitable evaluation rating to form evaluation set according to the risk level under the RNP operation at the high elevation airports. There are generally 5 levels, as $V = \{V_1, V_2, V_3, V_4, V_5\} = \{\text{lowest level}, \text{lower level}, \text{mid-level}, \text{higher level}, \text{highest level}\}$.

3) To establish index evaluation matrix: To determine the risk level of $M_i$ by experts, and then calculate the rating frequencies of each index belong to $V$. The proportion of the frequency to
the total number of the experts can be regarded as the degree of membership to establish evaluation matrix R.

(4) The comprehensive evaluation vector $C_i$ of each sub target $M_i$ is $C_i = B_{ir}$, and then form evaluation matrix of each sub target, $C = \{C_1, C_2, \cdots, C_i\}$.

(5) Each total target vector $M$ is $M=DR$. Determine the risk level of each risk according to maximum membership degree principles.

After using the above multi-grade fuzzy comprehensive evaluation mathematical model and adopting fuzzy operator $M(\cdot, +)$, we can make a evaluation on the risk under the condition of RNP operation at the high elevation airports. The index set consists of 36 elements, which can be divided into $M=\{M_1, M_2, M_3, M_4\}=$Human risk factor, Equipment risk factor, Environment risk factor, Management risk factor\}:

$M_1=\{M_{11}, M_{12}, M_{13}, M_{14}, M_{15}, M_{16}, M_{17}, M_{18}, M_{19}, M_{110}, M_{111}, M_{112}\}$

$M_2=\{M_{21}, M_{22}, M_{23}, M_{24}, M_{25}, M_{26}, M_{27}, M_{28}, M_{29}, M_{210}, M_{211}\}$

$M_3=\{M_{31}, M_{32}, M_{33}, M_{34}, M_{35}, M_{36}, M_{37}, M_{38}, M_{39}\}$

$M_4=\{M_{41}, M_{42}, M_{43}, M_{44}\}$

Risk options evaluation set $V=\{V_1, V_2, V_3, V_4, V_5\}=$lowest level, lower level, mid-level, higher level, highest level}. After finishing the above steps, we can get the risk condition under the condition of RNP operation at the high elevation airports.

3.2. The Risk Evaluation of RNP Operation at Nyingchi Airport

3.2.1 The Calculation of Risk Evaluation Index Weight at Nyingchi Airport

(1) To determine hierarchical structure

On the basis of the risk evaluation index system, AHP was applied to determine the index weight. The overall risk value F under the condition of RNP operation at Nyingchi airports was supposed as the overall target layer; the principle layer S includes human risk factor $W_1$, equipment risk factor $W_2$, environment risk factor $W_3$ and management risk factor $W_4$; the index layer includes $W_{11}, W_{12}, W_{13}, \cdots; W_{21}, W_{22}, W_{23}, \cdots; W_{31}, W_{32}, W_{33}, \cdots; W_{41}, W_{42}, W_{43}, \cdots$(As shown in figure 1~5). It determined the weight of the four aspects of principle layer to the overall target layer and the indexes of index layer to principle layer through creating judgment matrix.

(2) Tectonic judgment matrix

In this step the relative experts are invited to make binary comparison between the elements of the hierarchical structure. Firstly it applied 1~9 scale to determine the binary comparison matrix of the four factors of principle layer, then determine the binary comparison matrix of the elements of index layer.
Table 4. Binary comparison matrix of four factors of the principle layer

|       | W1 | W2 | W3 | W4 |
|-------|----|----|----|----|
| W1    | 1  | 1/2| 1/5| 1/3|
| W2    | 2  | 1  | 1/5| 1/2|
| W3    | 5  | 5  | 1  | 3  |
| W4    | 3  | 2  | 1/3| 1  |

Table 5. Binary comparison matrix between human risk factors

|       | W1   | W11  | W12  | W13  | W14  | W15  | W16  | W17  | W18  | W19  | W110 | W111 | W112 |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| W1    | 1    | 1/2  | 1/2  | 3    | 1/4  | 3    | 3    | 1/4  | 1/5  | 1/5  | 1/2  | 1/7  |
| W11   | 2    | 1    | 1    | 3    | 1/3  | 3    | 1/2  | 1/3  | 1/3  | 1/3  | 1/3  | 1/5  |
| W12   | 3    | 1/3  | 1/3  | 1    | 1/5  | 1    | 1/4  | 1/5  | 1/5  | 1/5  | 1/3  | 1/9  |
| W13   | 4    | 3    | 3    | 5    | 1    | 5    | 3    | 2    | 1    | 1    | 3    | 1/3  |
| W14   | 1/3  | 1/3  | 1/3  | 1    | 1/5  | 1    | 1/4  | 1/5  | 1/5  | 1/5  | 1/3  | 1/9  |
| W15   | 3    | 2    | 2    | 4    | 1/3  | 4    | 1    | 1/2  | 1/3  | 1/3  | 2    | 1/4  |
| W16   | 4    | 3    | 3    | 5    | 1/2  | 5    | 2    | 1    | 1/2  | 1/2  | 3    | 1/3  |
| W17   | 5    | 3    | 3    | 5    | 1    | 5    | 3    | 2    | 1    | 1    | 3    | 1/3  |
| W18   | 5    | 3    | 3    | 5    | 1    | 5    | 3    | 2    | 1    | 1    | 3    | 1/3  |
| W19   | 7    | 5    | 5    | 9    | 3    | 9    | 4    | 3    | 3    | 3    | 5    | 1    |

Table 6. Binary comparison matrix between equipment risk factors

|       | W4  | W41 | W42 | W43 | W44 |
|-------|-----|-----|-----|-----|-----|
| W4    | 1   | 1   | 4   | 1/2 |
| W41   | 1   | 1   | 4   | 1/2 |
| W42   | 1/4 | 1/4 | 1   | 1/5 |
| W43   | 2   | 2   | 5   | 1   |
Table 7. Binary comparison matrix between equipment risk factors

|   | W2   | W21  | W22  | W23  | W24  | W25  | W26  | W27  | W28  | W29  | W210 | W211 |
|---|------|------|------|------|------|------|------|------|------|------|------|------|
| W21| 1    | 1/3  | 1    | 1/3  | 3    | 1/3  | 1/2  | 3    | 1/3  | 2    | 3    |
| W22| 3    | 1    | 3    | 1    | 5    | 2    | 4    | 5    | 2    | 4    | 2    |
| W23| 1    | 1/3  | 1    | 1/3  | 3    | 1/3  | 1/2  | 3    | 1/3  | 2    | 3    |
| W24| 3    | 1    | 3    | 1    | 5    | 2    | 4    | 5    | 2    | 4    | 2    |
| W25| 1/3  | 1/5  | 1/3  | 1/5  | 1    | 1/4  | 1/2  | 1    | 1/4  | 1/2  | 1/4  |
| W26| 3    | 1/2  | 3    | 1/2  | 4    | 1    | 3    | 4    | 1    | 3    | 1    |
| W27| 2    | 1/4  | 2    | 1/4  | 2    | 1/3  | 1    | 2    | 1/3  | 1    | 1/3  |
| W28| 1/3  | 1/5  | 1/3  | 1/5  | 1    | 1/4  | 1/2  | 1    | 1/4  | 1/2  | 1/4  |
| W29| 3    | 1/2  | 3    | 1/2  | 4    | 1    | 3    | 4    | 1    | 3    | 1    |
| W210| 1/2  | 1/4  | 1/2  | 1/4  | 2    | 1/3  | 1    | 2    | 1/3  | 1    | 1/3  |
| W211| 1/3  | 1/2  | 1/3  | 1/2  | 4    | 1    | 3    | 4    | 1    | 3    | 1    |

Table 8. Binary comparison matrix between environment risk factors

|   | W3   | W31  | W32  | W33  | W34  | W35  | W36  | W37  | W38  | W39  |
|---|------|------|------|------|------|------|------|------|------|------|
| W31| 1    | 1/5  | 1/4  | 1/3  | 1/7  | 1/4  | 1/4  | 1/5  | 1/5  |
| W32| 5    | 1    | 2    | 3    | 4    | 2    | 2    | 1/2  | 1/2  |
| W33| 4    | 1/2  | 1    | 2    | 1/5  | 1    | 1    | 1/3  | 1/3  |
| W34| 3    | 1/3  | 1/2  | 1    | 1/6  | 1/3  | 1/3  | 1/4  | 1/4  |
| W35| 7    | 1/4  | 5    | 6    | 1    | 5    | 5    | 3    | 3    |
| W36| 4    | 1/2  | 1    | 3    | 1/5  | 1    | 1    | 1/3  | 1/3  |
| W37| 4    | 1/2  | 1    | 3    | 1/5  | 1    | 1    | 1/3  | 1/3  |
| W38| 5    | 2    | 3    | 4    | 1/3  | 3    | 3    | 1    | 1    |
| W39| 5    | 2    | 3    | 4    | 1/3  | 3    | 3    | 1    | 1    |

(3) The calculation of index weight and consistency test

According to the judgment matrix created in last step, Matlab6.5 was applied to conclude the weight vectors of each factor and index in principle and index layer and make the consistency test. Its result is shown in table 9 and 10.
Table 9. The weight vectors of each factor and index in the evaluation index systems

| Judgment Matrix | Weight Vector w |
|-----------------|-----------------|
| F               | (0.0823, 0.1276, 0.5644, 0.2257) T |
| W1              | (0.0293, 0.0399, 0.0399, 0.0183, 0.1241, 0.0183, 0.0647, 0.0967, 0.1264, 0.1264, 0.0662, 0.2498) T |
| W2              | (0.0748, 0.1803, 0.0748, 0.1803, 0.0259, 0.1239, 0.0593, 0.0259, 0.1239, 0.0405, 0.0904) T |
| W3              | (0.0216, 0.1926, 0.0589, 0.0354, 0.2513, 0.0624, 0.0624, 0.1576, 0.1576) T |
| W4              | (0.2456, 0.2456, 0.0696, 0.4393) T |

Table 10. The consistency test of judgment matrix

| Judgment Matrix | n | λ_max | CI | RI | CR | Consistency Test |
|-----------------|---|-------|----|----|----|------------------|
| F               | 4 | 4.0593| 0.0198 | 0.90 | 0.0220 | √ |
| W1              | 12 | 12.7842 | 0.0713 | 1.54 | 0.0463 | √ |
| W2              | 11 | 11.8937 | 0.0894 | 1.51 | 0.0592 | √ |
| W3              | 9 | 10.0564 | 0.1321 | 1.45 | 0.0911 | √ |
| W4              | 4 | 4.0277 | 0.0092 | 0.90 | 0.0103 | √ |

It can be concluded from table 10 that the consistency ratio of each judgment matrix CR< 0.1, which means consistency test is successful.

3.2.2 The Calculation of the Risk Assessment Rating at Nyingchi Airport

Nyingchi airport is located in the long and narrow, rugged valley in the southeast of the Yarlung Zangbo River, whose downstream is closed to India and belongs to the southeast of Tibet. The court area of Nyingchi airport is relatively flat, however, the terrain of the airport is complex and the climate is changeful. Moreover, the northeastern and lateral clearance are poor, the southwestern clearance is slight better. All the mountains around are above 4500m, while the elevator of the airport is only 2948.9m, which is a high elevation airport with a runway of only 3000m. Its surrounding terrain environment is extremely complex, which causes a great deal of difficulty to flight. The climate of Nyingchi airport belongs to subtropical mountainous monsoon of the southeastern of Tibet, which owns an apparent subtropical mountainous monsoon climate feature without distinct characteristics of the four seasons. In the summer-half year, it is influenced mainly by the southwest monsoon of India, so there is a humid climate with heavy clouds, much rain and an obvious trait of rainy season. While in the winter-half year, it is influenced by mainland monsoon, so there is a relatively dry climate with heavy wind, less rainfall and a prominent characteristic of dry weather. The airport is located in specific geographical environment in the southeastern of Tibet, which combines the complex geographic features of high elevation airport, mountain airport, canyon
airport and river valley airport. The geographical environment of Nyingchi airport not only directly affects the headroom conditions, but also directly affects the activities of the airport weather system. Additionally, the superimposed effect of atmospheric circulation and valley monsoon circulation further results in complexity and variety of the airport area aviation weather. According to meteorological statistics rule of Nyingchi airport, the main weather profiles of Nyingchi airport can be concluded into the following 5 points [5]:

1) There are 190 rainy days at Nyingchi airport annually. It owns a longer rainy season, mainly distributed from April to September with 142 precipitation day totally.

2) There are 265 days with low cloud at Nyingchi airport annually, among which there 209 days belong to from March to October with 26 day monthly.

3) There are frequent heavy ground winds at Nyingchi airport, most frequently from January to March and more frequently from October to December. The ground wind changes obviously daily and the heaviest ground appear in the afternoon. In 2002, there are 103 days with instantaneous wind speed greater than 17m/s, which own a SSE of direction.

4) There relatively less thunderstorms at Nyingchi airport, which mainly appear from March to October, especially in May.

5) There is a warm and humid climate at Nyingchi airport. Its reference temperature is 22°C and relative humidity average annually is 62%.

The risk level of $W_{ij}$ was given by experts, and then the frequency of the rating of each index belongs to $V$ was calculated. The ratio of the frequency to the number of all experts is the membership of each index, which Composes of the fuzzy evaluation matrix of the subsets of each index.

The evaluation matrix of Human risk factor $W_1$:

$$
R_1 = \begin{bmatrix}
0 & 0 & 0.2 & 0.6 & 0.2 \\
0 & 0 & 0.3 & 0.5 & 0.2 \\
0 & 0 & 0.1 & 0.8 & 0.1 \\
0 & 0 & 0.1 & 0.3 & 0.6 \\
0.1 & 0.2 & 0.4 & 0.3 & 0 \\
0 & 0 & 0.1 & 0.1 & 0.8 \\
0.1 & 0.4 & 0.2 & 0.2 & 0.1 \\
0 & 0.4 & 0.3 & 0.3 & 0 \\
0.1 & 0.2 & 0.4 & 0.2 & 0.1 \\
0 & 0.1 & 0.2 & 0.6 & 0.1 \\
0 & 0.1 & 0.2 & 0.6 & 0.1 \\
0.3 & 0.6 & 0.1 & 0 & 0
\end{bmatrix}
$$
The evaluation matrix of equipment risk factor $W_2$:

$$
\begin{bmatrix}
0 & 0 & 0.2 & 0.4 & 0.4 \\
0 & 0 & 0.6 & 0.3 & 0.1 \\
0 & 0 & 0.2 & 0.5 & 0.3 \\
0.2 & 0.2 & 0.4 & 0.2 & 0 \\
0 & 0 & 0 & 0.2 & 0.8
\end{bmatrix}
$$

$R_2 = \begin{bmatrix}
0 & 0 & 0.3 & 0.6 & 0.1 \\
0 & 0.1 & 0.3 & 0.5 & 0.1 \\
0 & 0 & 0 & 0.1 & 0.9 \\
0 & 0 & 0.4 & 0.4 & 0.2 \\
0 & 0 & 0.2 & 0.4 & 0.4 \\
0.2 & 0.3 & 0.3 & 0.2 & 0
\end{bmatrix}$

The evaluation matrix of environment risk factor $W_3$:

$$
\begin{bmatrix}
0 & 0 & 0 & 0.1 & 0.9 \\
0 & 0.1 & 0.3 & 0.4 & 0.2 \\
0 & 0 & 0.6 & 0.3 & 0.1 \\
0 & 0 & 0.2 & 0.6 & 0.2 \\
0.4 & 0.3 & 0.2 & 0.1 & 0 \\
0 & 0.1 & 0.6 & 0.2 & 0.1 \\
0 & 0 & 0.5 & 0.4 & 0.1 \\
0.2 & 0.3 & 0.3 & 0.2 & 0 \\
0.1 & 0.4 & 0.2 & 0.3 & 0
\end{bmatrix}
$$

$R_3 = \begin{bmatrix}
0.4 & 0.3 & 0.2 & 0.1 & 0 \\
0 & 0.1 & 0.6 & 0.2 & 0.1 \\
0 & 0 & 0.5 & 0.4 & 0.1 \\
0.2 & 0.3 & 0.3 & 0.2 & 0 \\
0.1 & 0.4 & 0.2 & 0.3 & 0
\end{bmatrix}$

The evaluation matrix of management risk factor $W_4$:

$$
\begin{bmatrix}
0 & 0.1 & 0.2 & 0.6 & 0.1 \\
0.1 & 0.1 & 0.3 & 0.4 & 0.1 \\
0 & 0 & 0.2 & 0.3 & 0.5 \\
0.1 & 0.2 & 0.3 & 0.4 & 0
\end{bmatrix}
$$

$C_i = w_i R_i$ was applied to make fuzzy evaluation to each index subset to form evaluation matrix of each sub target $C = \{C_1, C_2, \cdots C_i\}$. 
The weight of each index had been determined through AHP:

\[ W_1 = (0.0293, 0.0399, 0.0399, 0.1241, 0.0183, 0.0647, 0.0967, 0.1264, 0.1264, 0.0662, 0.2498)^T \]

\[ W_2 = (0.0748, 0.1803, 0.0748, 0.1803, 0.0259, 0.1239, 0.0593, 0.1239, 0.0405, 0.0904)^T \]

\[ W_3 = (0.0216, 0.1926, 0.0589, 0.0354, 0.2513, 0.0624, 0.0624, 0.1576, 0.1576)^T \]

\[ W_4 = (0.2456, 0.2456, 0.0696, 0.4393)^T \]

It can be concluded as following:

\[ \begin{bmatrix} 0.0818 & 0.0296 & 0.0231 & 0.1102 & 0.0106 & 0.0111 & 0.1065 & 0.2838 & 0.2311 & 0.2968 & 0.0818 \end{bmatrix} = R_{wC1} \]

\[ \begin{bmatrix} 0.1373 & 0.0353 & 0.0374 & 0.0219 & 0.0129 & 0.0222 & 0.0293 & 0.1926 & 0.0589 & 0.0354 & 0.2513 & 0.0624 & 0.1239 & 0.0593 & 0.1239 & 0.0405 & 0.0904 & 0.1264 & 0.1264 & 0.0662 & 0.2498 \end{bmatrix} = R_{wC2} \]

\[ \begin{bmatrix} 0.0996 & 0.0293 & 0.0358 & 0.0388 & 0.0240 & 0.0333 & 0.0817 & 0.0526 & 0.0405 & 0.0904 & 0.0219 & 0.0129 & 0.0222 & 0.0293 & 0.1926 & 0.0589 & 0.0354 & 0.2513 & 0.0624 & 0.1239 & 0.0593 & 0.1239 & 0.0405 & 0.0904 & 0.1264 & 0.1264 & 0.0662 & 0.2498 \end{bmatrix} = R_{wC3} \]

\[ \begin{bmatrix} 0.1126 & 0.0817 & 0.0526 & 0.0405 & 0.0904 & 0.0219 & 0.0129 & 0.0222 & 0.0293 & 0.1926 & 0.0589 & 0.0354 & 0.2513 & 0.0624 & 0.1239 & 0.0593 & 0.1239 & 0.0405 & 0.0904 & 0.1264 & 0.1264 & 0.0662 & 0.2498 \end{bmatrix} = R_{wC4} \]

The weight of the first-order index in the principle layer was determined as:

\[ W = (0.0823, 0.1276, 0.5644, 0.2257)^T \]

The evaluation matrix of the risk factor under the condition of RNP operation at Nyingchi airport is:

\[ R = \begin{bmatrix} C_1 & C_2 & C_3 & C_4 \end{bmatrix} \]

So the risk evaluation of the risk factor under the condition of RNP operation at Nyingchi airport:

\[ F = W \cdot R = \begin{bmatrix} 0.4718 & 0.7535 & 0.6457 & 0.5504 & 0.1392 \end{bmatrix} \]

According to the principles of maximum membership degree, the comprehensive risk evaluation result is high. The result agrees with the subjective description of the pilots who have finished several flights at Nyingchi airport. It also can be concluded from the result that the main risk factors are human risk factor and equipment risk factor.

Furthermore, human risk factor is mainly embodied in the following aspects: loss of situation awareness, loss of decision-making ability, physiological disability, stress out and mood disorder; equipment risk factor is mainly embodied in the following aspects: aircraft engine failure, brake system failure, power failure, decline of navigation performance and precision, navigation database error; environment risk factor is mainly embodied in the following aspects: low-level wind shear, complex weather conditions and terrain complexity; management risk factor is mainly embodied in the following aspects: improper operation plan and improper personnel selection and placement.

Therefore on the basis of risk evaluation result, we need to find out the sub factors which constitutes the risk and apply the effective and reasonable risk control strategies of evading, transfer, alleviation, acceptation and utilization to seek out and make effective measures conforms to the actual condition, in order to make the risk transfer into opportunity or reduce negative effects caused by risk to the acceptable degree.
4. THE RISK CONTROL AND PREVENTION UNDER THE CONDITION OF RNP OPERATION AT THE HIGH ELEVATION AIRPORTS

4.1. Overview of Risk Control

Risk identification and risk evaluation are the bases of risk management, while risk control is the ultimate destination of risk management. Risk control is to achieve optimal level of safety with the existing technologies and management level and with minimal consumption of resources. Its specific goals include reducing accidents frequency, the severity of accidents and the economic loss of accidents.

Risk control technology includes macro control technology and micro control technology. Macro control technology aims at the whole research systems and applies systematic engineering principle for effective control of risk. Its technology mainly includes legal means (policy, law and regulations), economic means (prize, penalty, compensation) and education means (long-term or short-term, school, social). Micro control technology aims at the specific risk source under the guidance of system engineering theory. Its technology mainly includes engineering and technical measures and management measures, which change according to the different research objects. Macro control and micro control are interdependent, complementary, restricted and indispensable to each other[6-7].

4.2. The Risk Control and Prevention under the condition of RNP Operation at The High Elevation Airports

On the ground of the risk identification and risk evaluation under the condition of RNP operation at high elevation airports, this paper put forward some Suggestions and measures of equipment of risk control from the four aspects of human, equipment, environment and management.

4.2.1 The Risk Control and prevention of Human Risk Factor

Human factor accidents account for a big proportion of aviation accidents. It plays an important role of safeguarding the plateau flight safety to control the human factor accidents under the condition of RNP operation at the high elevation airports.

It can be inferred from the preceding results of risk identification and risk evaluation that human risk factor is mainly embodied in the following aspects: loss of situation awareness, loss of decision-making ability, physiological disability, stress out and mood disorder. So it is necessary for the pilots and crew to live up to the flowing points to prevent and control human factor accident in plateau flight[8-9]:

1. Be familiar with and understand the corresponding regulations and standards of plateau flight. Strengthen the simulated training in normal times to lay solid theoretical foundation and train proficient flight skills.

2. Be familiar with the environment of plateau flight and understand a variety of conditions and special situations during the plateau flight. Apply crew resource management tools rationally to establish situational awareness.

3. Build healthy habits in daily life and build a healthy body. Ensure a good sleep and healthy diet before the task of plateau flight.

4. Understand the causes and contributing factors of stress out and mood disorder. Apply proper ways to control your emotion and stress.
4.2.2 The Risk Control and prevention of Equipment Risk Factor

It can be inferred from the preceding results of risk identification and risk evaluation that equipment risk factor is mainly embodied in the following aspects: aircraft engine failure, brake system failure, power failure, decline of navigation performance and precision, navigation database error. Therefore, it is necessary for the airlines to ensure the aircraft and its equipments meet airworthiness requirements of the corresponding regulations and rules before plateau flight to prevent and control equipment factor accident in plateau flight. Airlines intelligence and performance staff must update and maintain the navigation database of the aircraft in time and check the aircraft's navigation performance periodically. Airlines maintainer must carry out periodic inspection and maintenance to the aircraft according to the requirements of the relevant regulations and rules.

4.2.3 The Risk Control and prevention of Environment Risk Factor

It can be inferred from the preceding results of risk identification and risk evaluation that environment risk factor is mainly embodied in the following aspects: low-level wind shear, complex weather conditions and terrain complexity. Therefore, it is necessary for the aircraft to be equipped wind shear detection equipment to prevent and control environment factor accident in plateau flight. Airlines must take full prediction and tracking to the current a future weather in the flight plan. Flight crew must get acquaintance with and assess destination airport terrain, runway condition in the preflight preparation. Additionally, it needs to analyze the environment of the high elevation airports comprehensively and master its seasonal rule.

4.2.4 The Risk Control and prevention of Management Risk Factor

It can be inferred from the preceding results of risk identification and risk evaluation that management risk factor is mainly embodied in the following aspects: improper operation plan and improper personnel selection and placement. Therefore, it is necessary to strengthen the execution and supervision of the relevant regulations and rules of plateau flight to prevent and control management factor accident in plateau flight. The supervisors and managers of airlines must consider all kinds of impacts of flight plan on the flight when they made the flight plan. It is essential to select and train the pilots to form the aircrew of the plateau flight and strengthen the construction of safety culture.

5. CONCLUSION AND PROSPECT

On the basis of the preceding risk identification and the risk evaluation index systems, combined with the practical investigation to airlines and high elevation airports and questionnaire investigation and statistical analysis from the experts of pilots, performance, meteorologist, aviation psychologist, dispatcher, maintainer and air traffic controller about the risk evaluation, this paper applied AHP to determine the weight of risk evaluation indexes and fuzzy comprehensive evaluation to obtain the risk level under the condition of RNP operation at Nyingchi airport from the four aspects of human risk factor, equipment risk factor, environment risk factor and management risk factor and made further efforts to put forward measures of risk control and prevention.

Although this article explored and established risk evaluation methods and models for RNP operation at the high elevation airports, it is still in the continuous exploring phase and need further revisions and
improvements. It looks forward to develop the software and manual for airlines’ plateau flight. Additionally, plateau flight needs a continuous risk management process to control and prevent the risk comprehensively.

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