Safety risk assessment and prevention and control measures for reloading airdrop missions

Xu Jihui¹, Zhang Jing²*, Tian Wenjie³, Shi Jiahui⁴, Liu Tengfei⁵, Wang Xiaolin⁶, Chen Yujin⁷, Guo Rui⁸

¹Equipment Management and Unmanned Aerial Vehicle Engineering College Air Force Engineering University Xi'an, China
²Equipment Management and Unmanned Aerial Vehicle Engineering College Air Force Engineering University Xi'an, China
³Equipment Management and Unmanned Aerial Vehicle Engineering College Air Force Engineering University Xi'an, China
⁴Equipment Management and Unmanned Aerial Vehicle Engineering College Air Force Engineering University Xi'an, China
⁵Equipment Management and Unmanned Aerial Vehicle Engineering College Air Force Engineering University Xi'an, China
⁶Equipment Management and Unmanned Aerial Vehicle Engineering College Air Force Engineering University Xi'an, China
⁷Equipment Management and Unmanned Aerial Vehicle Engineering College Air Force Engineering University Xi'an, China
⁸Equipment Management and Unmanned Aerial Vehicle Engineering College Air Force Engineering University Xi'an, China

Abstract. In recent years, as the heavy equipment airdrop work continues to deepen, Chinese heavy equipment airdrop business has shown a vigorous development trend, and mission training is getting closer and closer to actual combat. From the perspective of task-oriented analysis of safety risks, this paper selects the reloading airdrop mission as the entry point, and conducts research on the safety risk analysis and evaluation methods of reloading airdrop missions. At the same time, it discusses the task-oriented system safety analysis and evaluation methods, in order to carry out other tasks. The task of system security research has laid the foundation[1].

1 Introduction

The research topic of Chinese heavy equipment airdrop began in 1967 and was first proposed by the airborne troops. In recent years, through the step-by-step exploration and hard work of aviation personnel, China has successively conquered many key technologies such as parachute opening technology and traction control technology, and initially established GJB 7789 "Requirements for Heavy Equipment Airdrop Test" and GJB 3280 "Vehicle Artillery" Airdrop Bundling Requirements" and other standards and specifications. These constitute a systematic airdrop equipment system. Chinese newest transportation platform also completed its first airdrop training on May 9, 2018, laying the foundation for further development.

This paper takes the reloading airdrop task as the research object, deeply analyzes the airdrop task process, and combines the SHEL model to carry out the system security analysis for the airdrop task. Based on the results of the questionnaire survey, the fuzzy comprehensive evaluation based on the entropy method is used for safety assessment, and the indicators with higher risks are found. At last, the precautions are given for the conclusions of the fuzzy comprehensive evaluation.

2 Safety risk assessment of reloading airdrop mission

Through the analysis of the safety risk of the airdrop process, it can be found that there are many factors that lead to the failure of the reinstallation airdrop mission[2]. In addition to the four aspects of personnel, hardware, software, and environment analyzed in the SHEL model, the mission itself has problems[3]. Has a certain influence on the completion of the entire task. Based on the objective actual investigation and analysis of the questionnaire, this chapter uses MATLAB software as the calculation method to evaluate the risk of the reloading airdrop mission process through the entropy method and the fuzzy comprehensive evaluation method, and uses the MCE Fuzzy software to simulate the calculation process, aiming at the score situation , Combined with the actual work of the troops, effective prevention and control measures are given.

2.1 Determining factor set

According to the indicator analysis performed by the SHEL model and the indicator screening of the questionnaire survey, the set of evaluation factors is determined as shown in Figure 1:
2.2 Commentaries

In this article, the risk is divided into five levels based on the situation of the reloading airdrop task, which are divided into "V1 risk is extremely high", "V2 risk is very high", "V3 risk is high", "V4 general risk", and "V5 Low risk" represents five different levels of security, then the comment set \( V = \{ \text{V1 is extremely risky}, \text{V2 is very risky}, \text{V3 is relatively risky}, \text{V4 is general risk}, \text{and V5 is low risk} \} \)[4].

2.3 Entropy method to establish index weight

In order to ensure the accuracy and credibility of the weights, this article uses MATLAB software as a calculation method to sort out the answers of 22 experts in the questionnaire and objectively calculate the weights of each indicator. The obtained indicator weights are shown in Table 1.

| First-level index | weight | Second-level index | weight |
|-------------------|--------|--------------------|--------|
| Human factor      | 0.1789 | Number of tasks A1 | 0.4281 |
|                   |        | Professional familiarity A2 | 0.3643 |
|                   |        | Cooperating ability A3 | 0.1255 |
|                   |        | Operation standard degree A4 | 0.0821 |
| Task factor       | 0.2194 | Task organization change B1 | 0.1794 |
|                   |        | Mission plan change B2 | 0.7079 |
|                   |        | Task time is tight B3 | 0.1127 |
|                   |        | Motor crane failure C1 | 0.2776 |
|                   |        | The firmness of the fixture C2 | 0.1875 |
|                   |        | Maintain the flight attitude C3 | 0.0774 |
|                   |        | Rope sail phenomenon C4 | 0.1002 |
|                   |        | Slide rail stuck C5 | 0.1362 |
|                   |        | Closing timer failure C6 | 0.1096 |
|                   |        | Out of lock failure C7 | 0.1011 |
|                   |        | Unit culture construction D1 | 0.4379 |
|                   |        | Implementation of unit regulations D2 | 0.4113 |
|                   |        | Airborne system safety D3 | 0.1507 |
| Hardware factor   | 0.2592 | Discrete gust E1 | 0.1348 |
|                   |        | Strong convection E2 | 0.2017 |
|                   |        | Cloud thickness E3 | 0.3096 |
|                   |        | Alpine coverage rate E4 | 0.3540 |

2.4 Construct fuzzy evaluation matrix

This paper collects data based on the questionnaire in Chapter 3. The fuzzy relationship matrix that can be obtained is as follows:

\[
A = \begin{bmatrix}
0.2679 & 0.3393 & 0.2857 & 0.1071 & 0 \\
0.5000 & 0.3393 & 0.1250 & 0.0357 & 0 \\
0.5000 & 0.3214 & 0.1429 & 0.0357 & 0 \\
0.5000 & 0.3750 & 0.0803 & 0.0179 & 0.0179
\end{bmatrix}
\]

\[
B = \begin{bmatrix}
0.1607 & 0.2321 & 0.3036 & 0.2857 & 0.0179 \\
0.0893 & 0.3750 & 0.1964 & 0.3393 & 0 \\
0.1964 & 0.3571 & 0.3750 & 0.0536 & 0.0179 \\
0.1789 & 0.3393 & 0.2679 & 0.3143 & 0 \\
0.3214 & 0.2679 & 0.3214 & 0.0893 & 0 \\
0.3214 & 0.3929 & 0.1964 & 0.0714 & 0.0179 \\
0.4286 & 0.3214 & 0.2321 & 0.0179 & 0 \\
0.3214 & 0.3909 & 0.1786 & 0.0179 & 0 \\
0.3571 & 0.4107 & 0.1786 & 0.0536 & 0 \\
0.3571 & 0.3393 & 0.2321 & 0.0714 & 0
\end{bmatrix}
\]

\[
C = \begin{bmatrix}
0.3571 & 0.4107 & 0.1786 & 0.0536 & 0 \\
0.3571 & 0.3393 & 0.2321 & 0.0714 & 0
\end{bmatrix}
\]
The fuzzy relationship matrix that can be obtained is as follows:

\[
D = \begin{bmatrix}
0.2321 & 0.3929 & 0.2679 & 0.1071 & 0 \\
0.4107 & 0.3036 & 0.2321 & 0.0536 & 0 \\
0.5000 & 0.3393 & 0.1071 & 0.0357 & 0.0179 \\
0.2982 & 0.4912 & 0.1579 & 0.0175 & 0.0351 \\
0.3509 & 0.3158 & 0.2456 & 0.0877 & 0 \\
0.1053 & 0.2982 & 0.2281 & 0.3333 & 0.0351 \\
0.1930 & 0.3684 & 0.3509 & 0.0877 & 0
\end{bmatrix}
\]

\[
E = \begin{bmatrix}
0.0000 & 0.5000 & 0.3214 & 0.1429 & 0.0357 \\
0.5000 & 0.3393 & 0.1250 & 0.0357 & 0 \\
0.2679 & 0.3393 & 0.2857 & 0.1071 & 0 \\
0.1053 & 0.2982 & 0.2281 & 0.3333 & 0.0351 \\
0.1930 & 0.3684 & 0.3509 & 0.0877 & 0
\end{bmatrix}
\]

2.5 Fuzzy comprehensive evaluation

For personnel, according to the previous text, we have known:

Weight matrix = \[
\begin{bmatrix}
0.4281 & 0.3643 & 0.1255 & 0.0821 \\
0.5000 & 0.3393 & 0.1250 & 0.0357 \\
0.5000 & 0.3214 & 0.1429 & 0.0357 \\
0.5000 & 0.3750 & 0.0803 & 0.0179
\end{bmatrix}
\]

Fuzzy relation matrix:

\[
\begin{bmatrix}
0.2679 & 0.3393 & 0.2857 & 0.1071 & 0 \\
0.5000 & 0.3393 & 0.1250 & 0.0357 & 0 \\
0.5000 & 0.3214 & 0.1429 & 0.0357 & 0 \\
0.5000 & 0.3750 & 0.0803 & 0.0179 & 0
\end{bmatrix}
\]

\[
A = \begin{bmatrix}
0.5000 & 0.3393 & 0.1071 & 0.0357 & 0 \\
0.5000 & 0.3393 & 0.1250 & 0.0357 & 0 \\
0.5000 & 0.3214 & 0.1429 & 0.0357 & 0 \\
0.5000 & 0.3750 & 0.0803 & 0.0179 & 0
\end{bmatrix}
\]

MATLAB software is an advanced technical computing language used for algorithm calculation, data visualization and numerical calculation. Based on its good matrix calculation ability, the fuzzy comprehensive scores of the secondary indicators A1, A2, A3, and A4 are calculated as:

\[
Z = \begin{bmatrix}
3.7680 \\
4.9462 \\
4.9283 \\
4.8049
\end{bmatrix}
\]

The fuzzy comprehensive scores of the secondary indicators A1, A2, A3, and A4 are obtained as: 3.7680, 4.9462, 4.9283, 4.8049. The personnel factor score obtained by Z=X*Y is 4.4280.

In the same way, the risk scores of all secondary indicators and primary indicators are calculated as shown in Table II:

Table II Fuzzy comprehensive score

| Total index          | Score | First-level index       | Score | Second-level index         | Score |
|----------------------|-------|-------------------------|-------|----------------------------|-------|
| Human factor         | 4.4280|                         |       | Number of tasks A1         | 3.7680|
| Task factor          | 3.4232|                         |       | Professional familiarity A2| 4.9462|
|                      |       |                         |       | Cooperating ability A3     | 4.9283|
|                      |       |                         |       | Operation standard degree A4| 4.8049|
|                      |       |                         |       | Task organization change B1| 3.391 |
|                      |       |                         |       | Mission plan change B2     | 3.2143|
|                      |       |                         |       | Task time is tight B3      | 4.7864|
|                      |       |                         |       | Motor crane failure C1      | 3.6840|
|                      |       |                         |       | The firmness of the fixture C2| 3.8214|
|                      |       |                         |       | Maintain the flight attitude C3 | 4.0896|
|                      |       |                         |       | Rope sail phenomenon C4    | 4.4289|
|                      |       |                         |       | Slide rail stuck C5         | 4.0644|
|                      |       |                         |       | Closing timer failure C6    | 4.0713|
|                      |       |                         |       | Out of lock failure C7     | 3.9818|
|                      |       |                         |       | Unit culture construction D1| 3.7500|
|                      |       |                         |       | Implementation of unit regulations D2 | 4.0714|
|                      |       |                         |       | Airborne system safety D3  | 4.2678|
|                      |       |                         |       | Discrete gust E1            | 3.9996|
|                      |       |                         |       | Strong convection E2        | 3.9209|
|                      |       |                         |       | Cloud thickness E3          | 3.1053|
|                      |       |                         |       | Alpine coverage rate E4     | 3.6667|

After the MATLAB calculation is completed, this article uses MCE Fuzzy to simulate the entire state process. The simulation results are roughly the same as the MATLAB calculations. It can be seen that the overall risk of reloading airdrop missions is at a higher risk stage, and relevant effective risk prevention and control must be done. Risk resolution. The simulation situation is shown in table III:

Table III Fuzzy simulation final score map

| Underlying index              | V1 extremely risky | V2 very risky | V3 relatively risky | V4 general risk | V5 low risk |
|-------------------------------|-------------------|---------------|---------------------|----------------|-------------|
| Closing timer failure C6      | 0.3571            | 0.4107        | 0.1786              | 0.0536         | 0           |
| Out of lock failure C7        | 0.3571            | 0.3393        | 0.2321              | 0.0714         | 0           |
| Unit culture construction D1  | 0.2321            | 0.3929        | 0.2679              | 0.1071         | 0           |
| Implementation of unit regulations D2 | 0.4107        | 0.3036        | 0.2321              | 0.0536         | 0           |
| Airborne system safety D3     | 0.5               | 0.3393        | 0.1071              | 0.0357         | 0.0179      |
| Discrete gust E1              | 0.2982            | 0.4912        | 0.1579              | 0.0175         | 0.0351      |
Results & Discussion

Based on the above comprehensive assessment of the reloading airdrop task, it can be seen that the risks of personnel, software, and hardware in the airdrop process are relatively high, and unsafe accidents are prone to occur. According to the score, the risk prevention and control measures for the reloading airdrop task are sorted out as follows:

| Risk factors                              | Precaution                                                                 |
|-------------------------------------------|-----------------------------------------------------------------------------|
| Number of tasks A1                        | Increase the number of training and drills and the degree of simulation     |
| Professional familiarity A2               | The unit arranges more related professional organization training, and hires experts to guide |
| Cooperating ability A3                    | Organize special training for team cooperation ability during training and drills |
| Operation standard degree A4              | Professional technical assessment, related training, wrong setting, forgotten, omission |
| Task organization change B1              | Strengthen the team’s ability to familiarize themselves with ordinary personnel, and organize multiple drills |
| Mission plan change B2                    | Reasonable deployment to ensure safety                                       |
| Task time is tight B3                    | Make preparations in advance to ensure that tasks can be carried out quickly |
| Motor crane failure C1                     | Before the mission starts, check the motorized cranes as planned, and use the cranes reasonably according to regulations |
| The firmness of the fixture C2            | List equipment installation and inspection procedures                      |
| The flight attitude remains unstable C3   | The equipment is fully secured before takeoff                               |
| Rope sail phenomenon C4                   | In the design stage, use reasonable mathematical techniques to predict the occurrence of the rope sail phenomenon |
| Slide rail stuck C5                       | Check the stuck objects in the slide rail on time, and check on time        |
| Closing timer failure C6                  | Check the closing timer setting before taking off                           |
| Out of lock failure C7                    | Check the quality of the landing release lock before the flight             |
| Unit culture construction D1              | Strengthen the construction of team work style, values, team awareness, etc.|
| Implementation of unit regulations D2     | Strict law enforcement, strict implementation, strict regulations            |
| Airborne system safety D3                 | Regularly arrange software testing, and implement evaluations of related software before take-off |
| Discrete gust E1                          | Enhance pilot training in bad weather and avoid dangerous areas before flying |
| Strong convection E2                      | Try to avoid dangerous areas when flying                                    |
| Cloud thickness E3                        | According to the instrument flight, try to avoid thick cloud areas          |
| Alpine coverage rate E4                   | Try to choose a flat area                                                   |

The next step:
1. The depth and breadth of the reloading airdrop mission process profile are greatly lacking. The next step is to comprehensively collect relevant definitions, and pay attention to real-time information and changes in related aspects, so as to have a more in-depth analysis and discussion of the entire mission process.
2. In the evaluation model, the analysis and evaluation of factors are not specific enough. The calculation process of the evaluation method is relatively simple, and more methods should be used to combine the evaluation results to make the evaluation results more comprehensive and credible.
3. This article does not cover many influences on the quality of the cargo platform, the smoothness of the landing ground, and the flight maintenance conditions. When the conditions are unsatisfactory, the evaluation results of this paper will have large errors. How to ensure the accurate evaluation of tasks in actual combat needs further research.

Conclusions

From the perspective of task-oriented analysis of safety risks, this paper selects the reloading airdrop mission as the entry point, and conducts research on the safety risk analysis and evaluation methods of reloading airdrop missions. At the same time, it discusses the task-oriented system safety analysis and evaluation methods, in order to carry out other tasks. The task of system security research has laid the foundation.

Foundation item: National Natural Science Foundation of China (52074309)
The flight attitude remains unstable in the entry point, and the flight maintenance conditions have large errors. How to ensure the cargo platform, the smoothness of the landing ground, and the flight maintenance conditions. To make the evaluation results more comprehensive and accurate, the following factors are not specific enough. The calculation process of factors is greatly lacking. The next step is to pay attention to real-time attention to the mission process profile.

The next step:

1. Strengthen the team's ability to familiarize themselves with ordinary personnel, and organize multiple professional technical assessment, related training, wrong setting, forgotten, omission drills. The equipment is fully secured before takeoff.

2. Enhance pilot training in bad weather and avoid dangerous areas before flying. Make preparations in advance to ensure that tasks can be carried out quickly.

3. Check the stuck objects in the slide rail on time, and check on time. The equipment is properly secured before takeoff.

4. Try to avoid dangerous areas when flying. Before the mission starts, check the motorized cranes as planned, and use the cranes reasonably.

5. The firmness of the fixture C2

6. Discrete gust E1

7. Strong convection E2

8. Out of lock failure C7

9. Motor crane failure C1

10. Alpine coverage rate E4

11. Professional familiarity A2

12. Cooperating ability A3

13. Fuzzy simulation membership ranking diagram

14. Professional technical assessment, related training, wrong setting, forgotten, omission

15. In the design stage, use reasonable mathematical techniques to predict the occurrence of the rope sail phenomenon.

16. The equipment is fully secured before takeoff.

17. Try to avoid dangerous areas when flying. Before the mission starts, check the motorized cranes as planned, and use the cranes reasonably.

18. The unit arranges more related professional organization training, and hires experts to guide.

19. Check the quality of the landing release lock before the flight.

20. Regularly arrange software testing, and implement evaluations of related software before take-off.