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

Xu Jihui[1,a],Zhang Jing[2*,b],Tian Wenjie[3,c],Shi Jiahui[4,d],Liu Tengfei[5,e],Wang Xiaolin[6,f],Chen Yujin[7,g],GuoRui[8,h]

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

[a]changan6018@163.com [b]jj18951011529@163.com
[c]jj18951011529@163.com [d]Sjh415409531@163.com
[e]jj18951011529@163.com [f]jj18951011529@163.com
[g]jj18951011529@163.com [h]supergr010925@163.com

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (http://creativecommons.org/licenses/by/4.0/).

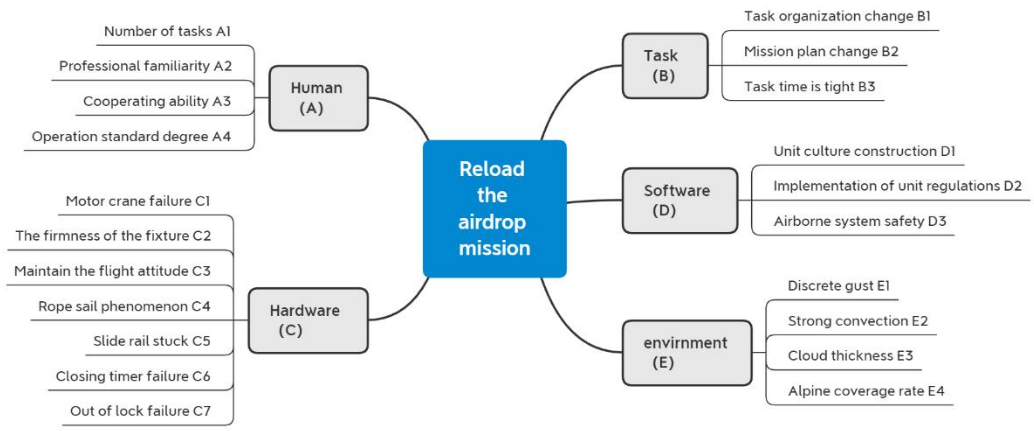

Figure 1 Factor set diagram

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={V1 is extremely risky, V2 is very risky, V3 is relatively risky, V4 is general risk, 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 Ⅰ.

Table Ⅰ Weights of risk indicators for reloading airdrops

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
Hardware factor	0.2592	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	0.1115
Software factor	0.2185	Unit culture construction D1	0.4379
		Implementation of unit regulations D2	0.4113
		Airborne system safety D3	0.1507
envirnmental factor	0.1240	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:

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

$$B=\begin{bmatrix} 0.1607 & 0.2321 & 0.3036 & 0.2857 & 0.0179 \\ 0.0893 & 0.3750 & 0.1964 & 0.3393 & 0 \\ 0.1964 & 0.3571 & 0.3750 & 0.0536 & 0.0179 \end{bmatrix}$$

$$C=\begin{bmatrix} 0.1789 & 0.3393 & 0.2679 & 0.3143 & 0 \\ 0.3214 & 0.2679 & 0.3214 & 0.0893 & 0 \\ 0.3214 & 0.3929 & 0.1964 & 0.0714 & 0.0179 \\ 0.4286 & 0.3214 & 0.2321 & 0.0179 & 0 \\ 0.3214 & 0.3909 & 0.1786 & 0.0179 & 0 \\ 0.3571 & 0.4107 & 0.1786 & 0.0536 & 0 \\ 0.3571 & 0.3393 & 0.2321 & 0.0714 & 0 \end{bmatrix}$$

$$D=\begin{bmatrix}0.2321 & 0.3929 & 0.2679 & 0.1071 & 0\\ 0.4107 & 0.3036 & 0.2321 & 0.0536 & 0\\ 0.5000 & 0.3393 & 0.1071 & 0.0357 & 0.0179\end{bmatrix}$$

$$E=\begin{bmatrix}0.2982 & 0.4912 & 0.1579 & 0.0175 & 0.0351\\ 0.3509 & 0.3158 & 0.2456 & 0.0877 & 0\\ 0.1053 & 0.2982 & 0.2281 & 0.3333 & 0.0351\\ 0.1930 & 0.3684 & 0.3509 & 0.0877 & 0\end{bmatrix}$$

2.5 Fuzzy comprehensive evaluation

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

Weight matrix $=\begin{bmatrix}0.4281 & 0.3643 & 0.1255 & 0.0821\end{bmatrix}$

Fuzzy relation matrix:

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

$$\text{Evaluation scale matrix}=\begin{bmatrix}5\\4\\3\\2\\1\end{bmatrix}$$

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 ： 3.7689、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
Reload the airdrop mission	3.8770	Human factor	4.4280	Number of tasks A1	3.7680
				Professional familiarity A2	4.9462
				Cooperating ability A3	4.9283
				Operation standard degree A4	4.8049
		Task factor	3.4232	Task organization change B1	3.391
				Mission plan change B2	3.2143
				Task time is tight B3	4.7864
		Hardware factor	3.9487	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	4.4829
				Slide rail stuck C5	4.0644
				Closing timer failure C6	4.0713
				Out of lock failure C7	3.9818
		Software factor	3.9598	Unit culture construction D1	3.7500
				Implementation of unit regulations D2	4.0714
				Airborne system safety D3	4.2678
		envirnmental factor	3.5894	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:

TableⅢ 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

Strong convection E2	0.3509	0.3158	0.2456	0.0877	0
Cloud thickness E3	0.1053	0.2982	0.2281	0.3333	0.0351
Alpine coverage rate E4	0.1930	0.3684	0.3509	0.0877	0
Evaluation summary	0.2765	0.3457	0.2321	0.1453	0.0043
Sort	2	1	3	4	5
Comment score	5	4	3	2	1
Final score : 3.7564					

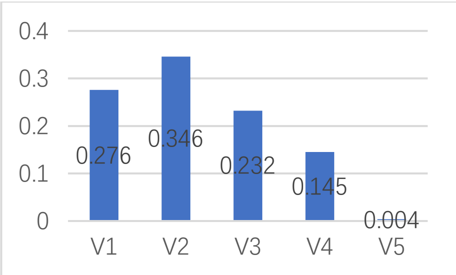

Figure 2 Fuzzy simulation membership ranking diagram

3 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:

TableⅣ Preventive measures

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.

4 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）

References

1. Tang Jianhua.Dynamic simulation calculation of airdrop system for vehicle-mounted gun[D]. Nanjing University of Science and Technology, 2016.
2. Wen Fangfang.Research on Risk Analysis and Evaluation of Real Estate Project Investment [D]. Xi'an University of Architecture and Technology, 2013.
3. Yin Shuyue,Yang Yun.Application of safety standards in military aircraft development [J].Aviation Standardization and Quality, 2010(03): 23-26.
4. Zhang Kangzhi, Li Shengxin. On the dissolution of task-based organizations and personnel [J]. Journal of Gansu Institute of Public Administration, 2007(02): 6-10.Xin Qi,Shi Zhongke.Three-dimensional nonlinear control law design for anti-crosswind anti-crosswind airdrop of transport aircraft at ultra-low altitude and heavy loading[J].Acta Aeronautica Sinica, 2013, 35(7).
5. Gui Bingying.Research on Dynamic Modeling and Control Technology of Heavy Loading Airdrop [D]. Nanjing:Nanjing University of Aeronautics and Astronautics, 2012.
6. Li Chuanlin. Research on the Structural Adaptability Evaluation Method of the Task-Oriented Command Information System [D].Hunan: National University of Defense Technology,2015.GJB 7789, requirements for reloading airdrop test[S].2012.
7. GJB 3280,Binding requirements for airdrop of vehicle artillery[S].1998.
8. GJB 6854, Requirements for the airdrop of airborne equipment[S].2009.
9. GJB 7472,General technical requirements and test methods for airdrop of logistics equipment materials[S].2012.
10. DOC 9859,Safety Management Manual[S].
11. CCAR-145-R3,Civil Aircraft Maintenance Organization Certification Regulations [S].2001.
12. CCAR-25,Airworthiness Standard for Transport Aircraft[S].1995.
13. Quanqing LI ,Yingxuan L,Department S.On Constructing an Air Security System to Solve the Problem of Controlling Complex Terrain[J]. Journal of Chinese People's Armed Police Force Academy, 2016.
14. Dan C.Analysis of Security in CDMA System Air-interface[J].Computer knowledge and technology, 2008.
15. Li S,Liu WD , Liu ZM,et al.Discussion on Multi-dimensional Security System of See-Air-Land in Nuclear Power Plant[C].International Symposium on Software Reliability.Springer,Singapore,2017.
16. Xi-Tao Z,Pei W.Design and simulation of control law for large transport aircraft with heavy cargo continuous airdropping[J].flight dynamics,2013.
17. Xu B.Disturbance Observer-Based Dynamic Surface Control of Transport Aircraft With Continuous Heavy Cargo Airdrop[J].IEEE Transactions on Systems, Man, and Cybernetics: Systems, 2016, 47(1):1-10.