2019 International Conference on Aviation Safety and Information Technology (ICASIT 2019)

Operational Risk Analysis in Flight Monitoring

Xingyu Liu
R & D Center
China Academy of Civil Aviation Science and Technology
Beijing, China
liuxy@mail.castc.org.cn

Weicun Xu*
R & D Center
China Academy of Civil Aviation Science and Technology
Beijing, China
xuwcun@163.com

Jie Yang
R & D Center
China Academy of Civil Aviation Science and Technology
Beijing, China
yangjie@mail.castc.org.cn

Xuhui Wang
R & D Center
China Academy of Civil Aviation Science and Technology
Beijing, China
wxhuii@126.com

***Abstract*—In order to reduce the level of insecurity and prevent major accidents, screening alarm events for each flight is to prevent and control the ground risk of major safety incidents, prevent the occurrence of major accident symptoms, and provide prompt information for immediate disposal through the application of the algorithm. The risk level of an alarm is measured by analyzing how many alarms will be generated after an alarm occurs. For each flight alarm event, we propose a joint flight operation risk analyzing method, which estimates the possibility of flight insecure event according to the number of system alarms during a certain time. According to the one-month alarm statistics of a certain flight by the flight monitoring system, combined with the self-defined flight risk analysis alarm filtering algorithm, timely early warning is successfully issued in low-oil accidents and runway events, providing all the space and time for dealing with events (such as incidents) in order to raise the company's attention to key events.**

Keywords—flight monitoring, operational risk analysis, Flight risk level, Alarm filtering algorithm

I. Introduction

Since August 24, 2010, CAAC has maintained a safety record of nearly nine years. In terms of aviation safety, it is at the world's leading level. Despite this, there have been many unsafe incidents in 2018, including: abnormal emergency down events, landing off-Runway events, transponder-coded alarm events, low-oil events, take-off acceleration and taxiing Tail events, etc. At the time of these incidents, the airline's operational control department was not monitoring or monitoring the severity of the incident, and no proper disposal was made. The essence of building a strong civil aviation country in the new era of our country is high-quality development and zero tolerance of potential safety hazards. Therefore, the purpose of screening alarm events for each flight is to prevent and control the ground risk of major safety incidents, prevent the occurrence of major accident symptoms, and provide prompt information for immediate disposal through the application of the algorithm. The risk level of an alarm is measured by analyzing how many alarms will be generated after an alarm occurs. In order to reduce the level of insecurity and prevent major accidents, for each flight independent alarm event analysis, we propose to carry out joint flight operation risk analysis, and inform the flight number before the occurrence of the insecure flight events.

II. Analysis of Current Flight Alarm Situation

A. International Regulations and Requirements for Flight Monitoring

The ICAO Annex 6, Operation of Aircraft, requires the dispatcher to provide the flight captain with the information required for safe flight in an appropriate manner. And in case of an emergency, the flight dispatcher should also be informed of relevant information. [1]

FAA Order 8900.1 requires dispatchers to monitor the progress of each flight under their control until the plane lands. [2]

The European Federal Aviation Administration (EASA) requires airlines to establish and maintain an aircraft tracking system by December 16, 2018 in its Regulation 965/2012 Amending Flight Recorders, Underwater Positioning Devices and Aircraft Tracking Systems. In this way, the flight with the maximum takeoff weight of more than 27 tons or the number of passenger seats exceeding 19 seats is tracked and monitored from takeoff to landing. [3]

In addition, the Canadian Department of Transportation in the Canadian Aviation Regulations (CAR7-725) requires the dispatch of elements affecting flight operations to be monitored, allowing separation of flight release and operational monitoring functions, as well as provisions for the crew's proactive reporting methods and timing. Its purpose is to find out the abnormal situation of air flights in time through monitoring, and to strengthen air-ground contact to provide better ground support for the aircrew.[4]

B. Current Situation Analysis of Domestic Flight Monitoring System

At present, with the high development of civil aviation industry, the operating environment of airlines is becoming more and more complex. It is necessary for airlines to build an automated information system based on big data application and information technology. Airlines can use operation monitoring systems and programs to automatically obtain flight operation and flight status information in real time, and report and dispose of abnormal situations found. The advantages of multi-data source aircraft communication addressing and reporting system ACARS, broadcast automatic correlation monitoring ADS-B, fourth generation maritime satellite aviation SwiftBroadband SBB, Beidou satellite radio measurement service RDSS, secondary surveillance radar SSR, etc. At present, the ground control department can monitor the operation of air flights. It can realize data-based position monitoring, track monitoring, altitude monitoring, fuel monitoring, weather monitoring, flight dynamic monitoring, abnormal monitoring and monitoring, transponder code monitoring, aircraft fault monitoring, and information delay monitoring. At the same time, the background algorithm can trigger abnormal maneuvering alarm (including emergency descent, hovering wait, return flight alarm, etc.), weather alarm, low fuel alarm, departure from the planned route alarm, forbidden zone alarm, etc. [5] In May 2019, the Civil Aviation Administration of China issued the Advisory notice "Guidelines for the Implementation of Operational Monitoring of Air Carriers" (AC-121-FS-2019-133). According to the requirements of the Advisory notice, companies will establish their own flight operation monitoring system to realize the warning function required in the Advisory Circular. [6]

C. Research and Analysis of Other Scholars

In the aspect of operational risk research, Chen Mingliang and other scholars have proposed the apron operational risk assessment based on safety performance, and assigned the severity value to different types of safety performance indicators. A risk assessment model for apron operation based on safety performance is proposed. [7] Yao Xiaoyan proposed an operational risk assessment algorithm that takes operational risk as the top event of the fault tree and makes qualitative analysis of the fault tree. [8] Wang Yantao and other scholars proposed to perform flight operation risk prediction based on rough set and support vector machine, and built a risk prediction model with support vector machine, and simulated it with MATLAB. [9] Liu Ningmin and other scholars proposed the research on airline operation control risk assessment system based on SHELL model and AHP analytic hierarchy process. [10] However, there is no effective and reliable solution to the problem of early warning of a security incident or accident. There are too many alarms, and the alarm focus is not prominent. It is still a key issue in operational risk research.

III. ALARM FILTERING ALGORITHM FOR FLIGHT RISK ANALYSIS

A. Define the type of alarm event

The first type is the transponder coded alarm, and the second type is other types of alarm. Including time deviation, deviation from planned route, altitude sudden change, circling waiting, overtime not landing, altitude deviation, alternate, failure, 4D15, return voyage, lack of fuel, fuel deviation, sunrise and sunset, low altitude, go-around, forbidden zone alarm, weather alarm, low fuel alarm, interruption of take-off and overweight landing.

B. Define $Types_i$

Define $Types_i$ to denote the number of types of alarms that occur. It is suitable for other types of alarms except Class A. It is used to count the types of alarms that occur. For the types of alarms, see the table below.

TABLE I. CLASSIFICATION OF ALARM EVENTS

category	**type of alarm events**
The first type A	transponder coded alarm-A
the second type B-U	time deviation-B, deviation from planned route-C, altitude sudden change-D, circling waiting-E, overtime not landing-F, altitude deviation-G, alternate-H, failure-I, 4D15-J, return voyage-K, lack of fuel-L, fuel deviation-M, sunrise and sunset-N, low altitude-O, go around-P, forbidden zone alarm-Q, weather alarm-R, low fuel alarm-S, interruption of take-off-T and overweight landing-U

C. Flight risk level

Set the risk value of each flight is Ri, set the flight safety risk assessment level to M, that is, R1, R2,... Rm, m is the greatest risk value. It is assumed that the occurrence of the alarm event A1 causes the occurrence of the alarm event B1 alarm event D1..K1, etc., and these alarm events occur intensively within an event segment. If an alarm is generated after a certain alarm occurs, the greater the risk level of the alarm set, the higher the risk level of the flight.

According to the empirical value, the risk level of the flight is up to the answering machine coded alarm, that is, when 7500, 7600, 7700 occurs. Therefore, when Class A alarm events occur, the flight risk level is the highest, and the system will directly generate flight number alarms that will not disappear automatically unless manually intervened. For alarm events of other categories B-U, the risk value is calculated by the formula of 2.4.

TABLE II. THE RISK VALUE TABLE

category	**the risk value Ri**
The first type A	Rmax
the second type B-U	calculated by the formula of 2.4.

D. Defining the Risk Value Algorithm for Flights

For other events other than Class A alarm events, calculate the flight risk value with a custom formula as follows:

$$R_i = \frac{Times_i}{t_{end,i} - t_{start,i}} \times \partial(Times_i) \times [Types_i - \mu] \quad (1)$$

$Times_i$ indicates the number of times the *i*-th flight has an alarm, $t_{end,i}$ - $t_{start,i}$ indicates the time difference between the last alarm time $t_{end,i}$ and the first alarm time $t_{start,i}$ (in minutes as the minimum unit). $Types_i$ denotes the number of types of alarms, and μ is a constant. In this paper, its value is set to 1 according to experience. $\partial(Times_i)$ is a function, as shown below.

$$\partial(Times_i) = \begin{cases} 1, & if\ (Times_i > 2) \\ 0, & otherwise \end{cases} \quad (2)$$

In the case where R_i is known, the value of the probability P_i of the *i*-th flight that requires special attention can be calculated as:

$$P_i = \begin{cases} 1, & Ri \ge \tau \\ 0, & otherwise \end{cases} \quad (3)$$

Among them, τ is a constant, which is set to 3 according to the empirical value in this paper.

E. In conclusion, the flow chart of flight number alarm logic is summarized as follows.

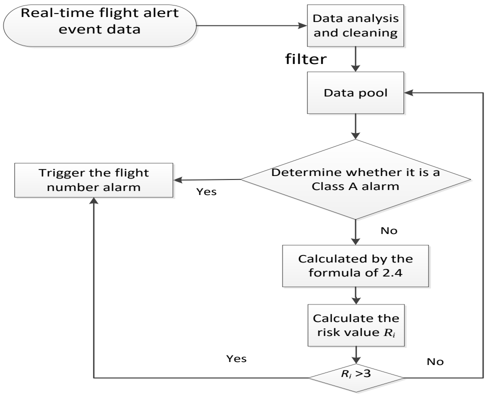

Fig. 1. The flow chart of flight number alarm logic

IV. CALCULATION RESULTS AND ANALYSIS

A. Data preperation and cleaning

An analysis of one month's flight alarms in a division shows that the total number of alerts is 14 033, of which 3 are false alarms and 14 030 are effective ones. According to the statistics of the alarm times of flights, the flight with the highest alarm number has 9 times and at least 1 time, as shown in the following figure.

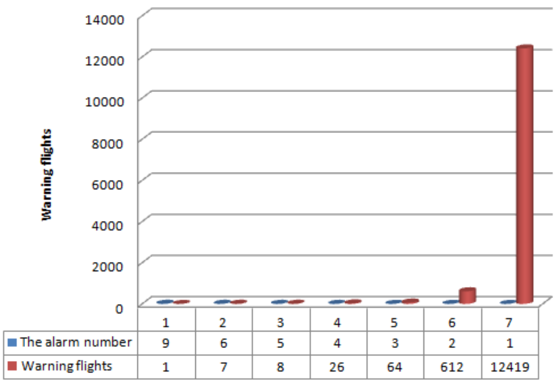

Fig. 2. A statistical table of the number of flights with this warning in a given month

According to the formula definition of flight risk value in this article, τ is a constant, which is set to 3 according to empirical value in this article. That is to say, based on experience, we believe that the 3rd and above alarms are valid flight risk analysis values. According to the flight risk analysis alarm filtering algorithm, except for the A-type alarm, the conditions of the second flight that do not constitute the flight number alarm After the alarm filtering, see the following figure.

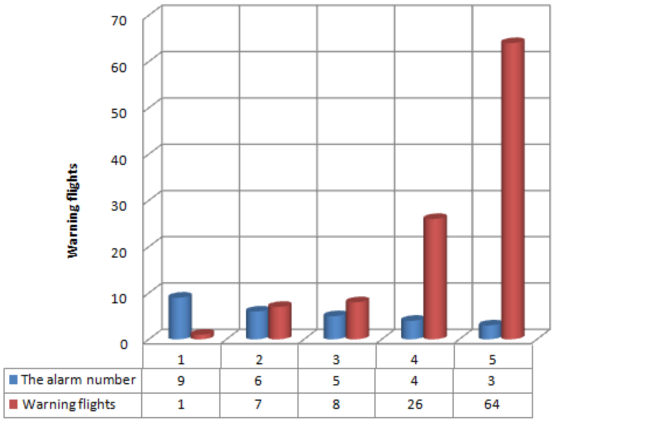

Fig. 3. Statistics of the number of times after flight risk analysis alarm filtering algorithm

B. Calculation process of risk value algorithm

According to the formula of risk value, one month's data of a certain airline is counted. When Ri > 3, the flight number is warned. The result of the flight number data which produces the warning is shown in the following table.

TABLE III. THE PROCESS OF CALCULATING THE RISK VALUE OF A FLIGHT NUMBER WARNING IN A MONTH

count	***Times**$_i$*	$t_{end,i}$ - $t_{start,i}$	***Types**$_i$*	***R**$_i$*
1	9	7	C+D+H	3.29
2	6	1	I	6
3	5	1	I	5
4-13	4	1	I	4
14	3	2	B+E+H	3.5
15	3	1	I	3
16-18	3	1	R	3
19	3	3	B+K+H	3
20	3	1	B+C+H	5
21	3	1	B+H	4
22	3	1	B+E+F	5
23	3	1	C+S+L	5
24	3	3	P+D+H	3
25-27	3	1	I	3

Then, the type of alarm event is analyzed by the type of alarm.

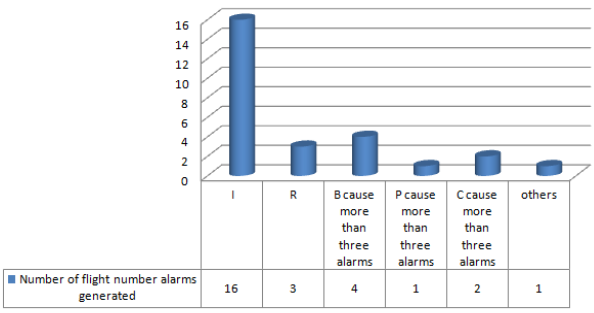

Fig. 4. Number of flight number alarms generated

It can be seen that the algorithm can accurately generate the flight number alarm before the unsafe event occurs, and the alarm time and the alarm amount are considered acceptable. Specifically, when the flight has an aircraft failure, the risk value is high, and a high-level flight number alarm can be quickly generated, so that the flight dispatcher can cooperate with the pilot for disposal. In addition, the weather alarm, the missed flight alarm, the time deviation alarm and the yaw alarm caused more than 3 alarm events also caused the alarm. At the same time the algorithm successfully generated the alarm before the low oil level event and the off-track event, providing the disposal space and opportunity for the safety events such as the accident symptom.

C. Contrast experiment

According to the risk value formula, we counted the data of a certain flight for one month. we also analyzed the event when 2<=Ri<3 the results of flight number data that generated the alarm are shown in the following table.

TABLE IV. CONTRAST EXPERIMENT RESULTS

count	$Times_i$	$t_{end,i}$ - $t_{start,i}$	$Types_i$	R_i
1	5	20	E+F+H	2.25
2	5	13	D+E+P	2.38
3	4	89	B+L+M	2.04
4	4	4	C+H	2
5	4	7	H+P+D	2.57
6	4	8	B+E+F	2.5
7	3	8	E+P+D	2.38
8	3	2	R+F	2.5
9	3	3	H+B	2
10	3	5	B+C+S	2.6
11	3	5	B+C+F	2.6
12	3	13	E+M+F	2.23
13	3	12	H+P+D	2.25
14	3	9	B+S+F	2.33
15	3	9	B+H+C	2.33

From the experimental results of the event when $2<=R_i<3$, in the risk value interval, the flight actually caused more returning and yaw events. This aspect is a normal phenomenon in flight operation. Special reminders and strengthened monitoring are sufficient. Therefore, events of this interval class are defined as system reminders, not mandatory alarm flight numbers.

V. CONCLUSION

Based on the one-month alarm statistics of a flight in the flight monitoring system and combined with the customized flight risk analysis alarm filtering algorithm, this paper proposes that flight risk levels should be divided. The purpose of screening each flight warning event is to prevent and control the occurrence of major safety events on the ground, prevent the occurrence of major accident symptoms, and through the application of algorithms. Successfully issued timely warnings in the event, for example, low-oil incidents and rushing out of the runway event, providing disposal space and timing for incidents such as incidents, providing a basis for increasing the focus of the company's key events.

The follow-up work will also measure the alarm risk level of an alarm by analyzing how many alarm events follow a certain type of alarm event, and find the internal relation and rule of the occurrence of the event. The eigenvalue algorithm of alarm events is further analyzed to provide suggestions for the safe operation of civil aviation flights.

REFERENCES

[1] ICAO Annex6 "Operation of Aircraft"

[2] FAA Order 8900.1 Volume3,Chapter25,Section 2"Operation Control for Air Carriers.

[3] EASA Eu No965"Air Operations"

[4] Canada Car Part7.725"Transport Flight Surveillance"

[5] LIU Xingyu，YANG Jie, LIU Kun, LIU Hong, "The Al-based global flight monitoring system"China Civil Aviation,2018,10(01):33-35.

[6] CAAC Advisory notice "Guidelines for the Implementation of Operational Monitoring of Air Carriers" (AC-121-FS-2019-133)

[7] CHEN Mingliang,ZHANG Yuan,CHEN Yanqiu,"Apron Operation Risk Assessment Based on Safety Performance,"[J] Journal of civil aviation, 2018,2(6):90-94.

[8] YAO Xiaoyan,"Operational Risk Assessment of Tubular Heating Furnace Based on Fault Tree,"[J] Total Corrosion Control, 2017,31(5):15-19.

[9] WANG Yantao, TANG Jianxun, ZHAO Yifei,"Prediction of risks in flight operations based on rough sets and support vector machine,"[J] China Safety Science Journal, 2017,27(09):158-163

[10] LIU Ningmin,LIU Kun,YANG Jie,"Research on Safety Risk Assessment of Airline Operation Control."[J] Journal of civil aviation, 2017,1(1):55-57,20.