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EVALUATION PROBABILITY OF INGOING FACTOR IN THE EMERGENCY SITUATIONS OF AIRCRAFT

Introduction

For the implementation in practice of aircraft safety control framework must:

- have objective information about the factors resulting in the emergence and development of specific situations;
- implement risk prediction factors and give them a quantitative assessment [1] – [3];
- have methodology for evaluating the effectiveness of measures;
- have method of development and optimal planning of measures to improve safety.

This paper defines the evaluation of the probability of factor risk assessment factor, the classification techniques that can evaluate lack of response to these factors in flight and the structure of the model risk assessments for various reasons (factors).

In the literature review on risk factors for accidents and frequency analysis of accident-related factors in databases provided by the ADREP, SKYbrary and EUROCONTROL gives the results of published studies regarding risks for accidents are presented only as a listing of information. The conclusions to be drawn from this are performed in the discussion by taking also the results from the database analyses into account. The analyses of the databases are presented in the form of tables presenting frequencies of the different types of factors. Especially when looking at the database evaluation results it can be seen, that factors stemming from a very detailed component and level combination are found in low frequencies. Databases of low grade of detail provide higher frequencies for single factors.

Aviation accidents are the accidents and events related to the complete destruction of the aircraft without the possibility to recover and further exploitation.

Factors that were in the aviation events form the basis of a causal structure that reflects the evolution of aviation events.

Under factor refers to any condition, a phenomenon that fact wrong actions or inactions of pilots, aircraft failure or ground equipment, which is found in connection with aviation event [4]–[5].

Under threat will mean the likelihood of a particular factor in catastrophic situations. Given the nature of the information that accumulates statistics, it usually refers not to specific situations and to aviation accidents in the future under threat implied probability of a factor in aviation accidents.

The problem of safety is reduced effectively hazards reflection.

The task of quantifying risk factors thus reduced to the evaluation of risks factors that occur in aviation events.

State of the art and background

Previous concept provides a method of regarding human functional failure generated by certain scenarios as accident causation process [19]. In the operational, all factors –independent of their origin or role within the accident causation process – are analyzed both by literature review on their contribution to an increase of risk or their share in causal contribution to the accident occurrence and by database analysis on their frequency of occurrence in the databases provided by the ADREP, ICAO, FAA, EASA. It is found that causes for accidents are coded and explained differently, thus first it is tried to develop an accident causation model based on factors.

The 1928 N.A.C.A. report goes on to present a methodology for analysing "two or more distinct causes and makes possible, by the use of percentages, the indication of the relative weight of each cause in any particular accident." The report does not define these causes and the subsequent reports delete this section. Most modern investigatory techniques do not attempt to quantify the weight or importance of particular causal factors. Organizations such as the National Transportation Safety Board (NTSB) and Canadian Transportation Safety Board (TSB) will distinguish between causes and contributory factors but percentages are not used.

Theoretical issues, definitions and classifications by NASA Langley Research Center, U.S.A. Accident-related factors are defined as all imaginable entities that contribute to the accident occurrence. These factors can be material things, but also circumstances, situations, events, maneuvers, ideas, attitudes, states, and conditions. They contribute to an accident in the sense that if they had not been present, the accident would not have happened. Usually they are found by investigators and in-depth accident analysis. The idea is to apply a causal contribution to these factors on a single accident level. In accident databases they are collected and by database analysis frequencies on how often the factors are found in the accident samples can be derived. The cause for an accident is seen as a combination of co-occurring accident-related factors. Accident causation models are often based on the idea that certain background circumstances provide the platform for certain interactions, where accidents can happen. Environmental, societal, economical, educational, political and other background conditions influence the flyway system, the time, and the crew. The actual conditions are interacting before the occurrence or non-occurrence of an accident.

An objective assessment of the problems preventing hazards and minimizing their consequences is one of the basic categories of aircraft safety [1], [2]. In-depth analysis of the problem preventing hazards and minimize their effects necessitates assessment of the probability of occurrence of hazards [3].

The probability of ingoing of a factor in aviation accidents

To evaluate and predict risk factors should have available the probability of occurrence of a factor in aviation accidents.

$$P_{ijt} = \frac{n_{ijt}}{N_t}$$

where P_{ijt} – the probability of the i-th factor in the j-th aviation events in the t-th time interval;

n_{ijt} – number of incidents of this factor;

N_t – number of flights performed by aircraft for the time period.

The tables that represent Automated Information Retrieval System (AIRS), you can get the number of occurrences of specific factors n_{ijt} and the number of flights N_t – over a given time interval. This information is output to assess risk factors [4].

Based on the definition of risk factor, as the likelihood of its occurrence in a catastrophic situation, we obtain:

$$P_i = \frac{n_i}{N} P_{np} ,$$

where P_i – quantitative value of risk factor;

n_i – manifestations of this factor over a fixed time interval;

N – number of flights during this period;

P_{np} – probability of non-prevention factor's action in flight.

Determination of the potential factor is determined directly in the processing of information obtained from AIRS [5].

As a result, we have factors that met separately or as several combinations lead to incidents or serious incidents. A dangerous combination of these factors lead to the aviation accident.

The method of sorting the hypotheses based on the use of full probability formula. For the 1st phase of flight probability of a successful outcome flight determined according to the formula:

$$P_{SF}^{(1)}(t) = Pk^{(1)}(A_0) + \sum_{i=1}^{N} P_i(A_i) + \sum_{i+jk}^{(C_N)^K} P_{i.j}^{(1)} + \ldots + \sum_{i+j}^{(C_N{}^K)} P_{i.j}^{(1)}(A_2) + \ldots + \sum_{i+j+N}^{(C_N)} P_{i.j\ldots N}^{(1)}(A_N)$$

where $P(A_0)$ – the probability that the flight will not appear any adverse factor.

$P_i(A_i)$, $P_{i.j}(A_2)$ – the probability that during the flight will be one unfavorable factor and the result will be successful flight, two factors etc.

$C_N^{\ K}$ – number of terms in the sum.

Suppose that:

$$P^{(1)}(A_0) = P_1 P_2 \ldots P_N \ ;$$
$$P_1^{(1)}(A_1) = \sum_N P_1 \cdot P_2 \cdot \ldots \cdot P_{i-1} \cdot q_i \cdot r_i \cdot P_{i+1} \cdot \ldots \cdot P_N \ ;$$
$$P_{ij\ldots N}(A_N) = q_1 r_1 q_2 r_2 q_3 r_3 \ldots q_N r_N \ .$$

Object modeling is a system of contacts between failures of aircraft and aviation personnel erroneous actions. Exploring together data about wrongdoing personnel and their implications for different types of events, you can get an idea of object modeling in general in the form of a mathematical model.

Structure model risk assessments for various reasons/factors

The problem of safety is reduced virtually to combat risk (reflectance danger). Since the dynamics of specific situations [4] we see that the catastrophic situation arises, as a rule, not immediately, but as a result of complications flight conditions in a difficult situation with a subsequent shift in emergency and disastrous. Risk factors that were in the disastrous situation in varying degrees are shown in complication flight conditions, and complex emergency situations.

The task of quantitative evaluation risk of factors thus reduced to the evaluation of hazards that occur in an aircraft accident. Danger various factors differs. These differences arise as to the frequency of occurrence of different factors, with different probabilities of their reflection in the flight crew.

In the mathematical formulation of the problem of determining risk factors can be formulated as a set of functional dependency level of safety on the factors specified in Automated Information Retrieval System AIRS ADREP, International Civil Aviation Organization (ICAO).

From the analysis of safety implies the following:

– level of safety defined as the probability that the flight does not appear catastrophic situation:

$$\eta = 1 - P_{CS} ,$$

where: η – level of flights safety(LFS),

P_{CS} – likelihood of appearance catastrophic situations in flight.

– catastrophic situation with a high probability go into a disaster, so we assume

$$P_{CS} \cong \frac{n_k}{N},$$

where: n_k – number of accidents, N – number of flights.

Take $P_{CS} \cong P_K$, where P_K – probability of disaster.

Problem of determining risk of various factors presented in the form of dependence:

$$P_K = f(\varphi_1, \varphi_2, \ldots, \varphi_i, \ldots, \varphi_m), \quad (1)$$

where: $\varphi_1, \varphi_2, \ldots, \varphi_i, \ldots, \varphi_m$ – adverse factors affecting on flight safety.

Establishment of functional dependence (1) combined with two key fundamental challenges:

- number of factors m in ADREP very large. There is no reliable mathematical apparatus suitable for direct formalization of functional dependence for a large number of variables;
- the nature of different factors so diverse and complex that it is not possible installation deterministic dependencies for most factors.

To establish the functional dependencies of type (1) in an aircraft accident that occurred in the operation of aircraft, use the model shown in Fig. 1.

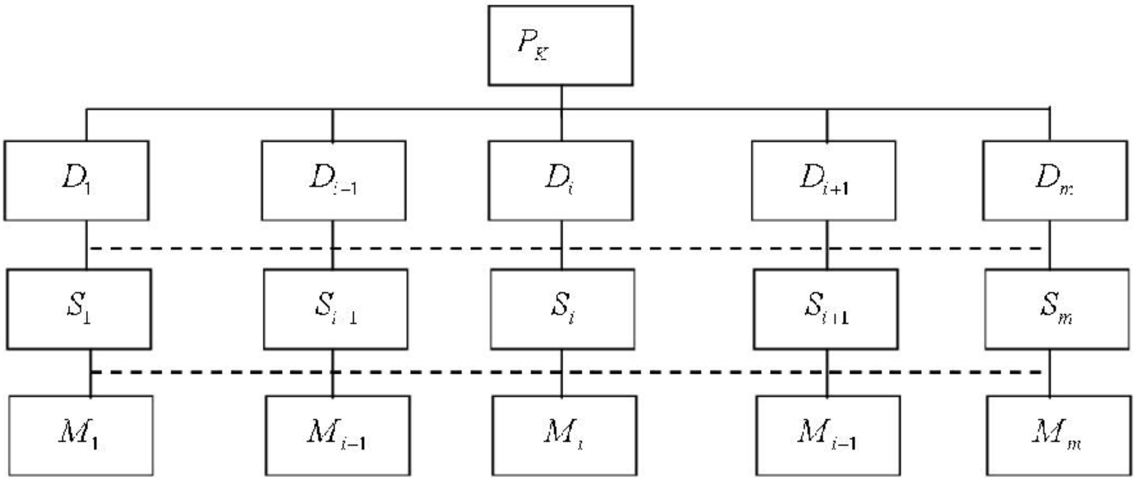

Fig. 1.

The upper level is probability of disaster *Pк*. At the level D consider incidents with complete destruction of the aircraft, due to factors at this level.

Each item of level D, in turn unites with the elements of the next level S. At the level S consider additional events associated with significant damage aircraft. At the next level M consider all aviation events, and each element level M the structure associate with multiple level elements S. Level *Pк* considered upper level, level M – lower.

Structural relations between two adjacent levels set in such a way that expression synthesis factor upper level is uniquely determined by low-level factors associated with it.

Ramification factors in the structure comes from the upper level to the lower. A number of factors at all intermediate levels determined on the basis of establishing logical connections.

Quantitative dependence in the model structure, assessment of hazards

To establish quantitative relationships probability of disaster from the factor structure element model assessment of hazards must add quantitative values. By analogy with the probability of disaster:

$$P_{CS} \cong \frac{n_k}{N}.$$

You can display quantitative values of other model elements. Given the dynamics of the transition from simpler to more complex situations in flight, to determine the elements of the model, you can use formulas that call the parameters of the model.

For level, which takes into account the hard type of incident that depends on three flight factors can write equation:

$$\frac{n_{D1}}{N}, D_2 = \frac{n_{D2}}{N}, D_3 = \frac{n_{D3}}{N}, \tag{2}$$

where: n_{D1}, n_{D2}, n_{D3} – respectively the number of accidents in which there were errors in the work crew, failure systems, errors in organization of flights.

Dependence of (2) in general form can be represented as dependence 3.

$$D_i = \frac{n_{Di}}{N}, \tag{3}$$

where: n_{Di}. –number of hard type incidents on *i*-th factor.

Similarly, we can write (4) for the level S :

$$S_i = \frac{n_{Si}}{N} + \frac{n_{Di}}{N}, \tag{4}$$

where: S_i–parameters of level S;

$\frac{n_{Si}}{N}$ – number of serious damages aircraft on *i*-th factor.

Respectively (5) for level M

$$M_i = \frac{n_{Mi}}{N} + \frac{n_{Si}}{N} + \frac{n_{Di}}{N}, \quad (5)$$

where: n_{Mi} – number of incidents, that occurred on *i*-th factor.

If we establish functional links between the elements of any two levels, then making the substitution, we can obtain the dependence of any top-level from any lower.

To get functional dependence between any two levels we will introduce the typical connection between these levels as shown in Fig. 3.

In Fig. 2 one top level element $\propto_j$ defined by m elements of the lower level. In the construction of structure event associated with the element $\propto_j$, can occur only as a result of the events of a different level associated with elements of type $\beta_i (i = 1, 2, \ldots, m)$. In accordance with the structure shown in Fig. 2 must be installed dependence form:

$$\propto_j = \propto_j (\beta_1, \beta_2, \ldots, \beta_i, \ldots, \beta_m). \quad (6)$$

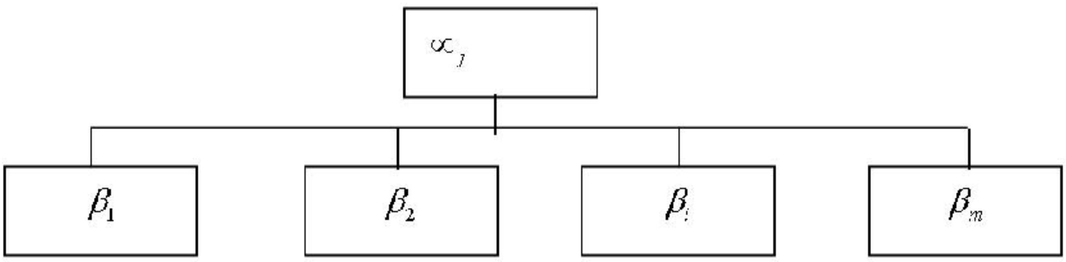

Fig. 2. Fragment of the model structure

Considering that the parameter at the level can be decomposed into components parameters β_i (Fig. 3.)

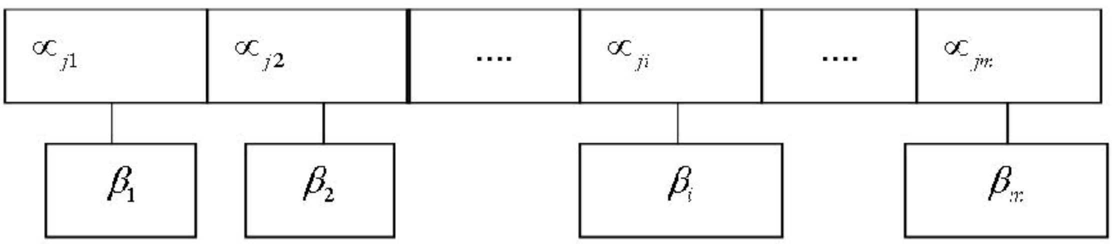

Fig. 3.

Defining dependence (6) for all substructures general model structure, respectively can be obtained:

$$\begin{aligned} P_k &= P_k(D_i), \\ D_i &= D_i(S_i), \\ S_i &= S_i(M_i) \end{aligned} \quad (7)$$

With completing the substitution of depending on (8) we can be obtained within the structure of the model of functional links:

$$P_k = f_1(D_i), \tag{8}$$

$$P_k = f_2(S_i), \quad P_k = f_3(M_i), \tag{9}$$

$$D_i = f_4(S_i), \quad D_i = f_5(M_i), \tag{10}$$

$$S_i = f_6(M_i). \tag{11}$$

Dependences (8) – (11) enable us to establish quantitative links in structure of risk within the concentrated factors D_1, $D_2 D_3$ manifested in various incidents, risk factors of breakdowns, breakdowns dependence on factors that were in the incidents.

Of all the dependencies of most interest from a position of control is dependence $P_k = f_3(M_i)$, that in more expanded form can be represented as (12):

$$P_k = f_3(M_1, M_2, \ldots, M_i, \ldots, M_m). \tag{12}$$

We can determine the value by the formula (13)

$$\alpha_i = K_{\beta_i} \beta_i, \tag{13}$$

where $K_{\beta_i} = \mathrm{tg}\gamma$.

Moving by the structure into up and getting value K_D, K_S, K_M for each of the parameters, we obtain the dependence of the probability of disaster i-th factor:

$$P_{ki} = K_D K_S K_M M_I. \tag{14}$$

Denoting

$K_i = K_{Di} K_{Si} K_{Mi}$

we can write the dependence (14) in a more compact form

$$P_{ki} = K_i \frac{n_i}{N}. \tag{15}$$

Dependence (15) shows that the risk of the *i*-th depends on the frequency of occurrence of this factor n_i. In aviation events and from the coefficient K_i, that assesses the probability of practical not reflecting *i*-th factors in flight.

To obtain the functional dependence of the form (11), by calculating all values n_i taking into account the linear dependences and using the method of superposition, dependence (12) can be represented in the form (16):

$$P = \sum_i P_{ki} P = \sum_i K_i \frac{n_i}{N}, \tag{16}$$

where P – total risk of all factors

K_i – danger of a single appearance of i-th factor.

To obtain quantitative dependencies in the model risk assessments every element of the model must be labeled according to the subsystem level model structure.

Elements of level D have one index. Index 1 is designated subsystem crew Index 2 – failure systems and 3 – index for organization of flight.

Risk assessment is necessary to prevent aviation accidents (development of recommendations to improve the level of flight safety and development of actions to eliminate the hazards), thus can happen that in the process of determining the hazards potential danger has lead to aviation accidents. To avoid this it is necessary to predict the risk of the next period. Prediction must succumb as values D_i, S_i, M_i, and coefficients K_{Di}, K_{Si}, K_{Mi}. Considering the fact that the for prediction of parameters and coefficients used similar mathematical apparatus, we can take the prediction like conditional parameter β, applying the approximation method tabular given function with subsequent extrapolation function in the forecast period.

Conclusions

This paper defines the evaluation of the probability of factor risk assessment factor. In the paper the classification techniques that can evaluate not removal of hazards. In the article the structure of the model risk assessments for various factors. Also the concept of risk is formulated, the numerical value of which is determined by the probability of occurrence of a factor in catastrophic situations.

The classification methods and distribution system impacts on emergency situations can be used to develop classifiers emergencies, monitoring and prevention of aircraft accidents.

The concept of danger, numerical value of which is determined by the probability of occurrence of a factor in the disastrous situation was formulated in this paper.

Also there is the mathematical model (which suggested in this paper) of estimation risk factors with using information of aviation events in the world statistics provided in the ADREP.

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