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MODEL OF MONITORING FLIGHT SAFETY CONDITION ON THE BASIS OF EVALUATION OF RISK LEVEL

Summary of the promotional work

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PROMOTION WORK
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The defence of the promotional work will be delivered……….2011 in Riga Technical University to the address: 1B, Lomonosova Street, Room B-III, Riga, Latvia.

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CONFIRMATION

I confirm that I have independently worked out this promotion work for defence at Riga Technical University for being conferred the degree of Doctor of Science in Engineering. The promotion work has not been presented to any other university to obtaining the scientific degree.

Igor Petukhov ……………………………..

Date : …………………………….

The promotional work is written in Latvian. It contains ____chapters, conclusion, bibliography, appendices,____illustrations,___pages and ____reference titles.

1. PROBLEM ACTUALITY

<u>The theme actuality</u> promotional work on the chosen subject assumes the decision of one of the actual objectives on flight safety (FS) management monitoring condition of aircraft in civil aviation.

According to ICAO Annex 6, Part 1.Since 1st January 2009, exploiter is obliged to install flight safety control system, which, at least:

- Defines risks for safety of flights;
- Provides corrective amendments;
- Provides monitoring and regular evaluation;
- Makes the aim to increase flight safety level.

Providing of civil aircraft flight safety is the difficult task, successful decision of which in many aspects depends on the available enterprise arsenal of technical means and ability to use the advanced scientific achievements in the field of complicated management systems, but not the only problem to analyse special situations. The important link in flight safety management system is the control of piloting eguipment and work technology of flight crews. It is caused by the appropriate control of flight crew actions during flight; there becomes possibility for efficient quality control of crew work, in particular, prevention of tendency to repeat the same errors during the flight.

Researches of the massive development and flow of aviation accidents (AA) and incidents have shown that probability of frequent failures of aviation techniques (AT) in flight four times exceeds freguency of errors made by flight crews, however, frequency from transition of incidents (special situations) in a catastrophic situation is four times more often, because of flight crews errors, rather than because of AT failures. The ***main*** reasons of the catastrophic situations, accidents, failures and incidents connected with collision of the serviceable aircraft with ground in the controlled flight, as a rule, follow from infringements of flight rules and lacks of professional work of the aviation personnel at all hierarchical levels in an aviation transport system. This problem becomes so obvious and critical that airlines (aircraft exploiters) of all countries, professional aviation associations and societies have actively started to solve it. Recently the International Flight Safety Fund and ICAO, have concentrated their efforts to solve this problem, in this case some changes in appendices 6, 11, 14 have been made to the Chicago convention.

Various approaches of the problems decision are available in R.Sakach, V.Zubkov, V.Shestakov's publication, etc. in which methods of FS level evaluation are offered, based on the system approach to investigate a FS management problem and include a number of successive stages. Basically, at the first stage admissible FS levels which trace in the subsequent aircraft maintenance are appointed. The problem of event revealing because of which there happened deviations from the present levels of safety, lays down further on supervising structures of airlines. The second stage includes definition of methods on prevention revealed events repeating, however this stage frequently is to develop requirements for flight crew professional skill improvement. However, many questions are still less investigated and they are not connected in the whole system, e.g. methods of quantitative evaluation of adverse factors risk rate in flight, evaluation of insignificant influence deviations on FS level, evaluation of adverse events risk level from showing adverse factors in flight. That allows to develop preventive actions in proper time and directly, for example: introduction new techniques or improving obsolete techniques, training some action under certain conditions, etc.

Therefore the primary goal of air transport FS management is to work out some measures to prevent the existing tendency leading to distress situations in civil aviation by creating the constantly operating control FS monitoring system. It should be based on the principles involved in international quality standards ISO-9000 and SAFETY MANAGEMENT SYSTEM (SMS) ICAO, first of all on the process approach to activity of an aviation enterprise. Such system should have an arsenal of the technical and economic analysis means and use all the scientific achievements in the field of goal management in the complicated systems for FS providing..

It also defines an actuality of the investigated theme.

2. PURPOSES AND RESEARCH OBJECTIVES

The purpose

The purpose of promotional work is to develop:

- Theoretical and methodological positions of the new approach concerning questions of the flight safety which are based on controlling risks from influence of adverse factors in flight;
- Methods of quantitative risk evaluation.

To achieve the raised purpose at work the analysis is carried out:

- The international, national and internal standard basis concerning flight safety;

- Traditional methods of the flight safety management in civil aviation;
- Providing exploiters with information about deviations in their activities, first of all the results of the flight information processing in airlines, as a basic source of information;
- The approach of different airlines concerning questions flight safety (FS) management level.

<u>The following objectives are solved:</u>

- The new approach to FS management level in an airline, based on the principles involved in the international quality standards ISO-9000 and ICAO SAFETY MANAGEMENT SYSTEM (SMS) is offered;
- The risk evaluation model in the initial flight in the cases of adverse factors influence is developed;
- The technique of adverse events ranging in aircraft with the use of expert evaluation methods is developed.
- Ranging of adverse events in flight showing the encountered adverse factors is spent;
- The method of quantitative risk evaluation for FS monitoring purpose while developing control system FS level on the basis of risk level evaluation.
- Ranging of risk level passed in civil aviation of Russia for a period of 1995-2006 allows to develop preventive actions: introducing new or improving obsolete techniques and training concerning actions under certain conditions, etc.;

3. THEORETICAL BASIS AND RESEARCH METHODS

- The theoretical basis of thesis research is based on V.Shestakov's, E.Barzilovich, B.Zhulev, B.Zubkov, E.Kuklev, A.Guzij, S.Ljulko, A.Voronovich, B.Smolnikov, R.Sakach, J.Chinjuchin, G.Malinetsky, B. Nartov, K.Glasser, J. Klinekt research publications. The methodical basis of work is risk rate evaluation, the theory of expert evaluation, algorithms of database creation, the system approach to investigate complicated systems.

<u>Object of research</u>:

The process of FS monitoring on the basis of risk rate definition clearing out adverse factors in flight and possible consequences of their influence.The subject for research is the following: questions of monitoring, calculation and analysis and quantitative risk evaluation from adverse factors in flight, including errors in the technique of piloting.

4. SCIENTIFIC INNOVATION

Scientific innovation of work consists of the following:

1. Theoretical and methodological positions of the new approach in the questions of providing FS based on risk control from influence of adverse factors in flight;
2. Methods of quantitative risk evaluation for receiving their integrated estimates with a purpose of FS control.

5. PRACTICAL IMPORTANCE

The developed methods of risk evaluation during flights allow:

1. To receive quantitative evaluation of adverse factors risks happening in flight.
2. To evaluate and co-ordinate crew activity in aviation enterprises taking into account requirements to appoint the reasonable FS levels;
3. To define the tendency of negative situations development, and also to define probability of adverse events transition into an aviation incident;
4. To carry out FS monitoring at any level (crew - flight division-airline-alliance of airlines);

THE WORK STRUCTURE AND CONTENT

In introduction the urgency of the research theme is proved, the main objective and the corresponding problem which is subject to the decision are formulated, the object, subject and research methods are defined, the scientific innovation and practical importance of promotional work are characterised.

In chapter 1 ICAO recommendations and requirements of the airworthiness regulations concerning questions of FS management are considered. It is shown that at present the crew control activity in flight is reduced to the analysis and statistics processing on aviation accidents and incidents. During the research the low level of efficiency in data use analysis because of lack of possible risk rate evaluation of flight crew errors in flight is noted.

Using chapter 1 analysis, the summary is the following: the nature of flight crews errors in flight is poorly studied, but the accepted non-system numerous preventive measures are not effective enough. Therefore, means of aircraft accident prevention because of flight crew errors are not found yet. One of main reasons of the revealed tendency is the wrong approach of airline authorities to solve the noted problem. Spending a lot of time resource for solving the revealed errors, airline experts of flight complex are not able to evaluate risk rate which allows:

- To define potentially dangerous situations;
- To evaluate probability of danger occurrence;
- To choose alternative decisions for reducing risk rate;
- To evaluate efficiency of the corresponding decision.

Therefore, for flight safety management level it is necessary to develop new approaches for effective work of flight services according to risk rate of the adverse factors put in the ACS which would allow to consider, to store, to analyse the necessary filed data and to work with all hierarchical levels of events, by means of algorithm.

The second chapter is devoted to question of applying a theory of risks for a flight safety management level and considering aviation enterprises approach to a question of evaluation of risk rate of events for the purpose of flight safety management.

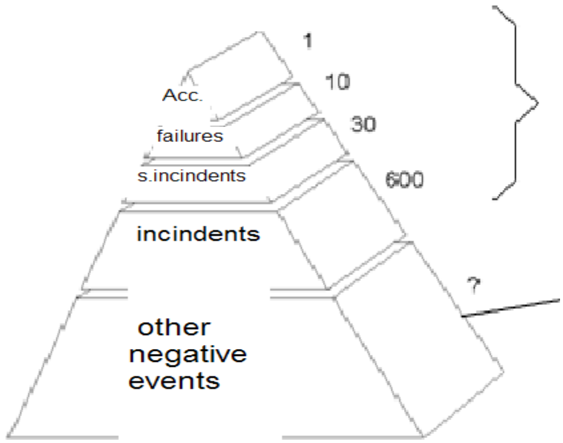
The proposed approach corresponds to ICAO requirements involved in «Safety Management Manual (SMM) », that is «introduction of the concept *of comprehensible level of flight safety* requires (in addition to the existing principles of safety providing standard requirements) to use the approach, based on safety indicators. The comprehensible flight safety level reflects those purposes (or the expected results) of the supervising authorities the exploiter or the supplier of service which should be reached in the field of safety. From this point of view the relations between the supervising authorities, exploiters/suppliers of service this concept establishes the definite purpose in the field of safety which exploiters/suppliers of service should reach while performing the basic production functions as a minimum level applicable for supervising authorities. The specified level is the standard in comparison with which the supervising authorities can evaluate the results in flight safety sphere. Defining the comprehensible flight safety level it is necessary to consider such factors, as an existing risk level, costs/benefits from system improving and society expectation concerning the safety in aviation industry».

In this chapter the analysis of existing methods of flight safety management level is carried out. For example, in the aviation enterprise "A", for many years, the quality of flight crew work is evaluated according to «Specifications of evaluation of flight performance quality». The quality evaluation of flight crew work is made on the basis of decoding results by means of the objective control, the information received from the ATC controllers and pilots-inspectors. Depending on the received evaluation the experts of a flight complex make decision to prolong flight licensing of a flight crew. The basic advantage of the given method is the system approach to quality check of flight crew work which allows to control a flight crew member separately, thereby, checking the professional level. Application of the considered method by experts of the flight complex "A" allows to achieve the essential increase of a flight safety level in an aviation enterprise. To the basic advantages of the chosen strategy it is possible to carry out the control over crew actions at every separate stage of flight. However, despite all advantages of the presented method, it also possesses one serious lack which says, that along with revealing of quantitative evaluation of flight crew work quality, experts of flight complexes do not consider probability of event occurrence, both the most dangerous, and not representing the obvious danger. That is, in the system of providing flight safety based on application of the considered methods, airlines make only the general analysis of occurrence probability of this or that event which does not give possibility to define the basic directions for work with a flight crew.

The advantage of technology of flight safety level management offered by the group of experts in the aviation enterprise "B" is the transition to evaluation of danger rate of adverse factors depending on quantity of incidents. In a method basis the following formula is made:

$$\Delta Nnorm.min = <\Delta Nfact = <\Delta Nnorm.max \tag{1}$$

The main principle, in monitoring providence of flight safety level in the aviation enterprise "B", says, that experts have reached the new level of dangerous events evaluation in flight. In other words, flight safety level in an airline is evaluated concerning adverse events of heavy level. Constantly reducing quantity of incidents, experts achieve a decrease in aviation incidents. The main lack of flight safety management of the considered methods is the support on events of “heavy level” (aviation accidents, incidents) while analysing the risk level and calculating adverse factors in flight, as well as roughness and nearness in risk level definition. Therefore, for minimisation of these lacks, the author suggests to analyse not only the dangerous cases and deviations, but also «other negative events» fig. 1.



Information source:
Materials of the state commission's investigation

Information sources:
- Materials of the objective flight control
- Materials of the subjective flight control (the instructor, observer LOSA, etc.)
- Materials of internal office investigations
- Data of their voluntary messages about flight safety

Figure1. Pyramid of negative events (the Rule 1:10:30:600)

We start from ICAO recommendations, «Other negative events», being less essential cases of safety threat, but they can be, nevertheless, harbingers of the latent problems with flight safety providing (ignoring such latent sources of safety threat can promote an increase of a number of more serious incidents). Repetitive events are above all others, making information about them rather attractive for the use of statistics evaluation.

The basic difficulty of the present method consists of weight factor definition of a negative event, because of inequality. Therefore, the purpose of the work is the system development of quantitative evaluation of weight factor of a negative event, on the basis of the theory of risk rate evaluation.

In the third chapter the research applying possibility of the expert theory evaluation with the purpose of flight safety management has been conducted, and also the existing method is considered according to influence of the AT reliability and crew training concerning flight safety.

Further possibility of evaluation of flight safety level in civil aviation with the usage of a risk concept is considered. Thus we recognise that the unification of flight safety theory position within the limits of risk for the present ICAO models is not achieved because of the following reasons:

- There is an ambiguity of risk concepts and models depending on a scope of risk models (the finance, ecology, engineering, etc.). Features in a sphere of activity are wrongly assumed as a basis of forming the new model of risk.
- From common positions of mathematical formalisation of natural phenomena and the theory of casual processes it is obviously possible to be limited, as it is given below, only two models or formulas of risk depending on rate of accident or uncertainty of the studied

phenomena. Moreover, it is possible to assert that within the limits of the general approach there are no special problems with definition of risk and evaluation of safety level of systems on the basis of risk in some areas of various systems interactivity.

- Formal distribution of the reliability theory methods on the sphere of danger evaluation of the phenomena arising due to systems failures, does not give satisfactory results and an unambiguous answer on a question about the reasons of occurrence of accidents as rare improbable events.

Each airline, which experts have already started risk researches, defines the most prior «risk zones» for their research and maintaining them at the present level. The most remarkable, the author considers methodology offered by the head of flight safety sector of the American air carrier «Northwest Airlines», Krissom Glasserom whose idea is that experts of airline focus the attention as to the most repeating events, either to the events averaged on hard consequence and repeatability. The given approach once again underlines all seriousness of the control of deviations in airlines, with the purpose of more serious adverse factors prevention.

In dangerous situations with probability of results about zero it is admissible to evaluate risk only on rate of possible damage. That is not enough efficient, but reflects when necessary, the practice of risk evaluation according to rate of losses, damages, or injuries, having insurance or evaluation of accident consequence.

Further in the considered chapter physical and mathematical senses of risk are defined, as well as search method of «the shortest ways to accident» on the basis of the danger analysis in various chains of J.Rizon which are found automatically by means of the computer module. It allows to evaluate risk of accident occurrence and to complete risk control, for example, by means of tables Risk Assessment Tool of structure ALAR Tool Kits. As it is marked, the idea of system modelling by means of change process of discrete conditions and transition graphs is known for a long time. However, such model in traditional interpretation through probabilities of transition is not efficient and cannot give important results in case of studying the distress phenomena. As a result, the rate of accident probability has no practical sense.

In the proposed scheme the new offer is the necessity of search combinations of all possible conditions and in making the corresponding ways – i.e. the chains leading to an accident. It is achieved by means of splitting the mass into numerical chains. Calculation of probabilities is not made and it is not required, but properties of the possible ways of system hit received from the mass in the final condition of an accident are analyzed.

In the fourth chapter the method of quantitative evaluation of danger rate of adverse factors in flight is offered. The risk evaluation allows ranking the revealed events for groups of the same events with decrease of a risk level and, using the received number, to establish a priority order of the accepted measures providing flight safety. For definition of risk evaluation by results of operational supervision we will use the rules of the flight airworthiness regulating probabilities of special situations in flight.

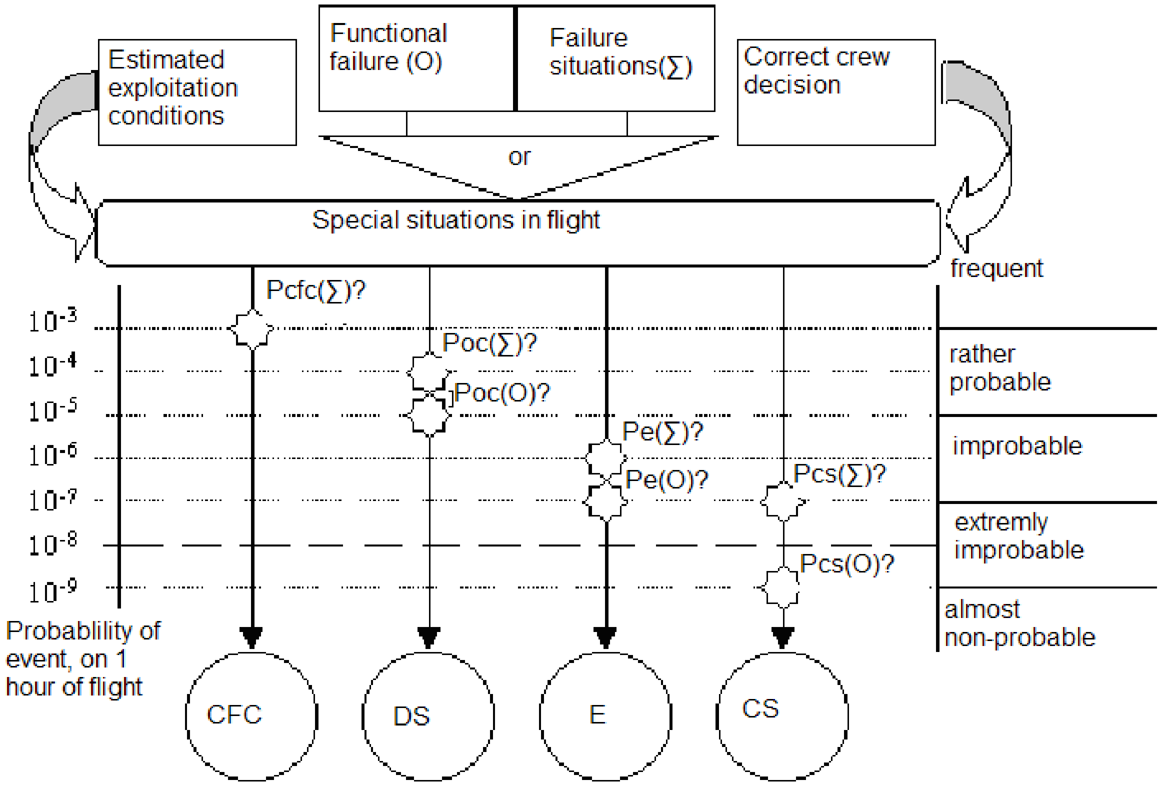


Figure2. Airworthiness requirements to functional reliability AT

P_{SS} (0) - probability of special situation occurrence caused by functional failure

P_{SS} (∑) - total probability of special situation occurrence caused by functional failures

Classifying negative situations in flight in accordance with airworthiness and accepting probability of an accident because of a catastrophic situation for 1, we have:

$$Q_{CS} = r_{CS} q_{CS},\ r_{CS} = 1,\ q_{CS} = n_{CS} / T, \qquad (2)$$

Where Q_{CS} - risk of a catastrophic situation,

r_{CS} - danger of a catastrophic situation,

q_{CS} - probability of a catastrophic situation,

n_{CS} - number of catastrophic situations on an interval of supervision time,

T - total flight hours on an interval of supervision time.

$$Q_E = r_E q_{CS},\ r_E = 10^{-1},\ q_E = n_E / T, \quad (3)$$

Where Q_E - risk of an emergency,

r_E - danger of an emergency,

q_E - probability of an emergency,

n_E - number of emergencies on an interval of supervision time,

$$Q_{DS} = r_{DS} q_{CS},\ r_{DS} = 10^{-3},\ q_{DS} = n_{DS} / T, \quad (4)$$

Where Q_{DS} - risk of a difficult situation,

r_{DS} - danger of a difficult situation,

q_{DS} - probability of a difficult situation,

n_{DS} - number of difficult situations on an interval of supervision time,

$$Q_{CFC} = r_{CFC} q_{CS},\ r_{CFC} = 10^{-4},\ q_{CFC} = n_{CFC} / T, \quad (5)$$

Where Q_{CFC} - risk of flight conditions complication situation.

r_{CFC} - danger of flight conditions complication situation.

q_{CFC} - probability of flight conditions complication situation.

n_{CFC} - number of flight conditions complication situations on an interval of time of supervision,

It is offered to enter an additional group of negative events without complication of flight conditions (WCFC) - for more detailed account of events decreasing in safety level, then

$$Q_{WCFC} = r_{WCFC} q_{CS},\ r_{WCFC} = 10^{-5},\ q_{WCFC} = n_{WCFC} / T, \quad (6)$$

Where Q_{WCFC} - risk of a situation,

r_{WCFC} - danger of a situation,

q_{WCFC} - probability of a situation,

n_{WCFC} - number of situations on an interval of time supervision.

In this case, the total evaluation of risk is defined by the sum:

$$R = Q_{CS} + Q_E + Q_{DS} + Q_{CFC} + Q_{WCFC} \quad (7)$$

As it is marked in the second chapter, the basic interest for the analysis, for the purpose of reaching the new flight safety level, there are events the most insignificant, on consequences. The evaluation of risk rate of such events, is offered to be made by a method of expert evaluation, in connection with impossibility of other application of mathematical methods for the purpose decision. The basic difficulties consisting of working out mathematical rules of quantitative evaluation of adverse factors in flight involve:

- Difficulties in ranging negative events of this sort;

- Difficulties in consequence definition, in connection with this sort of event approach;

- Difficulties in the development analysis of flight, in connection with this sort of even approach, in the whole chain of adverse factors;

- Difficulties in definition of flight outcome clearing out several range of events, for a little time interval;

- Difficulties in evaluation of approach of the given adverse factor in connection with approach of other and further development of chain occurrence of adverse factors.

Graphic representation of method quantitative evaluation of negative event rate is presented in fig. 3.

So, according to drawing, it is offered to apply a rule 1:10:30:600 (conditional ratio of negative event repeatability), and «1:10:100:10000: (> 10000) » (conditional ratio of special situations repeatability in flight):

$$n_A: n_F: n_{SI}: n_I = 1: 10: 30: 600$$

N_A - quantity of accidents, **n_F -** quantity of failures, **n_{SI} -** quantity of serious aviation incidents, n_I **-** quantity of aviation incidents.

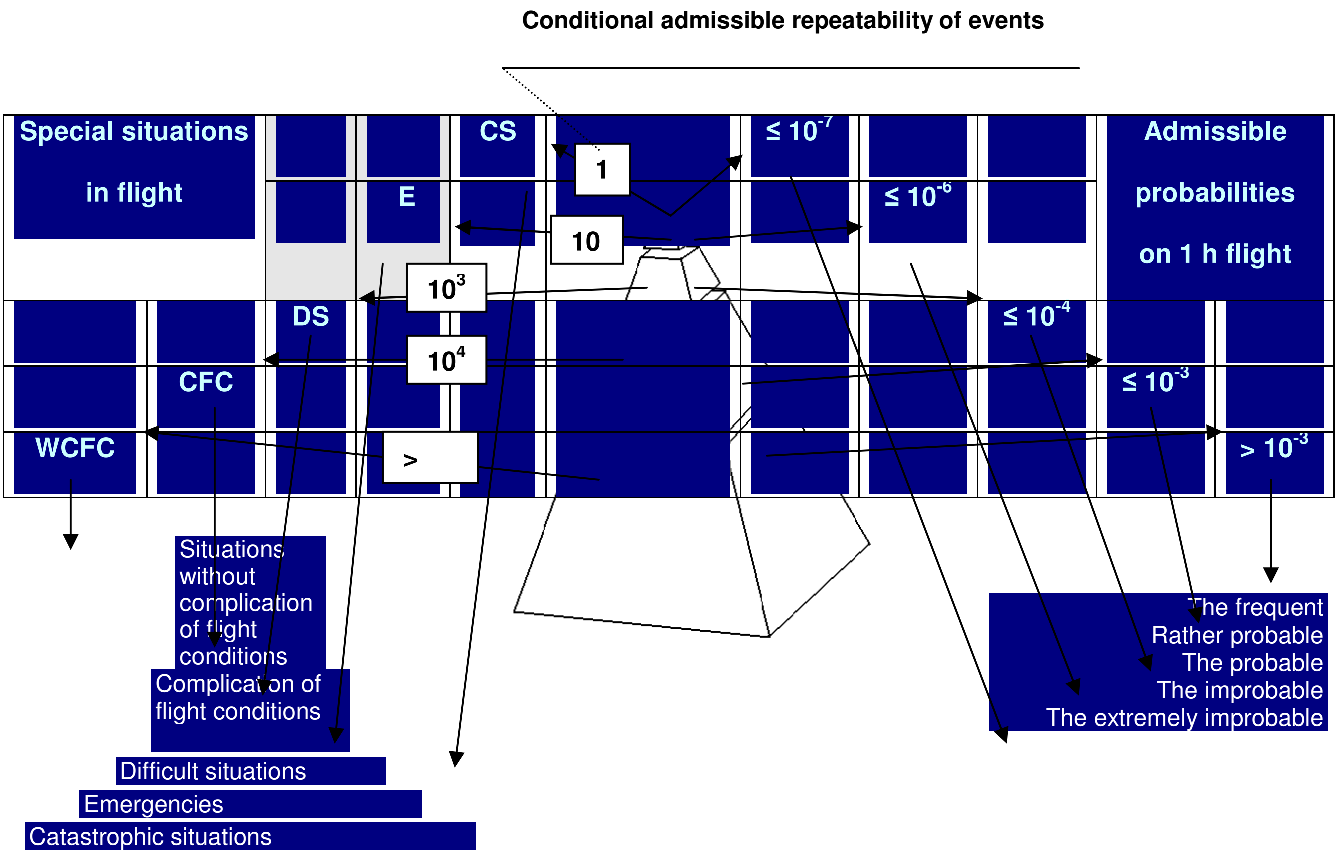


Figure 3. Use of airworthiness rationing at risk evaluation

$$n_{CS}: n_E: n_{DS}: n_{CFC}: n_{WCFC} = 1: 10: 10^3: 10^4: (> 10^4)$$

$\mathbf{n_{CS}}$ **-** quantity of catastrophic situations, $\mathbf{n_E}$ **-** quantity of emergencies, $\mathbf{n_{DS}}$ **-** quantity of difficult situations, $\mathbf{n_{CFC}}$ **-** quantity of situations of complication of flight conditions, $\mathbf{n_{WCFC}}$ **-** quantity of situations without complication of flight conditions. Thus, the risk level of flights R as integrated risk evaluation of occurrence of special situations on one hour flight is defined by the formula:

$$R = \sum_{i=1}^{5} R_i = \sum_{i=1}^{5} S_i Q_i = \sum_{i=1}^{5} \frac{n_i}{T} Q_i$$

Table 1.

Danger of an accident at a certain type of event

i **Index of event type**	**Event type** **(A special situation in flight)**	Q_i **Danger of accident**	n_i **Quantity of controllable events of i-type**	T
1	WCFC	Q 1=10-5	n_1 - Quantity of controllable events of WCFC type	Flight hours on an interval of time control of flight safety level
2	CFC	Q 2=10-4	n_2 - Quantity of controllable events of CFC type	
3	DS	Q 3=10-3	n_3 - Quantity of controllable events of DS type	
4	E	Q 4=10-1	n_4 - Quantity of controllable events of E type	
5	CS	Q 5=100	n_5 - Quantity of controllable events of CS type	

Risk classification is presented in table 2.

Table 2.

Risk classification

		Gravity of consequences				
		Insignificant (WCFC)	**Insignificant (CFC)**	**Significant (DS)**	**Dangerous (E)**	**Catastrophic (CS)**
Probability of event	**The frequent $10^{-3} < Q \leq 10^{0}$**	It is subject to the analysis	***Unacceptably***	***Unacceptably***	***Unacceptably***	***Unacceptably***
	Rather probable $Q \leq 10^{-3}$	It is subject to the analysis	It is subject to the analysis	***Unacceptably***	***Unacceptably***	***Unacceptably***
	The probable $Q \leq 10^{-5}$	It is comprehensible	It is subject to the analysis	It is subject to the analysis	***Unacceptably***	***Unacceptably***
	The improbable $Q \leq 10^{6}$	It is comprehensible	It is comprehensible	It is subject to the analysis	It is subject to the analysis	***Unacceptably***
	The extremely improbable $Q \leq 10^{-7}$	It is comprehensible	It is comprehensible	It is subject to the analysis	It is subject to the analysis	It is subject to the analysis

This evaluation is simple in application and allows to carry out monitoring of a current risk level in the process of flight safety management.

It is necessary to apply the theory of expert evaluation to define a class of event, because of other mathematical methods application impossibility (this problem is presented in the considered chapter). Display of the adverse factor, crew actions on parrying its consequences and a flight outcome are events casual, hence as an objective measure, integrally evaluating safety of a flight estimating level, the evaluation of an unsuccessful outcome probability of flight, failure or accident is accepted. Further this indicator is called as a flight risk level – Q.

The quantitative evaluation of a risk level on an interval of time [t_0, $t_к$] pays off as follows:

$$Q_i = q_i K_{oni},\qquad(8)$$

Where - $K_{опi}$ conditional probability non-decrab consequences of adverse factors on an interval of time [t_0, $t_к$], i.e. before flight end.

$$K_{опi} = \alpha\beta,\qquad(9)$$

Where α – factor of parrying complexity of the adverse factor;

β – factor of an outcome danger of a special situation in flight.

The factor α_{ij} – is defined as non-decrab probability by crew of the *i*-type adverse factor on a flight stage *j*:

$$\alpha_{ij} = (1 - Рп_{ij})\qquad(10)$$

Factors of parrying complexity, the shown adverse factors, make a likelihood matrix:

$$\{\alpha_{ij}\} = \begin{vmatrix} \alpha_{11}\ldots\alpha_{ij}\ldots\alpha_{1n} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \alpha_{i1}\ldots\alpha_{ij}\ldots\alpha_{in} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \alpha_{m1}\ldots\alpha_{mj}\ldots\alpha_{mn} \end{vmatrix}\qquad(11)$$

Where i – 1, n – n – quantity of flight stages;

j – 1, m – m – quantity of adverse factors.

The factor of an outcome danger of a special situation is defined as β_{ij} - probability of aviation incident, owing to non-decrab *i*-type adverse factor on *j*- stage of flight.

Factors of an outcome danger of a special situation in flight make a likelihood matrix:

$$\{\beta_{ij}\} = \begin{vmatrix} \beta_{11}\ldots\beta_{ij}\ldots\beta_{1n} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \beta_{i1}\ldots\beta_{ij}\ldots\beta_{in} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \beta_{m1}\ldots\beta_{mj}\ldots\beta_{mn} \end{vmatrix}\qquad(12)$$

Introduction of complexity factor concept of parrying the adverse factor and the factor of outcome danger of flight special situation, allows to define the factor of special situation danger caused by occurrence of the adverse factor and to define it as:

$$\{Коп_{ij}\} = \{\alpha_{ij}\} \otimes \{\beta_{ij}\}, \tag{13}$$

Where «$\otimes$» - means step-by-step multiplication of matrixes and $\{\alpha_{ij}\}\{\beta_{ij}\}$.

Thus, value $Коп_{ij}$ allows to evaluate danger rate of the adverse factor and at the known probability of the adverse factor occurrence apriori q_{ij} to evaluate a flight risk level Q_{ij}: ααα

$$Q_{ij} = Kon_{ij} * q_{ij} \tag{14}$$

Using quantitative values α, and β it is possible to define $Коп$, proceeding from rate of flight special situation danger, rational strategy of crew actions on parrying of consequences of the adverse factor, the requirement to technical systems of flight safety providing and requirements to preparation of flight crews.

It allows to evaluate the existing flight safety level at aircraft operation, and also to carry out the forecast of efficiency of planned preventive actions.

To be sure that there is a coordination in opinions of experts and it has not got a casual character, the criterion – factor concordat (W) is used.

The factor concordat pays off under the formula:

$$W = \frac{S}{N^2(M^3 - M)/12 - N\sum_{v=1}^{N} T_v}, \tag{15}$$

For evaluation of reliability of the received results value a hi-square under the formula is calculated:

$$\chi^2 = N(M-1)W, \tag{16}$$

Which then are compared to tabular values at χ^2_T(M-1) freedom degrees. On the basis of comparison it is found out, what probability of received value exceeds χ^2 tabular value χ^2_T, i.e.

$$P(\chi^2 > \chi^2_T) = g, \tag{17}$$

If the received sizes have appeared χ^2 significant with the big level of trust (*g*> 0.99) it specifies on not accidental coordination of all N in experts opinions.

The developed mathematical model of integrated flight risk evaluation has been used for reception of its quantitative values at occurrence of special situations by means of the expert method described in the fourth chapter. For this purpose from a database of the ACS "Safety" it is taken over 40 adverse events, taking place in operation of various types of aircraft.

The survey prepared for these purposes has been made by the flight crew structure for what it has been involved over 50 pilots. By results of the made questionaire the table (matrix) has been completed.

Table 3.

Ranging of adverse events by independent experts

Experts ------------ Events	1	2	...	i		M
1	c_{11}	c_{21}		c_{1j}		c_{m1}
2	c_{12}	c_{22}		c_{2j}		c_{m2}
….						
j	c_{1j}	c_{2j}		c_{ij}		c_{mj}
...						
n	c_{1n}	c_{2n}		c_{in}		c_{mn}

The number *m* table columns corresponds to number of the experts who have taken part in the survey, the number of lines *n* corresponds to number of adverse events evaluated by outside experts, and on crossing *of i th* column and *j* th line there is element *Cij* – a rank (place), given *by i th* expert *to j th* event.

According to the table of expert result survey the value of the considered danger indicators events and indicators of a expert opinion coordination on the considered events are evaluated.

Thus the received results allow to develop, thus, a rating scale of danger, i.e. to identify a situation (E, DS, CS, CFC, WCFC) in which the given adverse risk factor will result.

At the beginning some events have been split in to five groups, ten events in each group. The first group joins the most dangerous events, the second group less dangerous, etc. The fifth group joins eight less dangerous events. Further events are placed in each group of five in accordance with rate of danger , and the first place in a group event is corsidered to be the most dangerous, the second the less dangerous, etc. As a result, all events are ranged according to danger rate.

Ranging takes place under following circumstances:

1. On average statistical value of danger evaluation size (importance) of event (in points):

$$M_j = \frac{\sum_{i=1} C_{ij}}{m}; \tag{18}$$

Where *Mj* – average statistics value of danger evaluation size *of j th* event;

- *m* - quantity of the experts evaluating *j* th event;
- c_{ij} - evaluation (in points) *i* th expert *of j th* event ("rank");

2. A factor of "specific gravity" of the given event

$$K_{yj} = \frac{\sum_{i-1}^{m} C_{ij}}{k_{aej} \sum_{j=1}^{n} \sum_{i=1}^{m} c_{ij}}; \tag{19}$$

Where k_{yj} - factor of "relative density" *of j th* event, characterizing a share of the score, received *by j th* event, in a score, received by all events;

n - quantity of considered events;

k_{aej} factor of experts "activity" for *j* th event. The less these factors are, the more dangerous is an event.

To exclude a subjectivity element in maximum some evaluation is given:

- Dispersion of evaluation Dj given by all experts *to j th* event
- average square deviation
- Relative average square deviation υj;

These indicators are also taken into account at ranging.

For evaluation of an expert opinion coordination rate the concordation W is estimated. Thus, the considered events finally ranged on values of size μj (*kej*) taking into account Dj, υj, etc. As a result, all events have been placed in faccordance with danger rate. The 4th event (in the list of adverse events), - “collision with other aircraft ” appears to become the event with the highest risk level; the 26th event ("explosion"), further the 2nd event (“loss in flight controls”) follows; further the 3nd event (“collision with ground surface”) and so on.

Also, with the use of the developed methods, and analyses of flight safety in civil aviation in Russia for the period of 1995-2006 calculations of its functioning risks during this period have been carried out. The results of calculations for various variants (without the account of victims quantity and with the account, the results are shown in the form of tables and histograms). For evaluation of change dynamics of flight safety indicators for the period of time with use of relative indicators, there appears smoothing of the statistics data by means of a procedure of their processing on the basis of calculation of a sliding average for 5 years (According to ICAO FS road map). The fragment of these calculations is resulted in table 4.

Table 4.

Calculation of FS indicators for all aircraft park of Russian commercial aviation for the period of 1995-2006

Indicators	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
T, 10^5 h	22,41	19,2	16,91	14,54	14	14,53	15,7	16,6	16,98	18,09	18,18	20
N_{pas}, 10^6	31,25	26,83	25	21,76	21,5	22,2	25,06	26,73	29	33,3	35	37,86
N_c	13	14	10	9	7	5	10	7	2	6	7	10
10^{-1} n_f	4,1	2,9	2,5	2,4	1,4	1,2	1,7	1,4	0,7	1,1	0,5	0,3
$n_И$	1165	1093	1014	965	873	877	1015	985	940	947	874	877
10^{-3} n_{ds}	0,58	0,55	0,51	0,48	0,43	0,44	0,51	0,49	0,47	0,47	0,44	0,44
$10^{-4} n_{fcc}$	0,1107	0,1038	0,0963	0,0917	0,0830	0,0833	0,0964	0,0936	0,0893	0,0900	0,0830	0,0833
Σn_i	17,79	17,55	13,1	11,67	8,92	6,72	12,3	8,98	3,25	7,66	7,82	10,82
10^5 R	0,794	0,914	0,775	0,803	0,637	0,462	0,783	0,541	0,191	0,423	0,43	0,541
k_{RDR}	1,32	1,93	1,51	0,4	0,47	0,21	2,05	1,15	0,24	0,35	0,38	1,98
N_{DR} on10^6 per.	5,6	8,2	6,42	1,7	2	0,9	8,7	4,9	1	1,5	1,6	8,4
10^5R*	1,048	1,764	1,17	0,321	0,299	0,097	1,605	0,622	0,046	0,148	0,163	1,071

Here:

- T - the executed total annual flight hours in 10^5 h,
- N_{pas} - quantity of the transported passengers for a period of a year in 10^6 people,
- n_A - quantity of accidents,
- n_f - quantity of failures,
- n_{ds} - quantity of difficult situations,
- n_{fcc} - quantity of complicated flight conditions,
- Σn_i Total quantity of special situations
- R – risk quantity
- k_{RDR} – correction factor for the account of hard consequences on a death-roll

- The quantity of difficult situations (n_{DS}) and situations of complicated flight conditions (n_{FCC}) is conditionally defined from the assumption, the first of situation arises in approximately 5 % of incidents.

The formula of risk level calculation is situation the following:

$$R = \Sigma\, k_i\, n_i \backslash T, \qquad (20)$$

Where i – type of a special situation (i = C, F, DS, FCC)

Correction factors for hard consequence on a death-roll are defined for each year of supervision under the formula:

$$k_{RDR}(j) = N_{DR}(j) / \left(1/12 \sum_{j=1995}^{2006} N_{ПОГ}(j)\right) \qquad (21)$$

j - year (j = 1995…2006)

$$R^* = R\, k_{RDR;} \qquad (22)$$

The histogram of calculated FS indicator distribution is resulted in fig. 4.

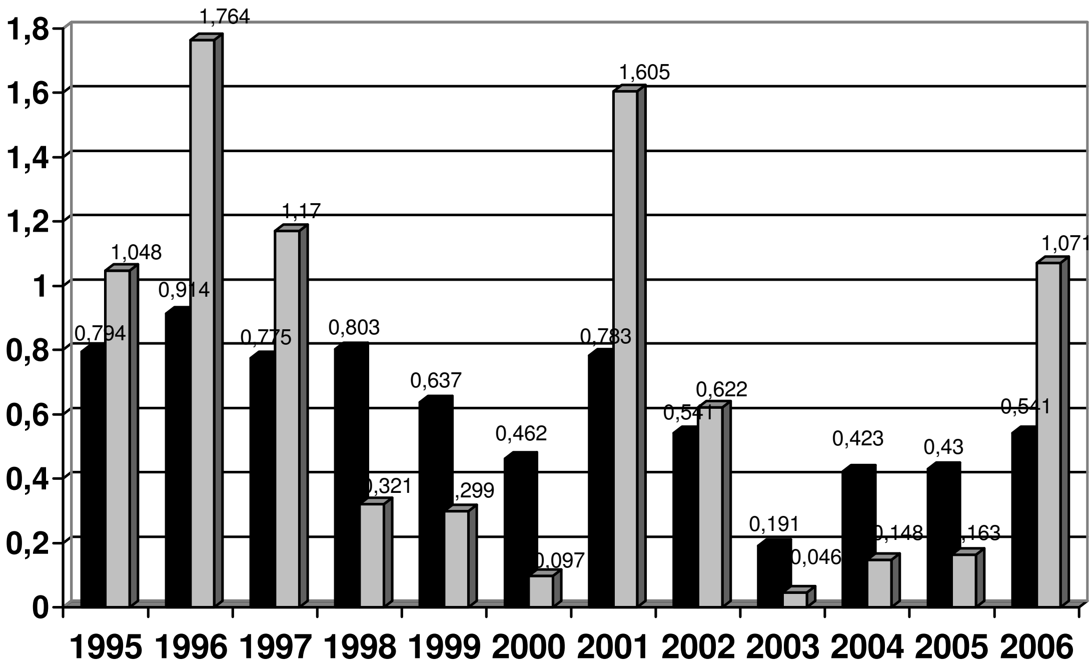


Figure 4. Histograms of risk distribution without the account of victims quantity (10^5 R – black colour) and with the account ($10^5 R^*$ - grey colour), the special situations calculated on occurrence in commercial civil aviation of the Russian Federation during the period of 1995-2006

For evaluation of change dynamics of flight safety indicators for a period of time, with use of relative indicators, the smoothing of the statistics data by means of their processing procedure on the basis of calculation of a sliding average calculation for a period of 5 years is made. The initial data and calculation of such FS indicators for all aircraft park of commercial aviation in Russia during the period of 1995-2006 are resulted in tab. 5.

Table 5.

Calculation of FS smoothing indicators for all aircraft park of Russian commercial aviation for the period of 1995-2006.

Years	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
$N_{АП}$ on 10^5 h	2,41	2,24	2,07	2,27	1,5	1,17	1,72	1,26	0,53	0,94	0,66	0,65
$N_{АП}$ * on 10^5 h	2,46	2,52	2,35	2,27	2,1	1,85	1,75	1,58	1,24	1,12	1,02	0,81
$N_К$ on 10^5 h	0,58	0,74	0,59	0,62	0,5	0,34	0,61	0,42	0,12	0,33	0,38	0,5
$N_К$ * on 10^5 h	0,5	0,58	0,58	0,51	0,61	0,56	0,53	0,5	0,4	0,36	0,37	0,35
$N_{ПОГ}$ on10^6 trans.	5,6	8,2	6,42	1,7	2	0,9	8,7	4,9	1	1,5	1,6	8,4
$N_{ПОГ}$ * on 10^6 trans..	5,22	6,48	6,36	5,64	4,78	3,84	3,94	3,64	3,8	3,4	3,54	4,9

Where $N_{АП}$ - quantity of aviation incidents on 10^5 h flight,

$N_{АП}$ * - the same, but smoothed indicators,

$N_К$ - quantity of accidents on 10^5 h flight,

$N_К$ * - the same, but smoothed indicators,

$N_{ПОГ}$ - quantity of victims on 10^6 transported passengers,

$N_{ПОГ}$ * - the same, but the smoothed indicators.

At smoothing of indicators for 1995-1998 the data resulted in tab. 4 are used.

Histograms of not smoothed and smoothed FS indicators are resulted in fig. 5, 6, 7.

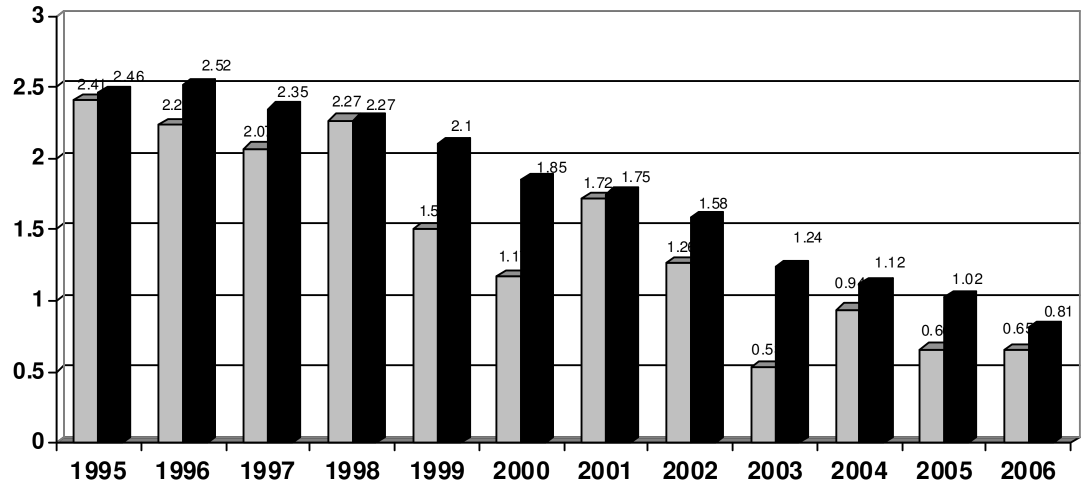


Figure5. Histograms of aviation incidents quantity distribution at 100 thousand hour flight of commercial aircraft of RF CA (not smoothed – grey colour, smoothed – black colour) during the period of 1995-2006.

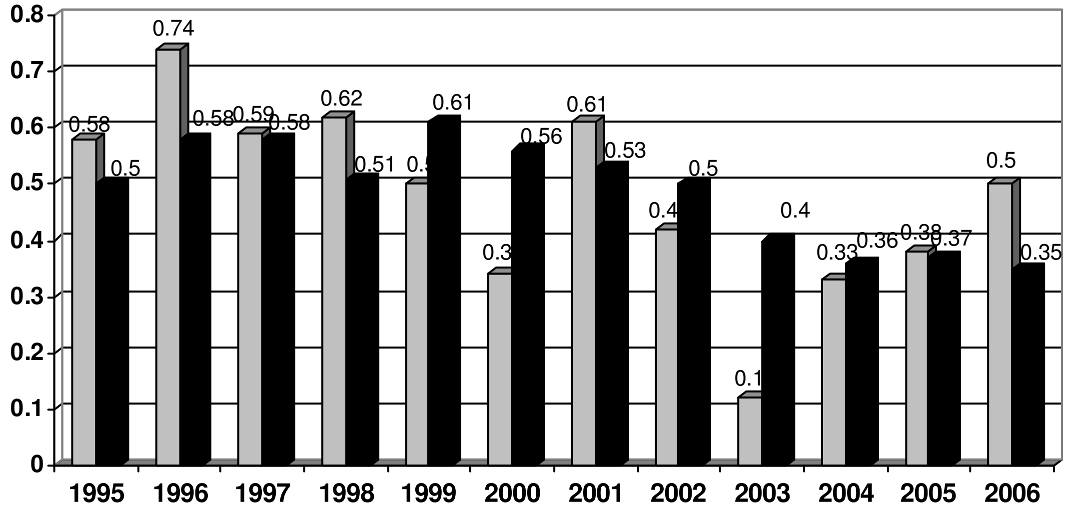


Figure6. Histograms of accident quantity distribution at 100 thousand hour flight of commercial aircraft of RF CA (not smoothed – grey colour, smoothed – black colour) during the period of 1995-2006

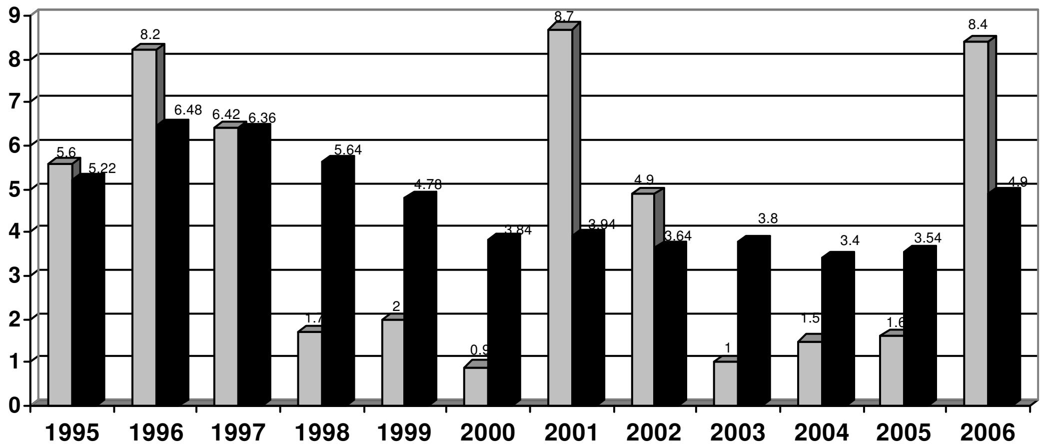


Figure7. Histograms of victims quantity distribution on 10 million transported passengers aircraft of RF CA (not smoothed – grey colour, smoothed – black colour) during the period of 1995-2006

Thus, the received size of risk level R characterises danger rate of the Russian civil aviation functioning for these years defines its rating. Similar calculations can be made in aviation enterprises, types of aircraft, etc. The results of calculations can widely be used for the purpose of monitoring and evaluation of FS condition and relatively-FS management.

THE CONCLUSION

As a result of the conducted scientific research the following results are reached on the basis of the analysis:

- Traditional management methods of flight safety in civil aviation;
- Information supply of exploiters about deviations in their activity, first of all the uses of flight information processing results in airlines, as a basic source of information;
- The international, national and internal standard base concerning flight safety; the approach of different airlines in questions of flight safety level management;
- Operating technologies of information supply of aircraft exploiters, and also the use of flight information processing results in airlines, as a basic source of information:

1. The following offers are developed:

- Theoretical and methodological positions of the new approach to flight safety management in the airline, based on risks management from influence of adverse factors in flight and the principles involved international quality standards ISO-9000 and SMS;

- Methods of integrated evaluation of risk levels of an outcome of flight, because of deviations in crew activity, or influences of the adverse factors, based on the concept of repeatability correlation of the negative events grouped in classes on rate of consequences danger (Accident – Failure – Serious incident-incident - Other negative events; the Catastrophic situation – the Emergency – the Difficult situation – Complicated flight conditions – Without complication of flight conditions);
- Technique of weight factors values choice for various classes of adverse events on the basis of the theory application of expert evaluation;
- Technique of ranging of adverse events in civil aviation with the use of expert evaluation methods;
- Methods of quantitative risk evaluation.

Together with civil aviation research centers ranging of adverse events showing the most appearing adverse factors in flight is made and calculation of risk level in CA of Russia for the period of 1995-2006 that has served revealing of sources of FS threat and development of preventive actions for the subsequent period (2009-2015) is carried out:

Thus, we can speak about creation of FS condition model monitoring for FS level management.

The basic results of research are published in five scientific articles, in two theses of reports in scientific conferences. Materials of publications were reported in:

the 44th International conference in RTU in 2003.,

the 47th Student' scientific and technical conference in RTU in 2007.,

the 1International scientific conference ”International transport: management, tehnologies, safety” in RAI in 2008.

the 2nd International scientific conference „International transport: management, tehnologies, safety” in RAI in 2010.

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