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Aviation safety management system: problem of balanced allocation of resources

Increasing of civil aviation safety level is one of principal objectives of world air transport development. Present research paper discusses approaches to assessment of the "safety space" of civil aviation activity.

The air transport industry plays a major role in world economic activity. One of the key elements to maintaining the vitality of civil aviation is to ensure safe and sustainable civil aviation operations. International Civil Aviation Organization (ICAO) sets the Standards and Recommended Practices (SARPs) necessary for aviation safety on a global basis [1, 2]. Development of global civil aviation safety system unites leading international and regional, intergovernmental and non-governmental organizations, research institutions and universities in order to improve global civil aviation safety level. But contemporary challenges of world air transport make it necessary to continuously increase level of safety and security of aviation system.

Considering, as before mentioned, search for new methods to assess the aviation "safety space" seems topical and important for future civil aviation development. Research paper is devoted to the subject and is a logical continuation of the author's several publications on the issue of development of aviation safety [3 - 10]. The peak values observed at the beginning of the curve illustrate the fact that accidents, being rare events, need to be considered in the light of a meaningful number of flights, reasonably at least a million flights per year (see Fig1.) [11].

At present time, aviation is an ultra-safe system, (i.e. a system that experiences less than one catastrophic safety breakdown every one million production cycles).

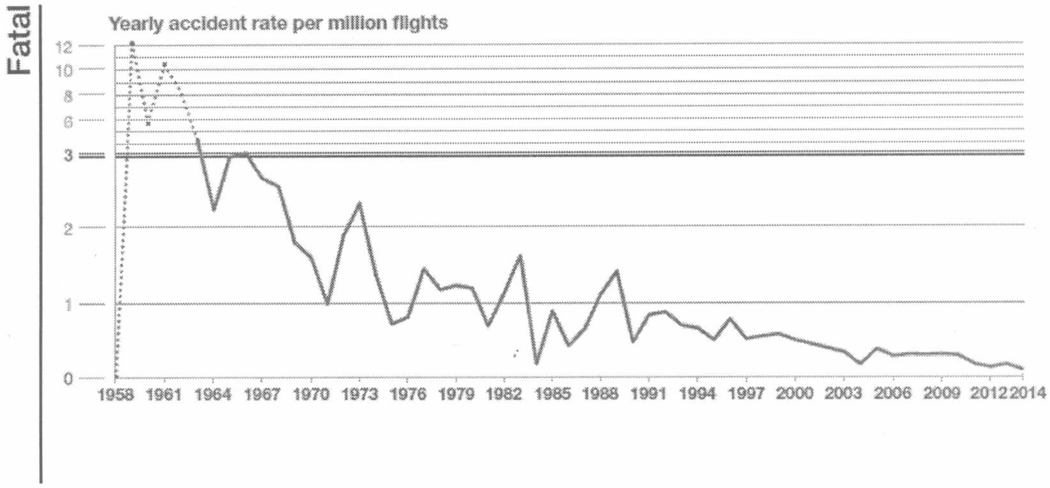

Fig 1. Yearly accident rate per million flights [11].
(Source: Commercial Aviation Accidents 1958 – 2014. A Statistical Analysis. Airbus S.A.S.)

. Accidents are rare occurrences, consequently their number may vary considerably from one year to the next. As a consequence, on the Fig.2, a 10 year moving average is used by Airbus experts i.e. for any given year, the accident rate is the average of the yearly accident rates over the 10 preceding years. The result of safety aviation activity is a virtually stable absolute number of accidents despite a massive increase in exposure [11].

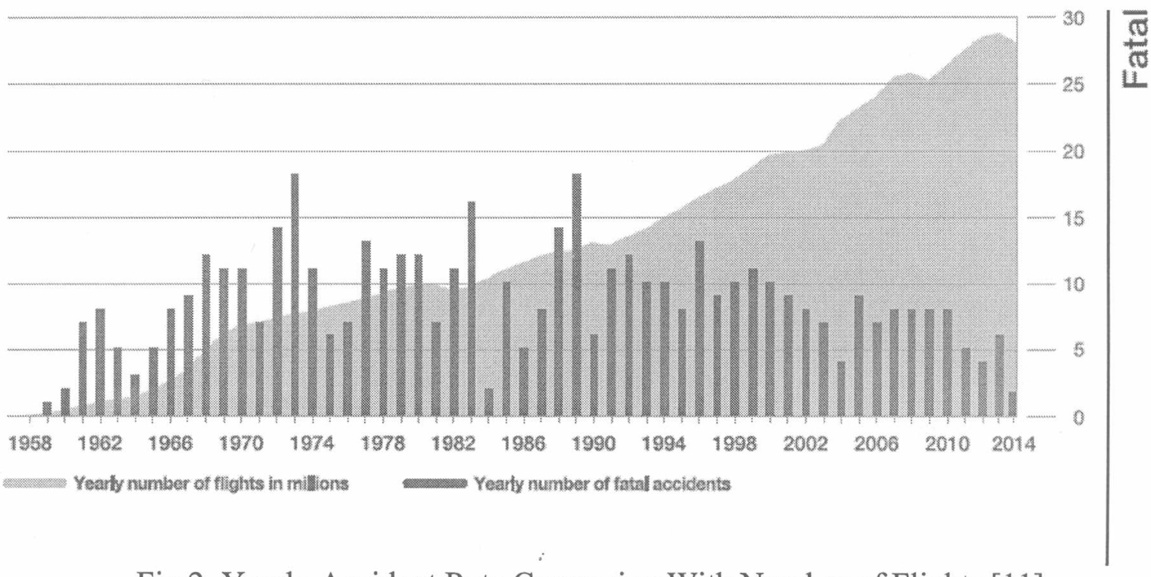

Fig 2. Yearly Accident Rate Comparing With Number of Flights [11].
(Source: Commercial Aviation Accidents 1958 – 2014. A Statistical Analysis. Airbus S.A.S.)

The graph below shows the constant increase in passengers carried over the year and a ratio metric related to the number of fatalities by the number of passengers carried on a specific year [12].

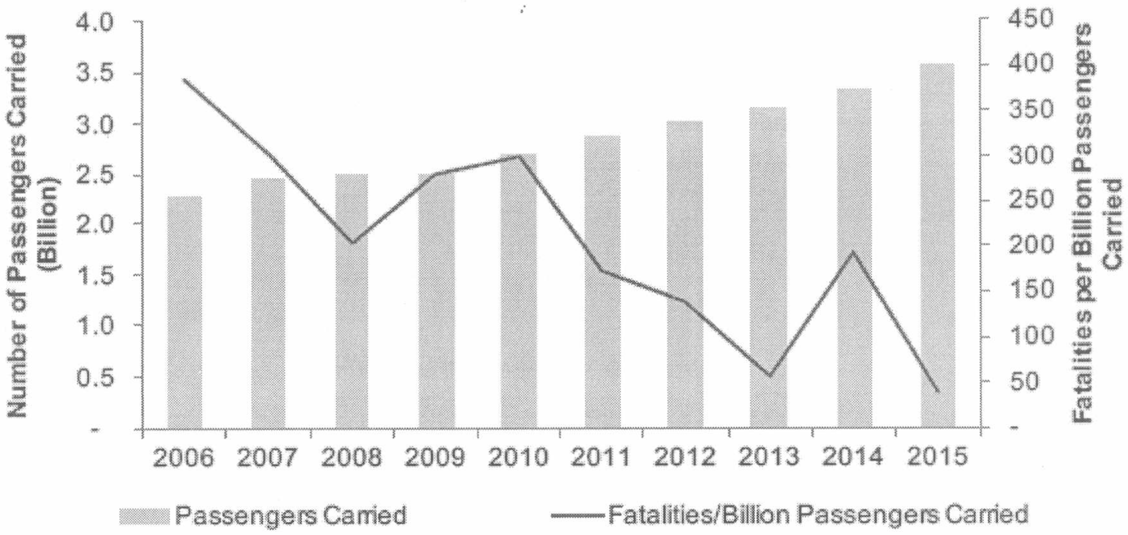

Fig 3. Number of Passengers Carried and Fatalities per Passengers Carried [12]. (Source: IATA Safety Report 2015).

But, unfortunately, we can never state that aviation activities will be absolutely safety. Philosophy of liberalization gradually developed and engulfed more considerable aviation markets during many years. This tendency resulted in the substantial increase of international air routes level of competition. But the idea of free competition is not an ideal and can demonstrate stagnation and negative tendencies on different stage of realization in changing conditions. No doubt, on the certain stage their competition is advantageous for a customer, passenger or cargo owner. A competition requires from an airline constantly perfecting conditions: high level service and fare policy flexibility. However ongoing growth of airlines aircraft operating costs provokes companies to maintain permanent regime of resources economy, which in same time results in the decline of service quality and in some case to the decline of the acceptable level of safety. From the other side, permanent exploitation on verge of profitability or unprofitable routes in general actually put normal existence of airline under a threat [13].

In this situation the main trend of contemporary aviation activity is adoption of a business-like approach to the safety management. Aviation Safety Management System (SMS) includes business management instruments to the management of safety. The development of business management instruments as aimed at the development of the aviation "safety space". Within "safety space", the aviation organization can provide operational activity, with the assurance that it is within a space of maximum resistance to the safety risks of the consequences of hazards. The main boundaries of "safety space" are production and protection (see Fig. 4) [2].

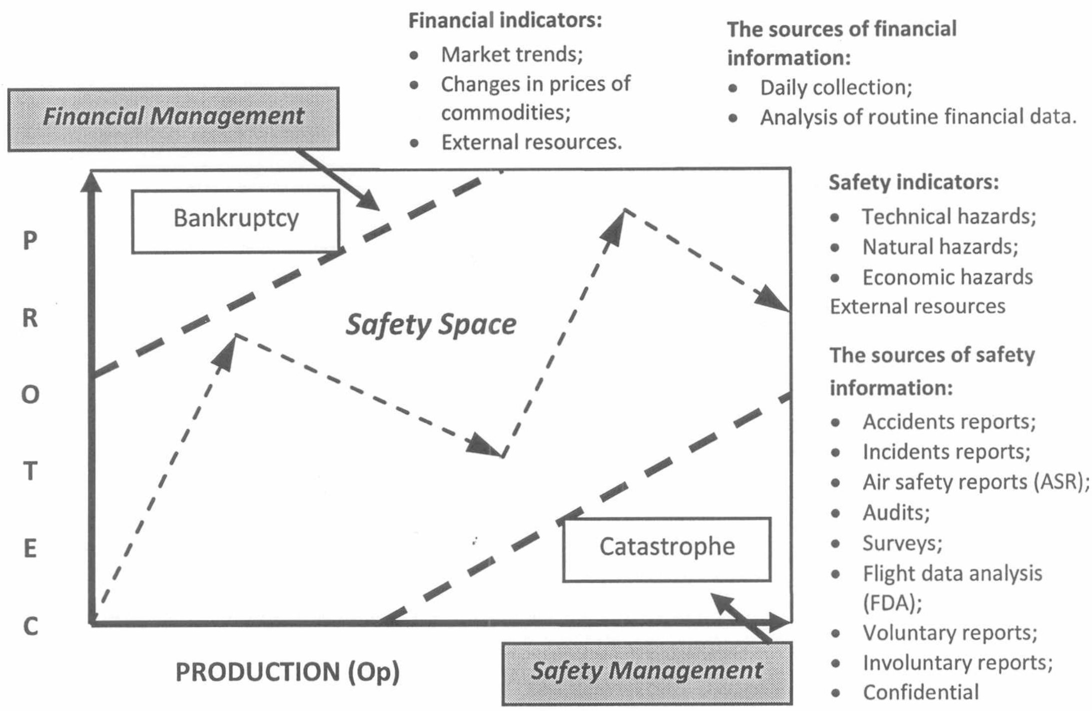

Fig 4. The safety space [2]
(Source: Safety Management Manual (SMM): ICAO).

From this point of view, it is very important to find the most correct methods of determining these boundaries, in order to prevent the problem of misallocation of resources of aviation organizations. There are two sides to the safety space, or two boundaries: the financial (production) boundary and the safety (protection) boundary [2].

The financial (production) boundary is defined by the financial management of the organization.

We can use following financial indicators:

- Market trends;
- Changes in prices of commodities;
- External resources [2]

The sources of financial information are:

- Daily collection;
- Analysis of routine financial data [2].

The safety/protection boundary of the safety space should be defined by the safety management of the organization. This boundary prevents incorrect allocation of resources, which may result in a catastrophe. We can use following safety indicators:

- Technical hazards;
- Natural hazards;
- Economic hazards [2]

The contemporary sources of safety information within Safety Management System are:

- Accidents reports;
- Incidents reports;
- Air safety reports (ASR);
- Audits;
- Surveys;
- Flight data analysis (FDA);
- Voluntary reports;
- Involuntary reports;
- Confidential communications [2].

Having considered the before mentioned information, search for new methods to assess the aviation "safety space" seems topical and important for future civil aviation safety, efficiency and development. There are various hypothesis tests, which can be found in the statistics textbooks. We present below an effective test, proposed by A. Wald [14], which, according to authors, can be very effective for improving the determining accuracy of the area of aviation organization, which is called "safety space".

A hypothesis is a proposed explanation for a phenomenon. For a hypothesis to be a scientific hypothesis, the scientific method requires that one can test it. Scientists generally base scientific hypotheses on previous observations that cannot satisfactorily be explained with the available scientific theories. Even though the words "hypothesis" and "theory" are often used synonymously, a scientific hypothesis is not the same as a scientific theory.

A *statistical hypothesis* is usually a statement about a set of parameters of a population distribution. It is called a hypothesis because it is not known whether or not it is true.

For instance, consider a particular normally distributed population having an unknown mean value θ and known variance 1. The statement "$\theta = 2$" is a statistical hypothesis that we could try to test by observing a random sample from this population. It is called the *null hypothesis* and is denoted by H_0. Symbolically, we can express the null hypothesis as

$$H_0: \theta = 2.$$

A primary problem is to develop a procedure for determining whether or not the values of a random sample from this population are consistent with the hypothesis. This process is called *hypothesis testing*. If the random sample is deemed to be consistent with the hypothesis under consideration, we say that the hypothesis has been "*accepted*"; otherwise we say that it has been "*rejected*."

The alternative to the null hypothesis, which the tester is actually trying to establish, is called the *alternative hypothesis* and is designated by H_1. For our example, H_1 is the hypothesis that "θ is less than 2" which can be written symbolically as

$$H_1: \theta < 2.$$

Let X be a random variable with the probability distribution f(x). Let the hypothesis H0 to be tested be the statement that the distribution of X is $f(x,\theta_0)$. Suppose that the alternative hypothesis H1 states that the distribution of X is given by $f(x,\theta_1)$.

If we denote a series of n observations by $X_n = (x_1, x_2, \dots, x_n)$, then the probability of these n observations is given by

$$P_0 = \prod_{i=1}^{n} f(x_i, \theta_0)$$

if H0 is true

and

$$P_1 = \prod_{i=1}^{n} f(x_i, \theta_1)$$

if H_1 is true.

Current tests of statistical hypothesis assume

1)a doubt about true of the hypothesis
2)possibility of at least two outcomes:

- to accept hypothesis,
- to reject it

As distinct from current test procedure method of sequential tests of statistical hypothesis is supplemented by the third outcome: «don't know». In such a case the scheme of hypothesis' testing assumes the following form.

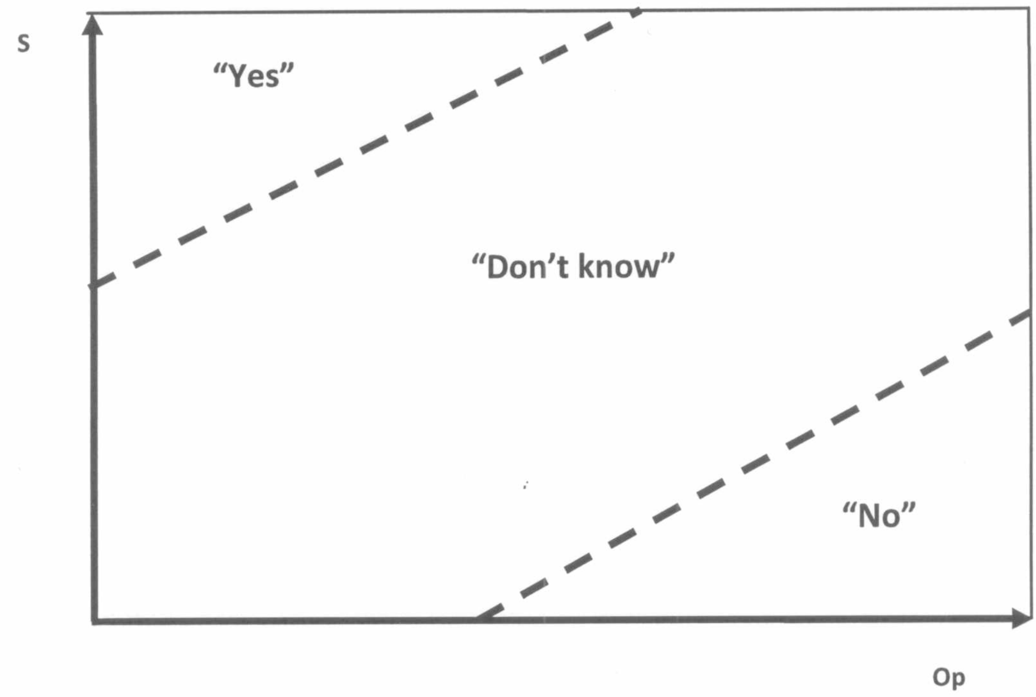

Fig 5. The scheme of hypothesis' testing assumes

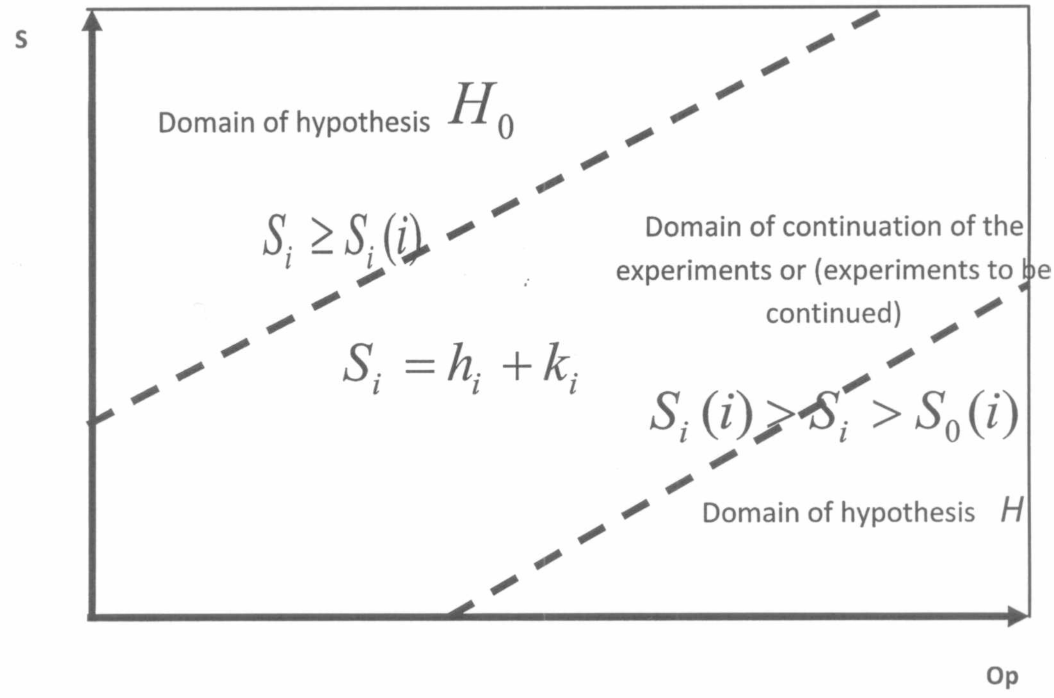

Fig 6. Explanation of sequential tests of statistical hypothesis

A number of steps ν is a random variable which depends on the «nearness» of the hypotheses (difference: $\theta_1 - \theta_0$), the values α and β and the probability of true or false of the hypotheses.

Practically by pre-assigned chosen values α and β and correspondence between values of the parameters θ_0 and θ_1 the expectation of the number of steps necessary to fulfill the sequential test procedure $M(\nu, H_0)$ to accept hypothesis H_0 if it is true; $M(\nu, H_1)$- to accept hypothesis H_1 if it is true and $M(\nu)$ - at worst if $\theta = 0{,}5(\theta_1 + \theta_2)$.

Formulas for pre-assigned estimation of these values are shown in the table 1. The effectiveness of the sequential analysis is estimated by formula

$$E = 1 - M(\nu) : N$$

Apparently, that if $E > 0$, the sequential procedure is preferable in comparison with the current one if the restrictions allow.

Conclusion

Search for new methods to assess the aviation "safety space" seems topical and important for future civil aviation safety, efficiency and development.

Due to the different nature of the aviation hazards (technical, natural and economic) and diversity of safety information channels (accidents and incidents reports, audits, surveys, flight data analysis (FDA), voluntary and involuntary reports and confidential communications) we need investigate different approaches to solve this problem, including various hypothesis tests, for example Effective Test, proposed by A. Wald [14], which, according to authors, can be very effective for improving the determining accuracy of the area of aviation organization, which is called "safety space".

The next publication of authors will be devoted to A. Wald's Effective Test. It will allow offering more correct responses to aviation safety hazards and is a prerequisite to further reinforcement of global safety level of civil aviation.

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