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Theoretical Aspects of Erroneous Actions During the Process of Decision Making by Air Traffic Control

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Abstract **– The Theoretical Aspects of Erroneous Actions During the Process of Decision Making by Air Traffic Control evaluates the factors affecting the operational decision-making of a human air traffic controller, interacting in a dynamic environment with the flight crew, surrounding aircraft traffic and environmental conditions of the airspace. This article reviews the challenges of air traffic control in different conditions, ranging from normal and complex to emergency and catastrophic. Workload factors and operating conditions make an impact on air traffic controllers' decision-making. The proposed model compares various operating conditions within an assumed air traffic control environment subsequently comparing them against a theoretically "perfect" air traffic control system. A mathematical model of flight safety assessment has been proposed for the quantitative assessment of various hazards arising during the process of Air Traffic Control. The model assumes events of various severity and probability ranging from high frequency and low severity up to less likely and catastrophic ones. Certain limitations of the model have been recognised and further improvements for effective hazard evaluation have been suggested.**

Keywords **– Air Traffic Controller, aircraft, erroneous actions, flight safety, special situations.**

I. Introduction

Technologically well-developed Air Traffic Control stations have evolved over the years introducing new challenges in the working dynamics of the air traffic controllers. Technological developments and associated challenges are mainly increasing mental workload of the human operator, mainly towards the decision making.

Air Traffic Controller's evaluation of a situation in the air space and precise monitoring and reaction to changes in the air traffic environment are of vital importance.

An Air Traffic Controller is responsible for flight safety within the controlled airspace and completion of the planned flight route in accordance to the published flight plan.

The main task of an Air Traffic Controller is to efficiently evaluate the available information and make the correct decision. An Air Traffic Controller always has to be aware of the situation in the airspace of his/her responsibility. Rapid changes in traffic movement or environmental conditions require a rapid response from the controlling unit [1]–[3].

II. Importance of the Precise Evaluation of Special Situations in the Air

An Air Traffic Controller has to evaluate a situation in the air and provide safe flight conditions for all participants within the controlled air space. He/she has to be aware of current situation all the time. During any changes, an Air Traffic Controller is responsible for making the right decision and correct evaluation of a special situation in the air. The process of decision making by an Air Traffic Controller is demonstrated in an "*Air Traffic Controller – crew – aircraft – environment"* system, which is responsible for a safe flight. Thus, an Air Traffic Controller is responsible for evaluating the system status, and after evaluating a special situation in the air he/she allocates it to one of the following conditions:

1. NC – Normal operational condition;
2. CE – Complicated operational condition;
3. CC – Complex operational condition;
4. ES – Emergency situation;
5. CS – Catastrophic situation.

1. NC – Normal operational condition. This is a standard situation in which the workload is maintained at the same level, i.e. normal.

2. CE – Complicated operational condition. A situation in which an Air Traffic Controller is experiencing a trivial work load increase or when non-essential flight parameter changes are taking place. CE does not require immediate flight plan changes and does not affect flight safety.

3. CC – Complex operational condition. A special situation involving a significant work load increase or a situation in which flight stability have worsened significantly; one or more flights are stepping back from minimum safe flight parameters but have not reached the risk border.

To avoid the escalation of Complex operational condition into an Emergency or Catastrophic situation, it is very important for an Air Traffic Controller and the aircraft flight crew to take timely and correct actions to immediately change the flight profile or any other parameter.

4. ES – Emergency situation. A special situation in which the aircraft crew is experiencing a serious work load increase or a situation in which flight stability or other flight parameters have worsen critically. This is a situation in the air in which the flight safety minimum has been reached.

5. CS – Catastrophic situation. When this special situation occurs, we assume that fatal results (loss of both human and aircraft) are unavoidable.

CS occurrences can be divided into the following groups:

1. Repetitive;
2. Moderately possible;
3. Slightly possible;
4. Rarely possible;
5. Practically impossible.

By analyzing all the assumed conditions and situations, it is quite visible how approximate is the difference between them in the *"Air Traffic Controller – crew – aircraft – environment"* system. A slight difference between conditions makes it hard for a decision making process to evaluate all information, parameters and each situation separately and to ensure flight safety in the Air Traffic Control area of responsibility [4]–[6], [7], [8].

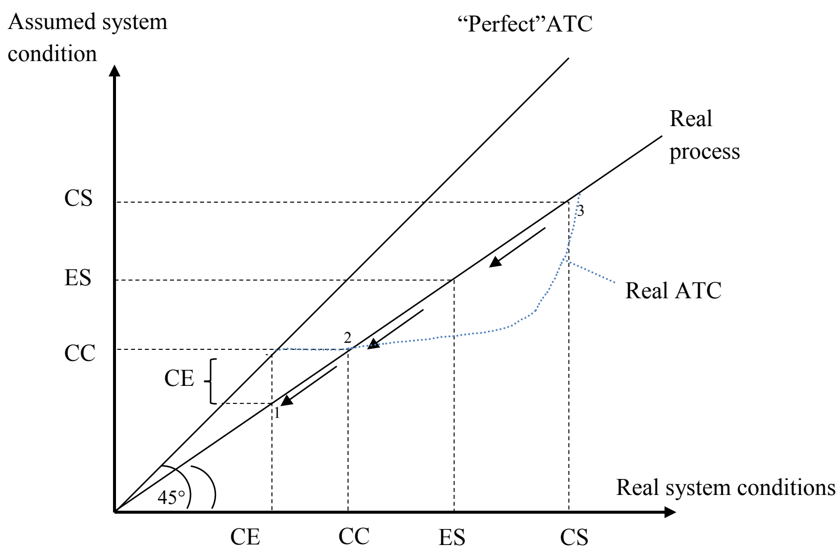

Fig. 1. The process of decision making by an Air Traffic Controller according to the "*Air Traffic Controller – crew – aircraft – environment*" system [7].

In Figure 1, the abscise axis sets real system conditions – an actual situation with real conditions; the ordinate axis sets a system condition assumed by an Air Traffic Controller. The “Perfect Air Traffic Controller” will always evaluate system conditions correctly, that is why his working line has an angle of gradient α = 45°. The real Air Traffic Controller will make some errors. His/her working line will have a smaller angle of gradient in case of a sudden risk reduction and will have a wider angle of gradient in case of a sudden risk increase.

The model for assessing the level of safety of flights due to the manifestation of risk factors by the Air Traffic Control (ATC):

Let us designate the level of flight safety for a certain period of time as η [9], [10].

For the unit of measure η, we will take the standard ICAO indicator – the probability of event occurrence per one hundred thousand flights (one flight) over a certain period of time:

$$R_{ij} = \frac{n_{ij}}{N} 10^5, \quad (1)$$

where

i events;
j factors;
R_{ij} event probabilities per 100 000 flights;
n_{ij} number of i-th factors appeared in events of j-th type;
N number of flights.

In accordance with the above, the mathematical model will include all occurrences of various levels such as disasters (CC), accidents (AS), failures (FU), emergency landings (ELG) and incidents (INC) (see Fig. 3).

Thus

$$\eta = \eta(R_{1,1}, R_{1,2}, \ldots, R_{i,j}, \ldots, R_{n,m}). \quad (2)$$

Given the relationship is a mathematical model of flight safety assessment, let us represent all the events taking place in the evaluation of the accepted index by the severity of their consequences in the form of several levels: disasters (CC), accidents (AS), failures (FU), emergency landings (ELG) and incidents (INC) (see Fig. 2).

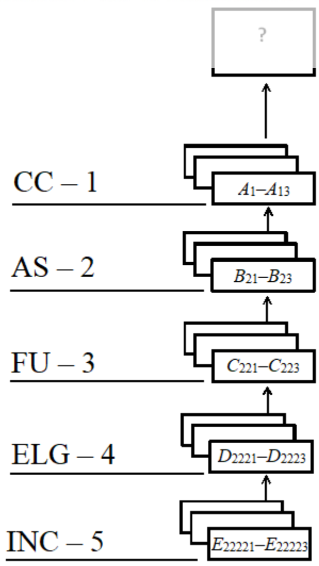

Fig. 2. Model of hazard assessment structure [11].

Given that the event rate is reduced with increasing severity of their consequences, a number of factors are allocated to each level depending on the operational situation, addressed by the ATC controller. As you move from top to bottom, from the CC to the INC, factors are disaggregated, so that each of them is uniquely determined by the disaggregated factors of the lower level. In the figure, each factor of the top level is determined by three factors of the lower level. Such an elementary cell consisting of three elements of the lower level and one upper-level element will be called a triad (see Fig. 3).

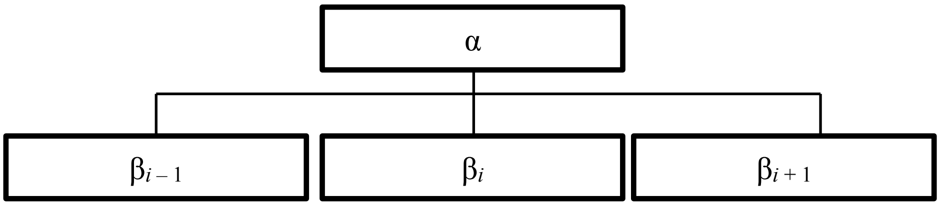

Fig. 3. The structure of a triad.

From an examination of this structure it follows that by setting dependences in all triads there is established a relationship of any element of the upper level with the lower level elements in contact with it.

$$\alpha = f(\beta_{i-1}, \beta_i, \beta_{i+1}). \tag{3}$$

Where η depends on all the elements of the structure. The elements of the lower level of the structure cover all the reasons provided by the statistics. At all other levels only generalized factors are located. In accordance with dependencies (1) and (2) and the accepted hypothesis, the model parameters are:

$$A_i = \frac{n_{\mathrm{CC}_i}}{N}10^5\,;\; B_i = \frac{n_{\mathrm{AS}_i}}{N}10^5 + A_i;\; C_i = \frac{n_{\mathrm{FU}_i}}{N}10^5 + B_i;\; D_i = \frac{n_{\mathrm{ELG}_i}}{N}10^5 + C_i;\; E_i = \frac{n_{\mathrm{INC}_i}}{N}10^5 + D_i\,; \tag{4}$$

where A_i, B_i, C_i, D_i, E_i are respectively the parameters on the level of catastrophes, accidents, failures, emergency landings and incidents calculated for the i-th factor;

The relationship between the two levels in the triad are established on the basis of statistical data of the factors emerging in certain events and are substantiated by the functional dependencies of the functions with three variables:

$$\begin{aligned} D_i &= D_i(E_{i-1}, E_i, E_{i+1});\\ C_i &= C_i(D_{i-1}, D_i, D_{i+1});\\ B_i &= B_i(C_{i-1}, C_i, C_{i+1});\\ A_i &= A_i(B_{i-1}, B_i, B_{i+1});\\ \eta_i &= \eta_i(A_{i-1}, A_i, A_{i+1}). \end{aligned} \tag{5}$$

By setting the relationships of type (5) for the triads of all structures and performing the substitution of the functional dependencies D_i on C_i, C_i on B_i, B_i on A_i, we will obtain the relationship (6) of the effect of any of the factors observed in the incidents on the criterion η.

$$\eta = f(\mathrm{E}_1, \mathrm{E}_2, \ldots, \mathrm{E}_i, \ldots, E_n). \tag{6}$$

In addition to relationship (6), dependencies η on A_i, B_i, C_i and D_i can be set. It is also possible to introduce dependencies of the parameters A_i on C_i, D_i, E_i, B_i on D_i and E_i. This allows us to determine the influence of factors on the occurrence of disasters, accidents, breakdowns and emergency landings. The essence of the obtained functional dependencies is as follows. Given that the parameters of the model are the probabilities of events in 10^5 flights calculated from the population statistics for each type of aircraft or for several similar aircraft types, relationship (6) is essentially a generalized formal experience in operating these aircraft types over a relatively long period. The result of this transformation is based on the linear relationship between the parameters α and β, therefore the triad with functional dependencies of (6) will also produce linear relationship:

$$\eta = \sum_{i=1}^{243} R_i E_i \tag{7}$$

The disadvantages of the obtained dependencies include the fact that they are determined by the already accomplished events and therefore are independent of time [12].

III. Calculation of Safety Indicators Based on the Risk of Erroneous Actions by the Controller

According to the materials of post-flight analysis a typical hazards to the flight in bad weather conditions was a hazard of reduced or lost pilot's awareness due to the erroneous actions of a controller. In this example, the deviation did not lead to the aviation occurrence. However, theoretically it could contribute to such an event. Since the reduced pilot awareness manifested itself during the flight, this deviation was not mitigated in advance relying on procedures which could protect against the loss of situational awareness. In the example shown, the deviation could lead to a dangerous situation [13].

Let us use a safety factor of flight operations – C_{fo}.

$$C_{fo} = S/F, \tag{8}$$

where

S is a summed quantification of deviations from the established requirements for flight operations during the period.

F is a number of flights during the period.

All the calculations are summarized in Fig. 4 forming a graph of performance data; the red line represents the valid (set) safety level of flight operations. The specified level of safety is a goal the airline aspires to reach. As can be observed from the Fig. 4, such goal was achieved only from the second quarter of 2012–2015 [14], [15].

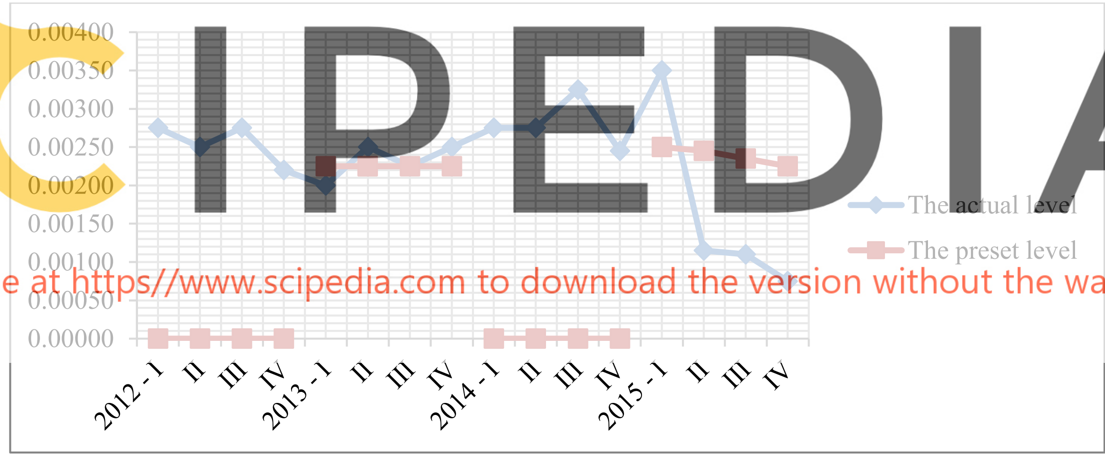

Fig. 4. Airline flight safety indicators for a period of 2012–2015.

IV. Conclusion

Our proposed method of safety status assessment makes it possible to identify and eliminate hidden hazards lying at the very bottom of the pyramid known as ICAO pyramid, which represents the ratio between the different levels of adverse risks.

As the calculations show, the desired (predetermined) level of flight safety in the given Air Traffic Control service is not provided, which requires more effective measures for risk elimination.

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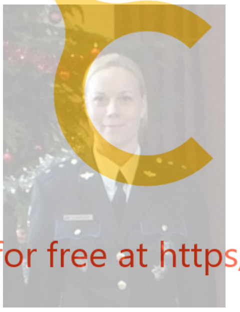

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