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METHODOLOGY FOR ANALYSIS OF DECISION MAKING IN AIR NAVIGATION SYSTEM

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Abstract. *In the research of Air Navigation System as a complex socio-technical system the methodology of analysis of human-operator's decision-making has been developed. The significance of individual-psychological factors as well as the impact of socio-psychological factors on the professional activities of a human-operator during the flight situation development from normal to catastrophic were analyzed. On the basis of the reflexive theory of bipolar choice the expected risks of decision-making by the Air Navigation System's operator influenced by external environment, previous experience and intentions were identified. The methods for analysis of decision-making by the human-operator of Air Navigation System using stochastic networks have been developed.*

Keywords: Air Navigation System, bipolar choice, human operator, decision-making, expected risk, individual-psychological factors, methodology of analysis, reflexive model, socio-psychological factors, stochastic network.

Statement of purpose

Currently, one of the main strategic problems of mankind on the path to sustainable development is the safety and stability of technogeneous production. The technogeneous production is a complex system that contains interrelated technical, economic and social objects. It has a multilevel hierarchical structure and a high level of risk [1]. Recent results show that there are frequent and common emergency such as disasters, accidents, crashes in hydraulic engineering, chemical and military industries, gas and oil pipelines, nuclear power plants and transport [2; 3; 4].

Aviation systems with its complex interrelation between a man and technologies have been evolved towards complex socio-technical systems. The interfaces between people and the technologies that comprise these systems are highly interactive, interdependent and affected by similar environmental events**.** The socio-technical systems also tend to have two common features: high technologies and high risk activities. As such, they require much less direct operation due to the fact that the technology replaces the human operator. On the other hand they require much more remote operator's supervision due to the modern tendency to supervise the technology by distance. The systems' work is not transparent due to increased difficulty to know exactly what technology is being used. The systems are also highly hazardous and of high-risk, and have greater potential for catastrophic consequences (i.e. accidents) [5].

Statistical data show that human errors account for up to 80% of all causes of aviation accidents [6]. Traditional actions like improving professional training, keeping work discipline and others may not be effective. Normally aviation personnel are trained professionally in a proper manner [7]. The causes of most aviation accidents are often connected with the psychology of the crew members which require appropriate consideration.

Modern approaches to control some factors (psycho-physiological, behavioural, ergonomic, professional, etc.) do not take into account the functional state of a human-operator (H-O) under conditions of dynamic changes of external and internal factors [6]. The ambient conditions determine the reaction of H-O, and this reaction changes the environmental conditions accordingly. One of possible approaches to solve these problems may be through formalization and mathematical description based on a system analysis of Air Navigation System (ANS) H-O's actions as a complex socio-technical system.

Review of research results

Ensuring safety in complex socio-technical systems like the aviation system is a key task to prevent threats at the operational level such as breakage of technical equipment or operating personnel's error [4].

Taking into account the influence of individual-psychological, physiological and socio-psychological factors of the environment on human-operator of ANS [8] allows us to predict his actions in specific flight situations. Using the theory of reflection the "large-scale" results which follow individual actions of a man may be assumed [9].

For the formalization of the behaviour of ANS H-O in flight situations the graphic models relationships between a cause and an impact - graphs, trees, events and functional networks of stochastic structures – might be useful [10]. To study the impact of decision making by H-O during the flight situations development we have applied the stochastic network type GERT (Graphical Evaluation and Review Technique). GERT allows to model increase of flight situation complication as well as its decrease and/or simplification. GERT is an alternative probabilistic method of network planning applicable in the case when these actions can only start after completion of a prior action including cycles and loops [10].

Purpose of work

The purposes of the article are:

– to develop a methodology for analysis of decision-making by H-O ANS;

– to research and formalize the factors that influence decision-making by H-O ANS as a complex socio-technical system;

– to develop the reflexive model of bipolar choice of H-O ANS in flight situations;

– to create stochastic network analysis of flight situations.

Methodology for analysis of decision-making by human-operator of Air Navigation System

The analysis of decision making by H-O ANS in non standard flight situations was based on the methodology developed by us and presented in the tab. 1.

As a result of previous studies we have identified factors that influence the decision-making H-O ANS: professional factors (knowledge, skills, abilities, experience) and non-professional factors (individual-psychological, psycho-physiological, socio-psychological factors). The influence of individual-psychological factors on professional activities H-O (civil pilots and controllers) has been studied [8].

The respondents were military pilots and navigators of different ages with different professional experience. We have identified the importance of their individual-psychological qualities (tab. 2, fig. 1, 2) and the influence of socio-psychosocial factors on decision making in their professional activity (tab. 3, fig. 3).

For analyzing the individual-psychological factors modified coefficients were used. They represented the multiplication of weight coefficients of factors and quantitative indicators which determine qualitative characteristics of flight situation's risk levels depending on their complexity [11].

By comparing the weight value the preferences system of non-professional factors for military aviation specialists have been defined.

Investigation of the individual-psychological and socio-psychological factors influence on professional activities of H-O ANS made it possible to obtain information about such structural components of aviation specialist's personality as behavioural motives, values and priorities, hierarchy and development of these dynamic categories at the stages of H-O decision-making: perception of information, identification of the situation, making decisions, undertaking actions.

Reflexive model of bipolar choice of human operator of the Air Navigation System in flight situations

With bipolar reflexive behavioural model of H-O in extreme situations [9] we have received W-functions of a positive and a negative choice. The model represents the subject (H-O) located before the bipolar choice of one of the alternatives: A (positive pole) and B (negative pole).

The choice of H-O ANS is described by the function (1):

$$X = f\,(x_1, x_2, x_3),$$

where X – is probability that H-O is ready to choose a positive pole A in the reality;

x_1 – is a pressure of the environment on H-O toward positive alternative at the moment of choice, $x_1 \in [0, 1]$;

x_2 – is a pressure of the previous experience of H-O toward positive alternative at the moment of choice, $x_2 \in [0, 1]$;

x_3 – is a pressure of the intention of H-O toward positive alternative in moment of the choice, $x_3 \in [0, 1]$.

An alternative solution is the choice of H-O which is determined by H-O decision-making system in a risk (stochastic uncertainty).

Table 1. **The methods of analysis of H-O ANS decision-making in flight emergencies (FE)**

Number	Phase of analysis	Result
1	Preliminary analysis of the problem	The choice of FE for the analysis - FE selected for analysis (FE SfA). Statistical analysis of aviation accidents, study of selection FE. Analysis of literature and forming a sample of 5-7 FE SfA
2	Technology of work of H-O (controller, pilot) in FE	Algorithm of aircraft crew's actions in FE SfA (according to aircraft type in the sample that formed). Algorithm of controller's actions in FE SfA. Flowchart of algorithm of aircraft crew's actions in FE SfA. Flowchart of algorithm of controller's actions in FE SfA
3	Determination of model's parameters	Determination of time t_i (t_i'), required for the performance of i-procedure according to the algorithm of aircraft crew's actions in FE SfA by the experimental (expert) method. Determination of time t_j (t_j'), required for the performance of i-procedure according to the algorithm of controller's actions in FE SfA by the experimental (expert) method. Comparative analysis of experimental (t_i, t_i') and expert data (t_j, t_j')
4	Development of graphic analytical models (GAM)	GAM of EF. GAM of H-O decision-making in FE. GAM of flight situations
4.1	Development of deterministic models of H-O decision-making in FE	Network planning of aircraft crew's (AC) actions in FE SfA: 1. Structural time-table of AC actions in FE SfA. 2. Network graph of AC actions in FE SfA. 3. Critical time of AC actions FE SfA. 4. Critical path of AC actions in FE SfA. 5. Stages of H-O decision-making to parry FE SfA
		Network planning of controller's actions in FE SfA: 1. Structural time-table of controller's actions in FE SfA. 2. Network graph of controller's actions in FE SfA. 3. Critical time of controller's actions FE SfA. 4. Critical path of controller's actions in FE SfA. 5. Stages of H-O decision-making to parry FE SfA
4.2	Development of stochastic models of H-O decision-making in FE	1. Structural analysis of FE SfA development. 2. Analysis of models' uncertainty. 3. Analysis of the effects of flight situations development. 4. Analysis of H-O decision-making using decision trees. 5. Analysis of H-O decision-making using stochastic networks. 6. Finding a minimal risk of flight situations development
4.3	Development of reflexive models of bipolar choice of H-O decision-making in FE	1. System analysis and formalization of the factors that affect H-O decision-making (individual-psychological, psycho-physiological, socio-psychological) during the flight situation development from normal to catastrophic: – preferences models of H-O individual-psychological factors significance; – models of psycho-physiological factors; – preferences models in impact of socio-psychological factors on H-O. 2. Determination of expected risks of H-O decision-making on the basis of the reflexive theory of bipolar choice

Table 2. **The significance of individual-psychological factors of military navigators and pilots in the conditions of flight situations development**

Number	Individual-psychological factors	Modified coefficients of factors									
		Normal situation		Complicated situation		Difficult situation		Emergency situation		Catastrophic situation	
		Navi-gator	Pilot	Navi-gator	Pilot	Navi-gator	Pilot	Navi-gator	Pilot	Navi-gator	Pilot
1	Temperament	0,2	1,1	0,9	3,3	2	6,5	5,6	13,6	4	17
2	Attention	1,3	1,6	4,8	4,8	8	8	12,8	8,8	13	11
3	Perception	0,9	0,7	3	2,7	6,5	4,5	10,4	13,6	16	17
4	Thinking	1,1	0,4	3	2,1	5,5	3,5	7,2	5,6	9	7
5	Imagination	0,7	0,9	0,9	1,2	1	2	1,6	2,4	2	3
6	Nature	0,4	0,2	2,1	0,6	3,5	1	3,2	1,6	7	2
7	Intention	1,8	1,3	5,4	3,9	9	5,5	14,4	7,2	18	9
8	Health	1,6	1,9	3,9	5,7	4,5	9,5	8,8	13,6	11	17
9	Experience	2	1,9	6	5,7	10	9,5	16	13,6	20	17
Risk level, units		10	10	30	30	50	50	80	80	100	100

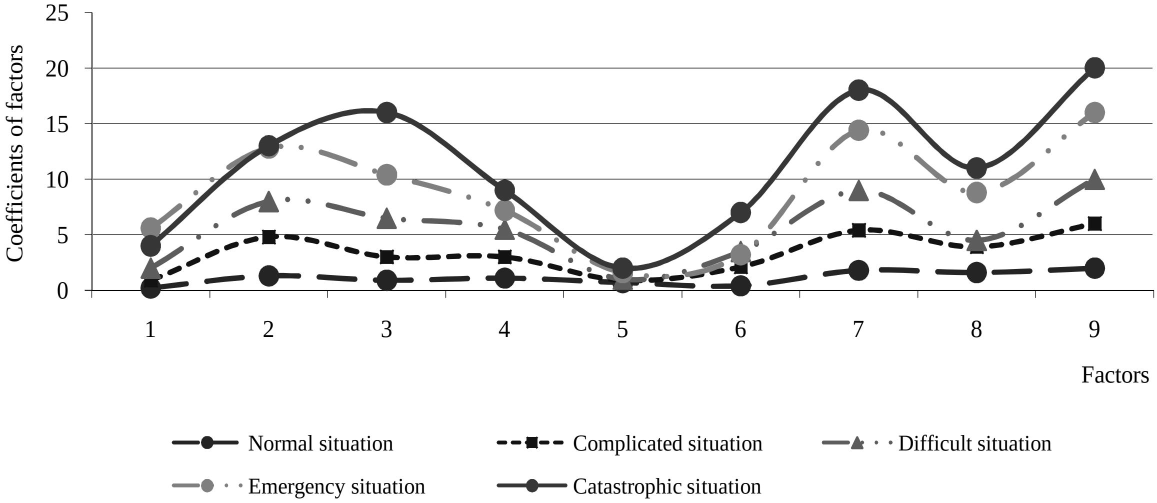

Fig. 1. The significance of individual-psychological factors of military navigators in the conditions of flight situations development:
1 – temperament;
2 – attention;
3 – perception
4 – thinking;
5 – imagination;
6 – nature;
7 – intention;
8 – health;
9 – experience

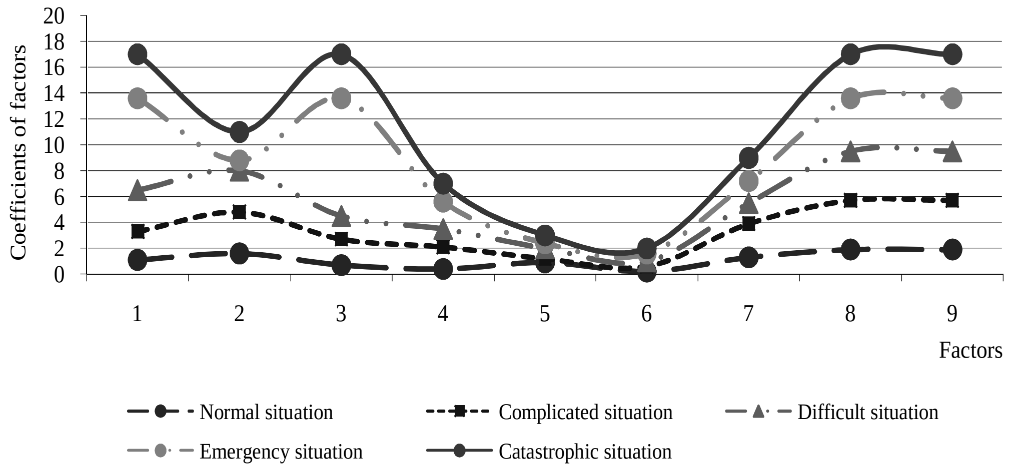

Fig. 2. The significance of individual-psychological factors of military pilots in the conditions of flight situations development:
1 – temperament;
2 – attention;
3 – perception
4 – thinking;
5 – imagination;
6 – nature;
7 – intention;
8 – health;
9 – experience

Table 3. **The preferences system of military pilots and navigators**

Number	Socio-psychological factors	Pilot			Navigator		
		Average of factor	Weight of factor	Rank of factor	Average of factor	Weight of factor	Rank of factor
1	Moral factors	4,67	0,07	5	4,75	0,07	5
2	Economic factors	2,00	0,27	2	2,20	0,27	2
3	Social factors	1,00	0,33	1	1,60	0,33	1
4	Political factors	4,33	0,13	4	4,20	0,13	4
5	Legal factors	3,00	0,20	3	2,30	0,20	3

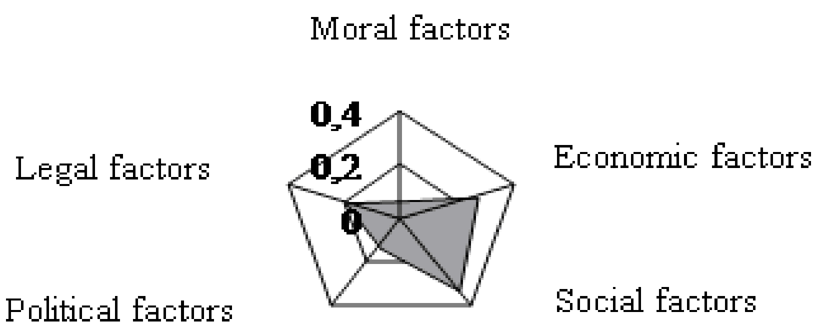

Fig. 3. The influence of socio-psychological factors on the professional activities of military pilots and navigators

The optimal solution is found by the criterion of an expected value with the principle of risk minimizing:

$$A_{opt} = \min\{R_{ij}\},$$

where R_{ij} - is expected risk for solution A_{ij}, which is determined by formula:

$$R_{ij} = \sum_{j=1}^{m} p_{ij} u_{ij}\ ,\ i = \overline{1,n},\ j = \overline{1,m},$$

where p_{jj} - is probability of j-factor influence during i-alternative solution choice, $\sum_{j=1}^{m} p_j = 1$;

u_{ij} – is a loss associated with choosing i-alternative solution during j-factor influence.

The alternative solution B is the choice of H-O which is determined by H-O preferences system under which any form of arrangement of F-set is understood, i.e., removing the uncertainty of choice of some element $f^* \in F$ on the basis of selection of a rule K. A selection of a rule K shows the concept of a rational behaviour of individual γ and his preferences system ρ in a particular situation of choice: $\{\gamma, \rho\} \rightarrow K$.

The H-O ANS preferences system is influenced by professional $\overline{F}_p$ and non-professional $\overline{F}_{np}$ factors:

$$\overline{F}_p = \{\overline{F}_{ed}, \overline{F}_{\exp}\};$$

$$\overline{F}_{np} = \{\overline{F}_{ip}, \overline{F}_{pf}, \overline{F}_{sp}\},$$

where $\overline{F}_{ed}$ – is knowledge, skills and abilities acquired by H-O during training;

$\overline{F}_{\exp}$ – is knowledge, skills and abilities, acquired by H-O during professional activity;

$\overline{F}_{ip} = \{f_{ipt}, f_{ipa}, f_{ipp}, f_{ipth}, f_{ipi}, f_{ipn}, f_{ipw}, f_{iph}, f_{\exp}\}$ – is a set of H-O individual-psychological factors (temperament, attention, perception, thinking, imagination, nature, intention, health, experience);

$\overline{F}_{pf}$ – is a set of H-O psycho-physiological factors (features of the nervous system, emotional type, sociotype);

$\overline{F}_{sp} = \{f_{spm}, f_{spe}, f_{sps}, f_{spp}, f_{spl}\}$ – is a set of H-O socio-psychological factors (moral, economic, social, political, legal factors).

For example, the preferences system of a pilot is on the set of individual-psychological factors $\overline{F}_{ip}$ (fig. 1) which reflect the objective characteristic of decision-making and thinking psychology of H-O: he is guided by a rational action [12] in cases of normal and catastrophic situations:

$$(f_{iph}, f_{\exp}) \succ f_{ipa} \succ f_{ipw} \succ f_{ipt} \succ \succ f_{ipi} \succ f_{ipp} \succ f_{ipth} \succ f_{ipn},$$

$$(f_{iph}, f_{\exp}) \succ (f_{ipt}, f_{ipp}) \succ f_{ipa} \succ \succ f_{ipw} \succ f_{ipth} \succ f_{ipi} \succ f_{ipn},$$

where f_{iph} – is health;

f_{ipexp} – is experience;

f_{ipa} – is attention;

f_{ipw} – is intention;

f_{ipt} – is temperament;

f_{ipi} – is imagination;

f_{ipp} – is perception;

f_{ipth} – is thinking;

f_{ipn} – is nature.

In both cases the most significant factors are health and previous experience. During a flight situation development towards catastrophy such factors as temperament and ability to perceive information are getting much more significant role. Other individual-psychological factors remain unchanged.

The obtained preferences models (fig. 2) for military pilots and navigators determine the priorities of socio-psychological factors $\overline{F}_{sp}$:

$$f_{sps} \succ f_{spe} \succ f_{spl} \succ f_{spp} \succ f_{spm},$$

where f_{sps} – social factors;

f_{spe} – economic factors;

f_{spl} – legal factors;

f_{spp} – political factors;

f_{spm} – moral factors.

Similarly to civil aviation controllers and pilots [8], military pilots and navigators are under influence of socio-economic factors. Detailed analysis of the influence of 13 socio-psychological factors (religious views, philosophical views, career, reputation, corporate interests, economic interests of enterprise, private economic interests, family interests, interests of colleagues, interests of the company's management, image, political interests, legal rules) demonstrated that for pilots their own image, corporation's image and family interests are on the first place. At the same time, for respondents-controllers main focus is on the family interests, their private economic situation and career development [8].

Stochastic networks analysis of flight situation development

In stochastic networks of the flight situation development of GERT type the tops are represented by stages of the situation (normal, complicated, difficult, emergency or catastrophic), and the arcs are represented by a process of transition between stages of the situation.

Let's consider the stochastic network model of the flight situation development GERT G = (N;A) with a set of tops N and a set of arcs A. The time t_{ij} of transition from i-flight situation to j-flight situation is a random variable. Transition (i;j) can be executed only if i-top has been done. For calculation of transition time t_{ij} from i-flight situation to j-flight situation it is necessary to know conditional probability (in discrete cases) or the density of distribution (in continuous cases) of random variable Y_{ij}. This allows to research the performance of the whole network G = (N;A) and to identify the moments of time distribution t_{ij} of network G, calculate mathematical expectation μ_{jE} and variance of execution time δ^2 of network G in case of a complicated, complex, catastrophic or emergency situation.

Let f_{ij} be conditional probability (density of distribution) of time to make the transition from flight situation G_i to flight situation G_j. Conditional producing function of moments of random variable Y_{ij} is defined by formula:

$$M_{ij}(s) = E\left[e^{Y_{ij}}\right]. \qquad (1)$$

In continuous and discrete cases the random variables formula (1) is being transformed to formulas and accordingly:

$$M_{ij}(s) = \int e^{sy_{ij}} f(y_{ij}) dy_{ij} ;$$

$$M_{ij}(s) = \sum e^{sy_{ij}} f(y_{ij}) .$$

If y_{ij}=a=const, then $M_{ij}(s) = E\left[e^{sa}\right] = e^{sa}$.

W-function for random variable Y_{ij} as a transmission coefficient of GERT-network is introduced:

$$W_{ij}(s) = p_{ij} M_{ij}(s) ,$$

where p_{ij} – probability that j-flight situation occurs and transition (i;j) has been made;

$M_{ij}(s)$ – conditional producing function of moments of random variable Y_{ij}.

The algorithm of stochastic network analysis is presented here on an example of GERT-network:

1. For obtaining close stochastic network, G is entered in the open stochastic network $W_E(s)$ additional dummy arc with a W-function $W_A(s)$ which connects the drainage of open network t with a source s (fig. 4).

2. For a modified network G determines all k-loops, $k = \overline{1,n}$.

3. The equivalent transmission coefficient for all k-loops of G-network, $k = \overline{1,n}$ is being calculated.

$$T(L_n) = \prod_{k=1}^{n} T_k = \prod_{k=1}^{n} \left[\prod_{(i,j)\in L_{k_1}} t_{ij} \right],$$

where $T_k = \prod_{(i,j)\in L_{k_1}} t_{ij}$ – is equivalent transmission coefficient for 1-loop L_{k1};

t_{ij} – is time of transition from i-flight situation to j-flight situation.

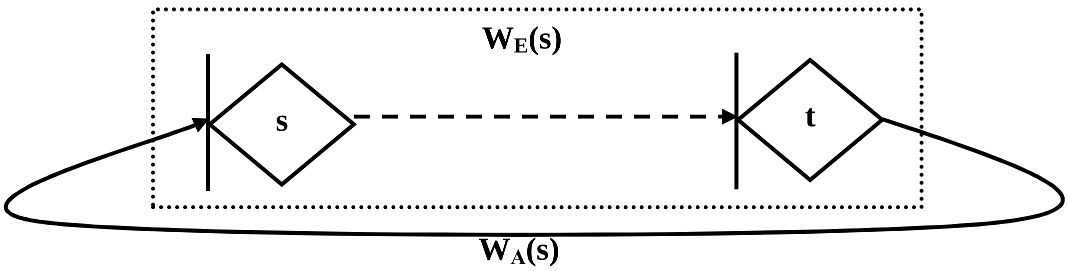

Fig. 4. GERT network
$W_E(s)$ – transmission coefficient of open network;
$W_A(s)$ – transmission coefficient of dummy arc;
s – source of network;
t – drainage of network

4. To apply Mason's rule for topological equation close stochastic network G:

$$H = 1 - \sum T(L_1) + \sum T(L_2) - \\ - \sum T(L_3) + ... + (-1)^k \sum T(L_k) + ... = 0, \quad (2)$$

where $\sum T(L_k)$ – is a sum of equivalent transmission coefficients for all possible k-loops.

5. From topological equation of the close stochastic network G (2) transmission coefficient of the open network $W_E(s)$ is determined.

6. To determine the first and the second moments of random variable Y_{ij}:

$$\mu_{jE} = \frac{\partial^j}{\partial s^j}\left[M_E(s)\right],$$

where μ_{1E} – is mathematical expectation of execution time of the network G;

μ_{2E} – is a standard deviation of execution time of the network G.

Thus according to results of stochastic network analysis of the flight situation development from normal to catastrophic the following values have been obtained:

- mathematical expectation of flight situation development time t_{ij};
- variance of flight situation development time t_{ij};
- probability of flight situation development p_{ij}.

For example, let's analyze catastrophic situation development under hazardous weather conditions using the decision tree and stochastic network GERT (fig. 5). According to the data of the National Transportation Safety Board (NTSB) [13] during the last 10 years 21,3% of aviation accidents happened due to weather conditions, of which 39,1% - in bad weather conditions. The major cause of aviation accidents in bad weather conditions (68%) considered improper and untimely decision-making by crew of the aircraft.

Based on the W-functions of positive and negative of H-O choice the Markov's network of flight situations' development from normal to catastrophic was constructed (fig. 6). Markov's process with discrete states W_{ij} is called process of death and life [14].

Expected risks R_A, R_B of H-O obtained in decision-making during the approach performed in bad weather conditions under the influence of external environment x_1, previous experience of H-O x_2 and intention of H-O x_3. Expected risk of H-O decision-making is:

$$R_{ПР} = \begin{cases} R_A = \min\{R_{ij}\}; \\ R_B = \{\gamma, \rho\}, \end{cases}$$

where R_A – is expected risk of H-O in decision-making taking into account the criterion of minimizing the expected value;

R_B – is expected risk of H-O decision-making taking into account his preferences model.

Conclusions

1. Regarding the Air Navigation System as a complex socio-technical system the research based on methodology of analysis of human-operator's decision-making has been carried out.

2. The impact of individual-psychological and socio-psychological factors on the professional activities of human-operator during the flight situation development from normal to catastrophic has been studied.

3. On the basis of the reflexive theory of bipolar choice the expected risks of decision-making of the Air Navigation System's operator have been studied and the influence of external environment, previous experience and intention of the human-operator has been identified.

4. The methods for analysis of decision-making by the human-operator of Air Navigation System using stochastic networks have been developed.

References

1. *Keating, C. B.; Fernandez, A. A.; Jacobs, D. A.; Kauffmann, P.* 2001. A methodology for analysis of complex sociotechnical processes. Business Process Management Journal. Iss: 1. Vol. 7: 33–50.

2. Bertsch, V.; Treitz, M.; Geldermann, J.; Rentz, O. 2007. Sensitivity analyses in multi-attribute decision support for off-site nuclear emergency and recovery management. International Journal of Energy Sector Management. Iss: 4. Vol. 1: 342–365.

3. *Flueler T.* 2006. Decision Making for Complex Socio-Technical Systems: Robustness from Lessons Learned in Long-Term Radioactive Waste Governance (Environment & Policy). Springer. 392 p.

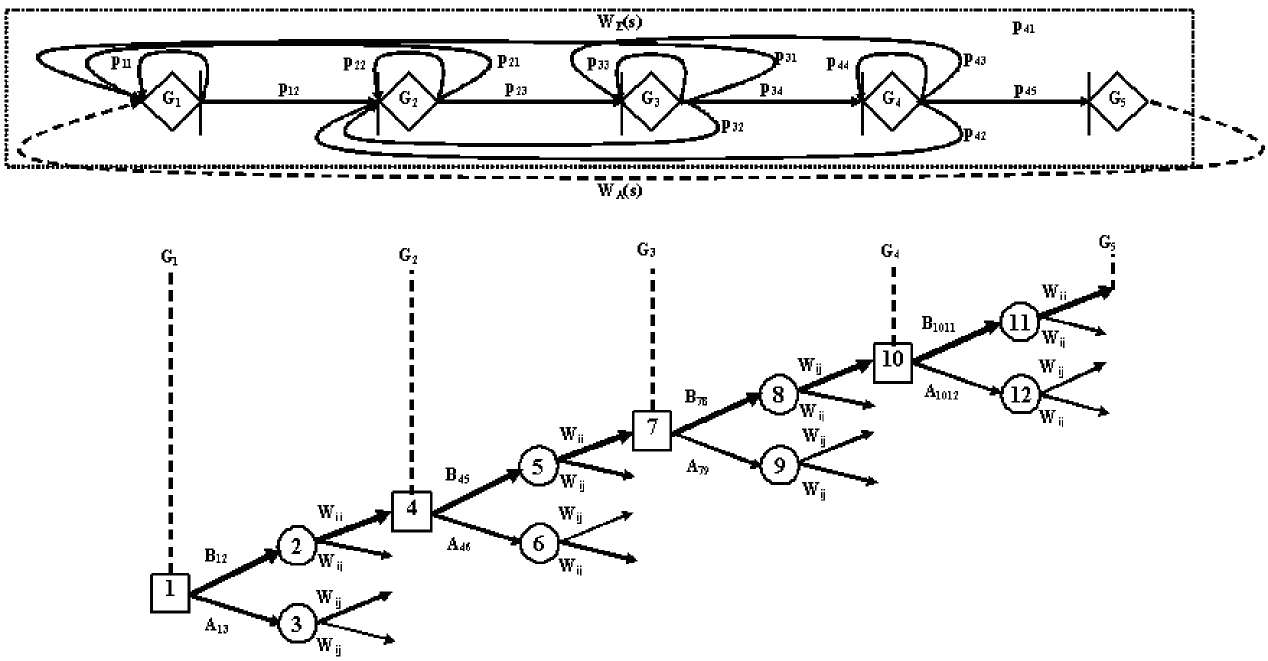

Fig. 5. Graphic analytical model of flight situations' development:

– decision tops;

– random tops;

A – choice towards the positive pole;

B – choice towards the negative pole;

W_{ij} – W-function, transmission coefficient of (i,j)-arc;

$W_E(s)$ – transmission coefficient of open network;

$W_A(s)$ – transmission coefficient of dummy arc;

G_1 – normal situation;

G_2 – complicated situation;

G_3 – difficult situation;

G_4 – emergency situation;

G_5 – catastrophic situation;

p_{ii} (p_{11}, p_{22}, p_{33}, p_{44}) – probability of stabilization of i-flight situation, $i = \overline{1; n-1}$;

$p_{i(i+1)}$ (p_{12}, p_{23}, p_{34}, p_{45}) – probability of development of i-flight situation toward complications, $i = \overline{1; n-1}$;

$p_{i(i-k)}$ (p_{21}, p_{32}, p_{43} – 1-loop; p_{31}, p_{42} – 2-loop; p_{41} – 3-loop) – probability of flight emergency situation parrying, $k = \overline{1; 3}$

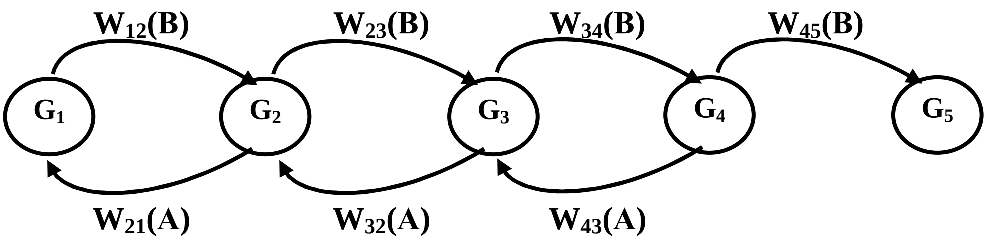

Fig. 6. Markov's network of flight situations' development:

G_1 – normal situation;

G_2 – complicated situation;

G_3 – difficult situation;

G_4 – emergency situation;

G_5 – catastrophic situation;

W_{ij} (A) – transmission coefficient of (i,j)-arc in positive choice;

W_{ij} (B) – transmission coefficient of (i,j)-arc in negative choice

4. *Энциклопедия* безопасности авиации / Н. С. Кулик, В. П. Харченко, М. Г. Луцкий и др. / под ред. Н. С. Кулика. – Київ: Техніка, 2008. – 1000 с.

[Encyclopedia of aviation safety. N.S. Kylik, V.P. Kharchenko, M.G. Lutskiy, et al. 2008. Editor N.S. Kylik. Kyiv. Technology. 1000 p.] (in Russian).

5. *Человеческий* фактор, управление и организация // Международная организация гражданской авиации: сб. // Circ. 247-AN/148. – Канада, Монреаль, ICAO,1994. – Вып. 10. – 38 с.

[Human factor, operation and organization: Collected material. International organization of civil Фviation. Circ. 247-AN/148. Canada. Montreal. ICAO. 1994. N 10 38 p.] (in Russian).

6. *Кросскультурные* факторы и безопасность полетов: сб. материалов по человеческому фактору // Circ. ICAO 302-AN/175. – Канада, Монреаль, ICAO, 2004. – № 16. – 52 с.

[Crossculture factors and safety of flights: Collected materials of human factors. Circ. ICAO 302-AN/175. Canada. Montreal. ICAO. 2004. N 16. 52 p.] (in Russian).

7. *Макаров, Р.Н.; Нидзий, Н.А.; Шишкин, Ж. К.* Психологические основы дидактики летного обучения. – Москва: МАПЧАК, 2000. – 534 с.

[*Makarov, R.N.; Nidziy, N.A.; Shishkin, G.K.* 2000. Psychological foundations of didactics in flight education. Moscow. MAPCHAK. 534 p.] (in Russian).

8. *Харченко, В. П.; Шмельова, Т. Ф.; Сікірда, Ю. В.* Графоаналітичні моделі прийняття рішень людиною-оператором аеронавігаційної системи // Вісник НАУ. – 2011. – №1. – С. 5–17.

[*Kharchenko, V.P.; Shmeleva, T.F.; Sikirda, Y.V.* 2011. The human operator's decision-making graphic analytical models. Proceedings of NAU. N 1: 5–17.] (in Ukrainian).

9. *Лефевр, В. А.; Адамс-Вебер, Дж.* Функции быстрой рефлексии в биполярном выборе // Рефлексивные процессы и управление. – 2001. – №1.– Июль-декабрь. – Т. 1. – С. 34–46.

[*Lefevr, V.A.; Adams-Veber, J.* 2001. Functions of rapid reflection in bipolar choice. Reflection processes and operations. N 1. July-December. T. 1: 34–46.] (in Russian).

10. *Филлипс, Д.; Гарсиа-Диас, А.* Методы анализа сетей: пер. с англ. – Москва: Мир, 1984. – 496 с.

[*Phillips, D.; Garcia-Dias, A.* 1984. Fundamentals of network analysis. Moscow. World: 496 p.] (in Russian).

11. *Бєляєв, Ю.Б.; Шмельова, Т.Ф.; Сікірда, Ю.В.* Моделювання процесу прийняття рішень оператором авіаційної ергатичної системи в особливих випадках польоту // Автоматизація виробничих процесів. – 2003. – №2 (17). – С. 17–23.

[*Belyaev, Y.B.; Shmeleva, T.F.; Sikirda, Y.V.* 2003. Modeling of decision-making by human-operator of aviation system when a special occasion in Automation of production processes. N 2 (17): P. 17–23.] (in Ukrainian).

12. *Рева О. М.* Прийняття рішень шляхом виявлення системи пріоритетів (переваг) авіаспеціаліста: методичні вказівки. – Кіровоград, 1996. – 18 с.

[*Reva, A.N.* 1996. Decision-making by detection of system of priorities (advantages) by specialist: methodological instructions. Kirovograd. 18 p.] (in Ukrainian).

13. *Aviation Accident Statistics* [Electronic resource] / National Transportation Safety Board. – Mode of access: www.ntsb.gov/aviation/aviation.htm. – Last access: 2011. – Title from the screen.

14. *Саати, Т. Л.* Элементы теории массового обслуживания и ее приложения: 3-е изд. / пер. с англ. – Москва: Книжный дом "ЛИБРОКОМ", 2010. – 520 с.

[*Thomas L. Saati.* 2010. Elements of queuing theory. With applications. 3nd ed. Moscow. Bookshop “LIBROCOM”. 520 p.] (in Russian).

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