Integration Deterministic, Stochastic and Non-Stochastic Uncertainty Models in Conflict Situations

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Abstract. The authors present an approach to conflict management in groups of operators, which is to enhance the effectiveness of Collaborative Decision Making (CDM) in an organizational setting. The decision making (DM) models such as DM in Risk and Uncertainty, DM in Certainty offered. The authors made an analysis of the International civil aviation organization (ICAO) documents on risk assessment. To determine the quantitative characteristics of risk levels, models for DM by the operators of the aviation systems under risk and uncertainty have been developed. The new methodology includes the process of Integration Deterministic Stochastic and Non-Stochastic Uncertainty Models for Network Planning models in Conflict Situations.

Keywords: Collaborative Decision Making, Decision Making in Risk and in Uncertainty, Decision Making in Certainty, Conflict management, Network Planning, Stochastic and Non-Stochastic Uncertainty Models

1 Introduction

Conflict management has advantages in different organization systems, including in Aviation systems, where operators decision making in difficult situations. Properly managed conflict can improve group results of decisions [1; 2]. The effectiveness of aviation systems and the provision of flight safety still depend primarily upon the reliability of aviation specialists and human decision making, individual and group outcomes of decisions.

In aviation, significant attention is paid to Safety Management. Safety is the state in which the risk is reduced to and maintained at or below, an acceptable level through a continuing process of hazard identification and risk management [3; 4]. In determining an acceptable level of safety, it is necessary to consider such factors as the level of risk that applies the cost/benefits of improvements to the system, outcomes after a decision by Conflict management methods, and public expectations on the safety of the aviation industry.

To determine an acceptable level of risk and balance between decision performance and safety requirements, it is necessary to have quantitative characteristics of DM under risk conditions in conflict (critical) situations. Safety is a dynamic characteristic of aviation with the help of which risk factors for flight safety should steadily decrease. The adoption of efficiency indices of ensuring flight safety is frequently influenced by internal and international standards and also by cultural features [5]. Aviation systems cannot be wholly free from dangerous factors and connected with them risks, while, the elimination of aviation events and serious incidents continues to be the final goal of human activity in the sphere of aviation safety. Neither human activity nor systems created by it guarantee a total absence of operating errors and their consequences [6].

International civil aviation organization constantly develops and improves proactive, based on the evaluation of the risks. A modern approach, founded on the characteristics (performance-based approach – PBA), based on the next three principles monitoring [7; 8].

- the main accent on desired/necessary results;
- decision making, oriented on desired/necessary results;
- using facts and data while DM.

Herein the principle "using facts and data while decision making" admits that tasks shall comply with the widely known in Western management criteria SMART (specific, measurable, achievable, relevant and timebound) [3; 8].

The Global Air Traffic Management Operational Concept [3] assumes provision collaborative decision making (CDM) between all operational partners [9]. Implementation of the CDM requires the use of a modern information environment based on the concepts of System Wide Information Management (SWIM) and Flight & Flow Information for a Collaborative Environment (FF-ICE) [3; 9; 10].

Such a level of accuracy of tasks determination may be achieved only using the new methodology includes the process of Integration Stochastic and Non-Stochastic Uncertainty Models for Network Planning models in Conflict Situations.

The purposes of the work are:

- analysis multi-DM in certainty using Network Planning Models for all operators in the same organization;
- building DM models - DM in Uncertainty and DM under Risk for maximization of effectiveness and minimization of risks in the Network Planning Model for operators in the organization.

2 The integration Stochastic and Non-Stochastic Uncertainty Models to Deterministic Model of Multi-Decision Making

2.1 Deterministic Models in Multi-Decision Making

The Decision making by operators in a conflict situation and for the analysis of the actions of operators with the aid of the Network Planning methods gave a chance to obtain:

1. Identify the technology of H-Os for the project.
2. Determination of a group of DM in problem/conflict situation for building a multi DM graph.

3. Expert estimation of priority of DM in problem/conflict situation using Expert Judgment Method (EJM)
4. Decomposition of main technology (problem/conflict situation) on procedures of each DM graph.
5. Flowchart of performance technology works (problem/conflict situation) by procedures for each DM graph.
6. Determination of the times of operating procedures using the Expert Judgment Method (according to experimental, to statistics data too).
7. Structural-timing table of operational procedures and time on the operating procedures in main technology (problem/conflict situation).
8. Network graph of operating procedures main technology (problem/conflict situation).
9. Analysis each part of main technology (problem/conflict situation) using assessment by DM in Stochastic Uncertainty (DM in Risk) and Non-stochastic Uncertainty (DM in Uncertainty) methods.
10. Integration of Deterministic and Stochastic models for CDM.
11. Determination of critical time for each DM in the project (problem/conflict situation) and main DM.
12. Determination of the critical path for each DM of the project main DM

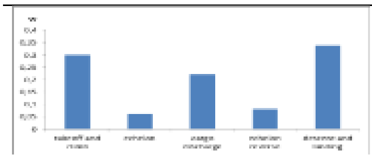
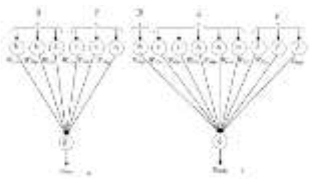
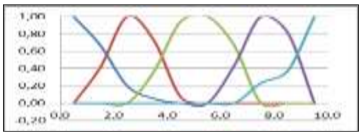
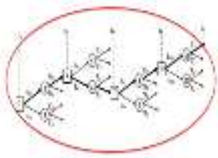
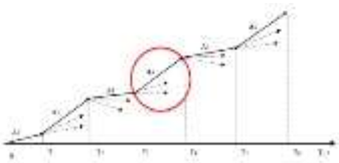
As known, the environmental conditions (natural, social, communication, etc.) determine the reaction of operators, while the reaction of the latter, in its turn, changes the environmental conditions themselves. The systemic analysis has been carried out as well as the formalization of the factors which affect DM by operators in the Air Navigation System (individual-psychological, psycho-physiological and social-psychological) in the emergency [11; 12]. The impact of individual-psychological and socio-psychological factors on the professional activities of operators during the conflict situation and development from normal to catastrophic has been studied. On the basis of the reflexive theory of bipolar choice, the expected risks of DM have been studied and the influence of the external environment, previous experience and intention of the operator have been identified [11].

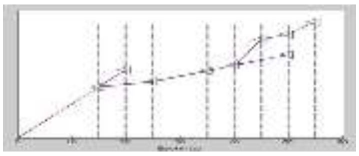
It is very important to create highly intelligent joint DM systems for operators those decision problems in the one team. In research are presented DM models for operators (pilots of manned and unmanned aircraft, air traffic controller's , engineers, flight dispatch, etc.) in emergencies in ANS [11]; the deterministic and stochastic models of DM for different operators of ANS and collaborative DM; stochastic models type Markov Chains; Stochastic models type GERT's (Graphical Evaluation and Review Technique) network; Neural Network models; Fuzzy logic models; Reflexive models of bipolar choice; models of diagnostics of emotional state deformation in the professional activity of operators in the ANS; Graphical-Analytical Models of situation Development; Graphical-Analytical Models of DM by human-operator (H-O) etc. [11].

In the recent documents, ICAO defined new approaches - the organization of Collaborative Decision Making (CDM) by all aviation operators using collaborative DM models (CDMM) based on general information on the flight process and features of the critical situation [9; 10].

In the process of analysis and synthesis of DM models in critical situations makes sense to simplify complex models and solutions. So, for example, stochastic and non-stochastic of uncertainty models, the Markov and GERT-models, reflexion models integrate into deterministic models. The models for decision and predicting of the critical situation using CDMM – technology presented in Table 1.

Table 1. *The models for decision in critical situations using CDMM-technology*

Models	Describing of modelling emergency
	Expert assessment of the complexity of the Situations, for example flight stages.
	Neural Network Model to determine potential alternative of the critical situation completion. Determination of weight coefficients of neural network (probabilities for the model – DM in risk) and effectiveness of critical situation completion: $\{Y_G; Y_{Gaer}; Y_{Glf}; W\}$.
	Fuzzy logic to determine quantitative estimates of potential loss - functions of estimation risk R / outcomes U for next models of DM in Risk and Uncertainty-$\{g_r\}$
	DM in Risk (stochastic of uncertainty model). Stochastic models types' tree, GERT's network for DM and critical situation developing. The optimal solution is found by the criterion of an expected value with the principle of risk - A_{dopt}
	DM in Uncertainty (non-stochastic of uncertainty models). In DM matrix: alternative actions A = $\{A_1, A_2, \dots A_i, \dots, A_m\}$, states of situation or factors $\lambda = \{\lambda_1, \lambda_2, \dots \lambda_j, \dots, \lambda_n\}$ and outcomes u_{ij}
	DM in certainty (Deterministic model) using Network Planning method and DM in Risk / Uncertanty for each branch. Determined models for an operators with deterministic procedure - $t_i; ;T_{cr}; T_{mid}; T_{min}; T_{max}$



Optimal decision for action in critical situation for all operators in team.

However, for the formation (modeling) of DM, H-O has the property such as the ability to apply different levels of DM complexity depending on the factors that influence the DM. For DM in a difficult situation (S) it is necessary to identify:

– The class of situation (Q);
– Level of Complexity (U);
– Choosing the optimal actions (A*).

For example, $Q = \{q_j\}$ - the set of consequences of choosing the completion alternative; $U = \{u_j\}$ - vector of the characteristics of the consequences, the results of the choice of the alternative of the completion; $A = \{a_i\}$ is the set of alternative solutions) and choice the optimal actions (A*).

On Figure 1 scheme of process of simplifying a difficult situation presented. This process is necessary to apply for complex systems and solution too. It is important to create Expert system (ES) when analyzing the complexity, significance, and responsibility of subsystems before synthase and synchrony of collaborative mathematical models.

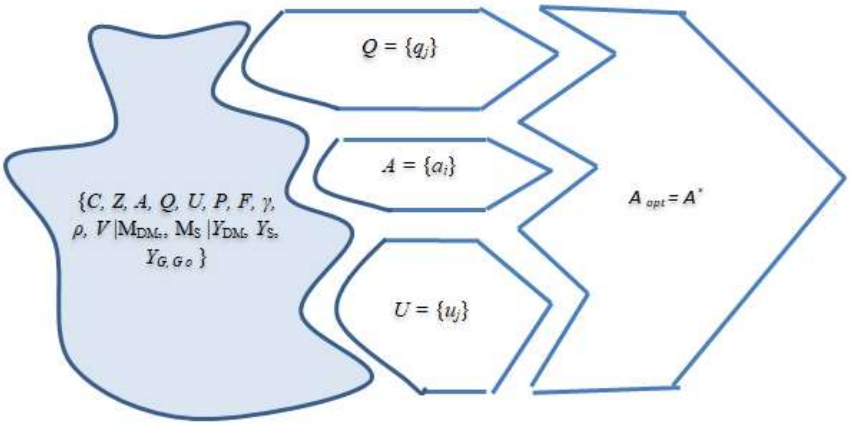


Fig. 1. *The scheme of process of simplifying a difficult situation*

The ES, one branch of artificial Intelligence (AI), is a computer system that simulates the DM ability of a human-operators. The ICAO documents recommend developing Intelligent ESs in aviation to support of operators [10]. Knowledge - characteristics of systems obtained as a result of practice and professional experience of experts. To build an ES, the following Algorithm of the building of Expert Systems is used:

*The Algorithm of the building of Expert Systems***.**

1. Building main components of ES: Users interface; Database; Base Knowledge.

2. System analysis of complex system. Decomposition of complex systems on subsystems:

1) Definition subsystems for expert estimation of their significance and description of the characteristics of subsystems.

2) Definition of criteria estimation and description of criteria features.

3) Estimation of subsystems using EJM by criterion and obtaining weight coefficients of subsystem significance by criterion.

3. Aggregation subsystems in systems.

1) Additive aggregation of subsystems:

$$W_j = \sum_{i=1}^{n} \omega_i F_{ij}, i = \overline{1,n}, j = \overline{1,m} \tag{5}$$

2) Multiplicative aggregation of subsystems:

$$W_j' = \prod_{i=1}^{n} F_{ij}^{\omega_i}, i = \overline{1,n}, j = \overline{1,m}, \tag{6}$$

4. Results of significance of subsystems in ES.

To build an ES, it is necessary to determine the significance of the subsystems (parameters, characteristics, values, etc.) in the system, which is investigated with the help of expert knowledge. The main method for building the Knowledge Base in the Expert System is the *EJM*. To build an ES, the following Algorithm of *Expert Judgment Method* is used:

Algorithm of Expert Judgment Method (EJM)

1) Questioners for experts, m – is a number of experts, $m \geq 30$

Matrix of individual preferences - determine opinion of the experts and their systems of individual preferences, R_i – is a system of preferences of i-expert, $i = \overline{1,m}$.

2) Matrix of group preferences R_{ij}

3) The experts' group opinion R_{grj} (sample average, arithmetical mean): $R_{grj} = \frac{\sum_{i=1}^{m} R_i}{m}$

4) The coordination of experts' opinion:

a. Dispersion for each factors (procedures, phases of flight of the aircraft,…):

$$Dj = \frac{\sum_{i=1}^{m} \left(R_{grj} - R_i\right)^2}{m-1}$$

b. Square average deviation (Squared deviations): $\sigma_j = \sqrt{D_j}$

c. Coefficient of the variation for each factors (procedure, phases of flight of the aircraft, etc…):

$$v_j = \frac{\sigma_j}{R_{grj}} \bullet 100\%$$

d. Kendal's coefficient of concordance or to provide interrogation of the experts:

$$W = \frac{12S}{m^2(n^3 - n) - m\sum_{j=1}^{m} T_j},$$

e. Rating correlation coefficient R_s (Spearman's coefficient):

$$R_{si} = 1 - \frac{6\sum_{j=1}^{n}(x_{ij} - y_{ij})^2}{n(n^2 - 1)}.$$

5) Significance of the calculations.

a. The significance of the calculations W, criterion - χ^2: $\chi_f^2 = \dfrac{S}{\frac{1}{2}m(n+1) - \frac{1}{12(n-1)}\sum_{j=1}^{m} T_j} > \chi_t^2,$

where χ_f^2 - factual value of variable; χ_t^2 - table value of variable.

b. The significance of the calculations R_s using Student's t - criterion:

$$t_{critical} = r_s\sqrt{\frac{n-2}{1-r_s^2}} > t_{st}.$$

6) Effectiveness of solution (preferences, priority of solutions) - weight coefficient w_j: $w_j = \dfrac{C_j}{\sum_{j=1}^{n} C_j}$; $C_j = 1 - \dfrac{R-1}{n}$

7) Results of solutions.

For example, analysis and synthesis of DM models in critical situation for operators in team presented on Figure 2.

When analyzing a critical situation in a team, each operator determines his actions to solve this problem. After building a structural-timing table of operational procedures with time on the operating procedures (using EJM for obtaining solution times) building Network graphs of operating procedures for all operators on Figure 2.

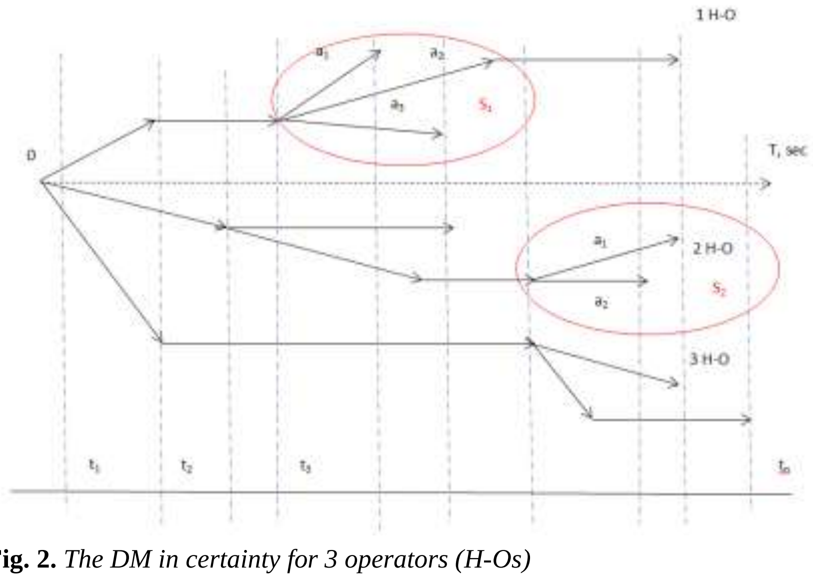


Fig. 2. *The DM in certainty for 3 operators (H-Os)*

The parallel process of simultaneous execution of technological operations in the situation can be represented as a consolidated multi-channel network. For a consistent optimization of such a network in order to achieve the cross-cutting efficacy of joint decisions, it is advisable to use a multi-criteria approach: achieving a minimum time for consolidation of critical situation operators' actions. Ways to optimize the network graph for performing procedures by operators in the critical situation (by minimizing time with maximum safety) are:

$$A_{opt} = \min\{R_m\}.$$

Risk of CDM by the operators in the critical situation (Fig. 3, situation S_2):

$$R_m = F_m(t_m; \{A, \alpha, p, u\}) = t_m(\sum_{k=1}^{n} p_k u_k + \alpha_k),$$

where R_m and $(<;>)R_{m-1}$.

For example, for decision tree in Fig. 3:

$R_3(A_{41}; A_{42}) = A_{41}$, because $A_{41} < A_{42}$,

where $A_{41} = t_3(p_{411}u_{411} + p_{412}u_{412}) + \alpha_{41}$;

$A_{42} = t_3(p_{421}u_{421} + p_{422}u_{422}) + \alpha_{42}$;

Analogically for $R_2(A_{31}; A_{32})$ and $R_1(A_{11}; A_{12})$:

$R_2(A_{31}; A_{32}) = A_{32}$, $A_{31} > A_{32}$,

$R_1(A_{11}; A_{12}) = A_{12}$, $A_{11} > A_{12}$.

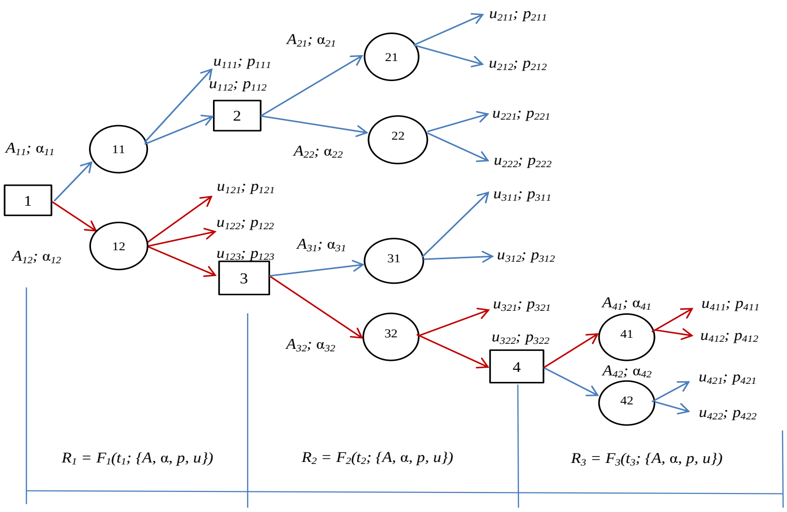


Fig.3 Decision tree for example DM in critical situation (CS), for part of situation S_2: t – is a time of CDM stage; A – is an alternative of decision; α – is a shift in the risk of developing CS according to stages on decision tree; p – is a probability of adverse effects; u – is a damage due to negative solution.

In order to simulate CDM under conditions of a critical situation, the next steps are a deep analysis of CS; intelligent data processing; identification of situation; formalization of the situation using integrated models; decomposition of the complex situation into subclasses; synthesis of adapted deterministic models to determine certain actions.

For decision-making in the presence of several decisions (part of situation S1), it is advisable to apply the DM model in uncertainty. In conditions of non-stochastic uncertainty, when the probability distribution that corresponds to the factors which influence the decision making (DM), either unknown or cannot be determined, the methodological basis for CDM is a matrix of decisions in Uncertainty (Figure 4).

Table 2. *The matrix of DM in Uncertanty*

		Factors influence DM in critical situation					
		λ_1	λ_2	…	λ_j	…	λ_n
Alternative actions in critical situation	A_1	U_{11}	U_{12}	…	U_{1j}	…	U_{1n}
	A_2	U_{21}	U_{22}	…	U_{2j}	…	U_{2n}
	…	…	…	…	…	…	….
	A_i	U_{i1}	U_{i2}	…	U_{ij}	…	U_{in}
	…	…	…	…	…	…	…
	A_m	U_{m1}	U_{m2}	…	U_{mj}	…	U_{mn}

Selecting the method (criteria for analyzing the decision problem) of decision making under uncertainty such as Laplace criterion (for often decisions); Criterion of Wald (for rare decisions); Savage criterion (for re-calculation of decisions); Hurwicz criterion (for decisions with different risk using the coefficient of optimism-pessimism) is carried out in accordance with the conditions of a problem situation.

The aggregated deterministic model with integrated stochastic models is shown in Fig. 4.

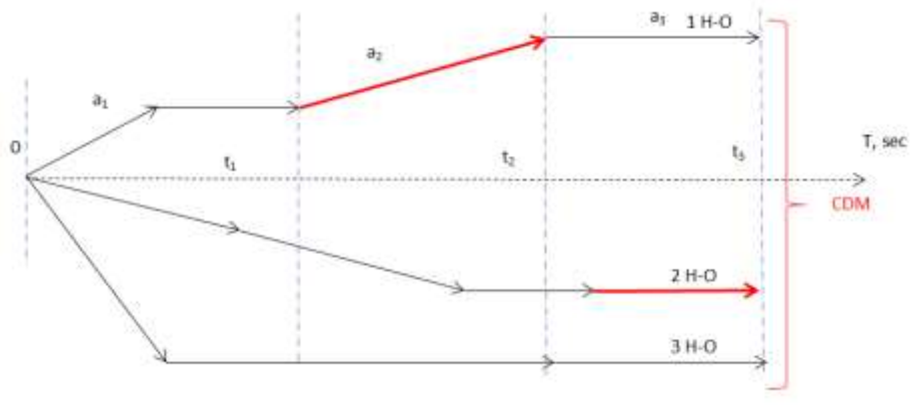


Fig.4 The aggregated deterministic model with integrated stochastic model

After correction network graphs using Stochastic and Non-Stochastic Uncertainty Models next step the determination of critical time and the critical path of the optimal collective solution

3 Conclusion

The CDM an uninterrupted process of presenting information and individual DM by various interacting participants, as well as providing synchronization of decisions taken by participants and the exchange of information between them. It is important to ensure the possibility of making a joint, integrated solution with partners at an acceptable level of efficiency. This is achieved by completeness and accuracy of available information. Solutions planning should provide using DM different models such as deterministic models; stochastic and non-stochastic of uncertainty models; the Markov and GERT-models, reflexion models. After analysis of the situation needs synthesis (aggregation) of stochastic models for the correction of deterministic model.

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