Decision-Making Modeling in Emergency "Unlawful Interference"

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Nomenclature

ACFT	Aircraft
ATCO	Air traffic control officer
CDM	Collaborative decision-making
DM	Decision-making
DMM	Decision-making model
ICAO	International Civil Aviation Organization

1 Introduction

Civil aviation, as an integral part of the transport system, is important for the economy and is playing an increasing role in the globalized economy. At the same time, aviation objects remain one of the most vulnerable to various hazards and can pose a significant threat to the public and the environment, even if all safety standards are met. Aviation is a source of increased danger to humans. From the second half of the last century, special attention has been paid to the fight against acts of unlawful interference in the activities of civil aviation – the most dangerous crimes in this area. Evidence of this is the numerous terrorist attacks on aircraft that have not stopped since the second half of the twentieth century.

One of the forms of unlawful interference in the activities of civil aviation is the hijacking of an aircraft (ACFT), which can take place both in the air and on the ground. According to the Aviation Safety Network (Aviation Safety Network,

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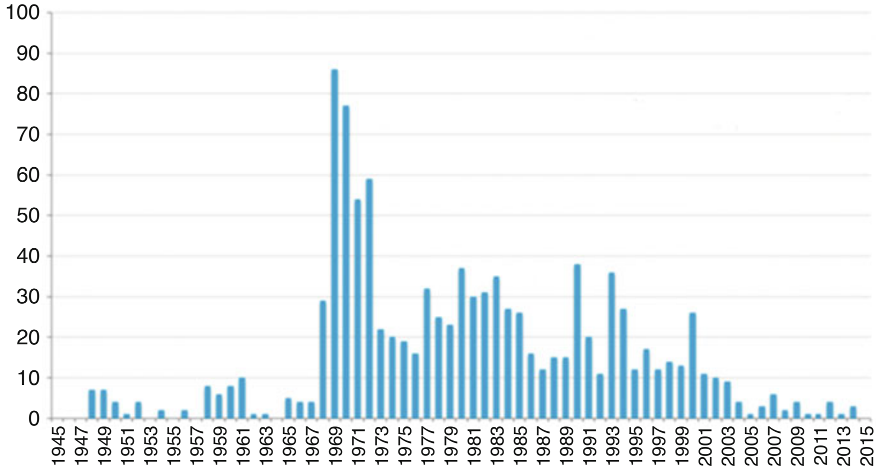

Fig. 1 Aircraft hijackings per year, 1945–2015

2021), hijackings are less common these days. In 1969, 86 aircraft (maximum) were hijacked. From 2002, the average is only 3.5 per year (Fig. 1).

Of particular importance in these situations is the coherence of all participants (flight crew (pilot, co-pilot, flight attendant), air traffic control officer (ATCO), supervisor, flight dispatcher, ground handler, aviation security and airport rescue service, military, Security Service of Ukraine, etc.), due to the acute shortage of time for decision-making (DM), incompleteness and lack of information, and significant psychophysiological load. Decision-making models (DMM)s by human operators in conditions of certainty, risk, and uncertainty were developed to timely diagnose the aircraft in emergency flight situations, to predict their development, and to be able to promptly provide appropriate assistance to air navigation system operators. Unexpected notification of a special accident in flight, acute shortage of time, and a sudden awareness of an emergency can lead aircraft crewmembers to erroneous actions (Shmelova & Sikirda, 2021a).

The goal of the work is to increase the effectiveness of air navigation system operators' actions in an emergency with the help of working out of operators' DMM under conditions of certainty, risk, and uncertainty on an example of emergency "unlawful interference" (an example from the scientific work of the bachelor of the National Aviation University (Ukraine) Eizhena Protsenko, the fourth year of study, specialty "Aviation Transport," qualification "Air Traffic Services," discipline "Informatics of Decision-Making").

2 Decision-Making by Operators in Emergency "Unlawful Interference"

2.1 Integration of Deterministic, Stochastic, and Non-stochastic Uncertainty Models in Emergency

In the recent documents, ICAO defined new approaches for effectiveness in aviation – application of artificial intelligence models for the organization of collaborative decision-making (CDM) by all participants using collaborative DMM on the basis of common information about the flight and characteristics of emergency (ICAO, 2014). In the process of analysis of the emergency are building DMMs to complexity from deterministic to stochastic models (Shmelova, 2019). In the process of synthesis of models and for effectiveness of DM in emergencies, there is a sense to simplify complex models and solutions. So, for example, stochastic and non-stochastic uncertainty, neural, the Markov, GERT (Graphical Evaluation and Review Technique), and dynamic models may be integrated into deterministic models (Fig. 2).

Collaborative DMMs in individual and collective information by various interacting participants, such as pilots, flight dispatchers, and ATCOs, in professional solutions and optimal solutions were obtained using the method of the objective-subjective decision in conditions of uncertainty (Shmelova, 2019). The integration of DMM in conditions of certainty, risk, and uncertainty is the basis for the building of a decision support system for a human operator in the event of a flight emergency. For the modeling of DM, human operator can apply different levels of DM complexity depending on the factors that influence the DM. For example, the technologies of ATCO work ASSIST (Acknowledge, Separate, Silence, Inform, Support, Time) are presented by EUROCONTROL as an online emergency training package (SKYbrary, 2021). The form of individual DM matrix in uncertainty for operators O_k is presented in Table 1 (Shmelova & Sikirda, 2021b).

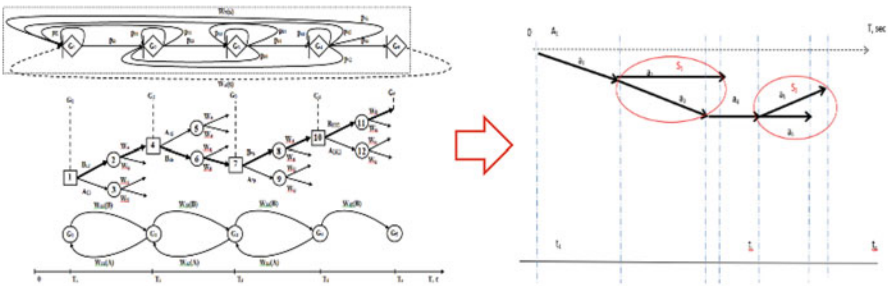

Fig. 2 The integration of the stochastic DMM in the deterministic model

Table 1 DM matrix in uncertainty for O_1 operator

Alternatives	Factors influencing DM					
$\{A\}$	λ_1	λ_2	...	λ_j	...	λ_n
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}

In Table 1, $\{A\} = \{A_1, A_2, \ldots A_i, \ldots, A_m\}$ are the alternative solutions of the operators; $\{\lambda\} = \{\lambda_1, \lambda_2 \ldots, \lambda_j, \ldots, \lambda_n\}$ are the objective and subjective factors that affect DM by operators; and $\{U\} = \{U_{11}, U_{12}, \ldots, U_{ij}, \ldots, U_{mn}\}$ are the outcomes of DM matrix ($i = 1, \ldots, m$; $j = 1, \ldots, n$).

2.2 Decision-Making in Emergency Under Uncertainty

The methods (criteria for analyzing the DM problem) of DM under uncertainty are Wald criterion (maxmin), Laplace criterion, Savage criterion, and Hurwicz criterion. For DM in the emergency under uncertainty in case of "unlawful interference" during the flight on-route are the next initial data: emergency landing, "Continue" (A_1), and emergency landing, "Allow" (A_2). The following are a set of factors that affect the decision $\lambda = \{\lambda_1, \lambda_2, \ldots \lambda_n\}$: the availability of fuel onboard (λ_1), the remoteness of the aerodrome (λ_2), the technical characteristics of the runway (λ_3), the weather conditions (λ_4), the approach lighting system (λ_5), the navigation approach system (λ_6), and the subjective factor (λ_7). The factors λ_1–λ_6 are the same for all participants of CDM objective factors, and the subjective factor λ_7 differs from each other for the different participants of CDM: pilot (O_1), co-pilot (O_2), flight attendant (O_3), ATCO (O_4), supervisor (O_5), military sector of the air traffic services (O_6), flight dispatcher (O_7), ground handler (O_8), aviation security (O_9), airport rescue service (O_{10}), Alpha unit of the Security Service of Ukraine (O_{11}), etc. (O_k).

The interaction of services, in which pilots have the opportunity to participate in emergency "unlawful interference," is fully dependent on the flight attendants. In the event of unlawful actions on board, they must, by all means and capabilities, prevent intruders from entering the aircraft cockpit. If, nevertheless, it did not work out, then there is a high probability that pilots will fall out of this interaction of services. The aircraft becomes completely uncontrollable or is controlled by the terrorists. Then the interaction will take place only between ground services, and the ATCO becomes the main source of information. For example, DM matrix for the optimal solution of ATCO in emergency "unlawful interference" is presented in Table 2.

According to obtained matrices, we see that by three criteria (Wald, Laplace, Hurwicz the most optimal solution is to continue the flight, by Savage criteria – to perform **an** emergency landing at the aerodrome.

Table 2 DM matrix in emergency "unlawful interference"

	Factors							Results			
	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	Wald	Laplace	Hurwicz	Savage
A_1	8	3	8	2	6	9	8	2	6.28	5.5	7
A_2	6	7	2	1	1	3	1	1	3	4	6

3 Results and Discussion

DMMs are built for many types of emergencies (engine failure, fire onboard, rejected take-off, decompression, etc.) and for many air navigation system operators (pilots, unmanned aerial vehicle operators, ATCOs, flight dispatchers, etc.). Integrated DMMs for several operators are proposed (Shmelova, 2019). The problem of optimizing the CDM of the pilot (remote pilot), flight dispatcher, and ATCO in emergencies with the help of consolidated deterministic, stochastic, and non-stochastic models is studied (Sikirda et al., 2021; Shmelova & Sikirda, 2021b). The algorithms of CDM by different aviation operators during the selection of the optimal solution in an emergency are developed. The example of choosing the optimal solution by ATCO in emergency "unlawful interference" using the methods of decision-making under certainty, risk, and uncertainty is presented.

4 Conclusion

The optimal DM for both a single operator and a group of operators is determined by the objective and subjective factors. The effective use of CDM is providing synchronization of decisions taken by participants, the exchange of information between them, and the effective balancing between safety and cost in collective solutions. It is important to ensure the possibility of making a joint, integrated solution with partners at an acceptable level of efficiency. The direction of further research is working out DMM for all CDM participants within the airport CDM concept that can combine the interests of partners in united work, to create the basis for effective DM through more exact and timely information that provides all co-workers at the airport a single operational view of air traffic.

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