Intelligent Integrated Training System for the Aviation Specialists "Collaborative Decision-Making –Education" (CDM-E)

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Abstract

The authors present a new approach to the practical training for aviation specialists using collaborative decision-making (CDM) methods, needed especially in emergencies. An intelligent integrated system for the practical training of aviation specialists (pilots, air traffic controllers, flight dispatchers, ground services personnel, and other maintenance staff) is considered. A comparative analysis of the training of aviation personnel (pilot/air traffic controller) at the stages of basic training was carried out. The structure of the concept of the formation of basic competencies of CDM in the conditions of a joint educational environment for aviation specialists is presented. The method of collaborative learning in the practical training of aviation specialists based on the CDM models in the conditions of the flight situation development (normal, complicated, complex, and emergency) is designed. CDM models under conditions of certainty, risk, and uncertainty are built based on the following CDM methods: the method of integration of stochastic and non-stochastic models of decision-making (DM); the method of CDM optimization due to construction of the individual (subjective) and collective (objective) DM models under conditions of uncertainty; the method of managing of the situation development using the integration of DM models (non-stochastic, stochastic, and deterministic models), and CDM models (individual and collective DM models). The effectiveness of the intelligent integrated training system for the aviation specialists "CDM – Education" is presented on the example of emergency landing through engine failure. The total time for the execution of all technological operations by the pilot is 132 seconds. Optimal alternative of flight completion place with minimal risk and maximum safety based on the Wald criterion from the point of view of three operators (pilot, air traffic controller, and emergency service specialist) is flight on a known route to the coast.

Keywords [1]

Air traffic controller, artificial intelligence, deterministic model, emergency, engine failure, non-stochastic model, pilot, risk, stochastic model, uncertainty

1. Introduction

According to the current forecasts [1–3], by 2030 the capacity of the global aviation transport system will double, and this will require thousands of new pilots and air traffic controllers (ATCOs). However, along with the undeniable advantages, uncontrolled growth rates of air traffic can also lead to increased flight safety risks if they outpace the growth rates of the normative and infrastructure projects necessary to support them [1; 2]. The efficiency of the air navigation system depends on competent and qualified professionals. In this regard, the main actors in air traffic service are the air traffic controller and the pilot (without diminishing the importance of other aviation specialists). The pilot and the air traffic controller know the importance of joint decision-making and its implementation under certain circumstances and in a certain professional environment. The work of ATCOs and pilots is considered to be a complex type of human-operator activity. Even before the start of their professional training,

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future ATCOs (and pilots as well) need to undergo a multi-level assessment of their suitability for this type of activity [4; 5], which, among other things, is characterized by:

- Teamwork. Processes of automation have a significant impact on the interaction and communication models between the main participants in the air traffic management process: "ATCO-ATCO", "ATCO (pilot)-flight support services", and "ATCO-pilot"
- Constant mental presence in the control loop of the ATCO and pilot. This requires readiness to take control "on themselves" despite the development of functionality and reliability of ground and onboard automated flight management systems and air traffic control processes
- A joint production of the cognitive processes and collaborative decision-making by the ATCO and pilot to support the integrated mental "picture" of situational awareness and the evolving air traffic situation

According to the National Transport Strategy of Ukraine for the period up to 2030, problematic issues in the field of professional training include the mismatch of the education system in the transport industry and the professional training to modern innovative challenges [6]. The importance of bilateral professional awareness of the activities of pilots and ATCOs is also unquestionably recognized by one of the leading international airlines in Ukraine [7]. Thus, the task of the initial training system for such specialists is to purposefully develop the knowledge, skills, and abilities (basic competencies) necessary for collaborative decision-making in the process of their interaction and communication.

For enhanced inter-professional integration, this research proposed the implementation of the intelligent integrated system for the practical training of aviation specialists (pilots, ATCOs, and flight dispatchers) based on the concept of joint training, during which the basic competencies of collaborative decision-making will be formed in a joint educational environment (Collaborative Decision Making – Education (CDM-E)).

It is proposed to perform flight training (for future ATCOs) and air traffic control training (for future pilots) on synthetic training devices for 45 hours. This is the minimum requirement for a person to qualify for a private pilot license. For future ATCOs, the amount of hours during basic training is approximately the same [4; 5]. The degree of simulation of the operating environment and flight conditions is carried out to the extent required by state civil aviation authority.

2. A state-of-the-art literature review

Today, the problem of interaction between pilots and ATCOs plays a key role in ensuring the safety of air traffic. The lives of hundreds of air passengers in the sky and on the ground depend on the adequate and correct perception of each other (the pilot and the ATCO). Despite the improvement of aircraft and air traffic control systems, the human factor still has a significant impact on flight safety: 80% of aviation accidents are caused by human error, and 42% of errors are related to errors in decision-making [8–11]. At the same time, a person is the main link in the pilot-ATCO interaction chain.

In ensuring flight safety, a key role is played by the ability to organize an operational CDM between the crew, ATCO, and other participants based on their communication and the assessment of information in real-time [12–14]. For example, the program "Joint Operational Incidents Training" [15], which is used between the German air traffic service and the Lufthansa airline (JOINT/DFS/DLH), confirmed that CDM increases the situational awareness of operators (pilot, ATCO) to create a general image of flight. This allows active monitoring of the air situation, predicting the development of the flight situation, and preventing its development in the direction of deterioration.

In [16–19], the deterministic, stochastic, non-stochastic, and neural-network CDM models for the various aviation operators (pilot, UAV operator, ATCO, flight dispatcher, rescuer, engineer, etc.) in different emergencies are proposed. To improve the CDM process between all aviation partners, based on whole information about the flight and emergency characteristics, Human & Artificial (Hybrid) Intelligence can be used [20; 21]. In [22], integrated models of training of aviation specialists (pilot, ATCO) are proposed, in [23] – a game approach to support the implementation of collaborative decision-making at the airport (A-CDM) in a large European airport, in [24] – partnership programs between aviation educational institutions and airlines.

As is known, familiarization flights of ATCOs in the cockpit are a common practice all over the world. ATCOs must perform such flights as part of the aircraft crew at least once every three years.

However, it is also important for pilots to know how ATCOs work, to see the real situation in the workplace, and to understand the specifics of the tasks of those specialists who guarantee their safety in the sky while working on the ground. There is a practice of familiarizing pilots with the work of ATCOs directly at their workplaces in the air traffic control room [7]. Table 1 demonstrates the similarity of features of the educational and professional environment of the pilots and ATCOs in many professionally oriented disciplines during their initial training [4; 5].

Table 1

Similarities of features of the educational professional environment of the pilots and ATCOs

№	Pilots/ATCOs
1	Knowledge of regulatory requirements for air traffic service and rules of flight
2	Decision-making under time pressure and stressful workload
3	Application of aviation radio communication rules and phraseology not lower than level "4" according to the ICAO scale
4	Knowledge of aerodynamics of flight and flight-technical characteristics of aircraft
5	Knowledge of air navigation
6	Knowledge of aviation meteorology and the impact of weather phenomena on flight operations
7	Interaction with air traffic service units and flight support services
8	Teamwork skills
9	Skills in using automated systems

However, the training of these essential types of operator activity for the air transport system is carried out separately. In this case, there are no inter-professional links in the processes of joint production and decision-making, which can be a critical risk factor for flight safety.

The purposes of this work are:

- To present a concept of the formation of CDM basic competencies for aviation specialists in the conditions of a joint educational environment
- To design the method of collaborative learning in the practical training of aviation specialists based on the CDM models in the conditions of the flight situation development (normal, complicated, complex, and emergency)
- To evaluate the effectiveness of an intelligent integrated system for the practical training of aviation specialists "Collaborative decision-making – Education" (CDM-E) in the example of a flight emergency

3. Concept of the formation of collaborative decision-making (CDM) basic competencies in the conditions of a joint educational environment

Figure 1 shows the structure of the concept of the formation of CDM basic competencies for the aviation specialists (pilots, unmanned aerial vehicle (UAV) operators, ATCOs, flight dispatchers, ground services personnel, and other maintenance staff) in the conditions of a joint educational environment. The fourth stage (highly specialized professional CDM training) concerns the formation of specialized core competencies in accordance with the activities of the organization, workplace and professional tasks and responsibilities.

4. Method of collaborative learning in the practical training of aviation specialists

Method of collaborative learning in the practical training of aviation specialists based on the CDM models in the conditions of the flight situation development (normal, complicated, complex, and emergency) includes next steps:

1. Selection and analysis of the flight emergency (FE):

- FE analysis according to Flight Operation Manual (FMO)
- FE analysis according to the typical technological cards of ATCOs action in emergency and abnormal situations ASSIST (Acknowledge, Separate, Silence, Inform, Support, Time)

2. FE analysis as a complex situation: identification of cause and effect relationships, chains of events/operations, sequence, and time for operations:

- Block diagram of the algorithm of actions (operations) of operators in FE (pilot, UAV operator, ATCO, flight dispatcher, ground services personnel, and other maintenance staff)
- Average time t_i for each operation (method of expert assessments)
- Structure-time table of execution of actions by the operator

3. Design of the individual deterministic decision-making (DM) models of the operators (pilot, UAV operator, ATCO, flight dispatcher, ground services personnel, and other maintenance staff) in FE under conditions of certainty (network planning method):

- The deterministic DM models of the pilot (Figure 2), ATCO (Figure 3), and other operators are the network graphs for the execution of a set of operations in FE

4. Optimization of the individual network graphs for the execution of a set of operators operations in FE:

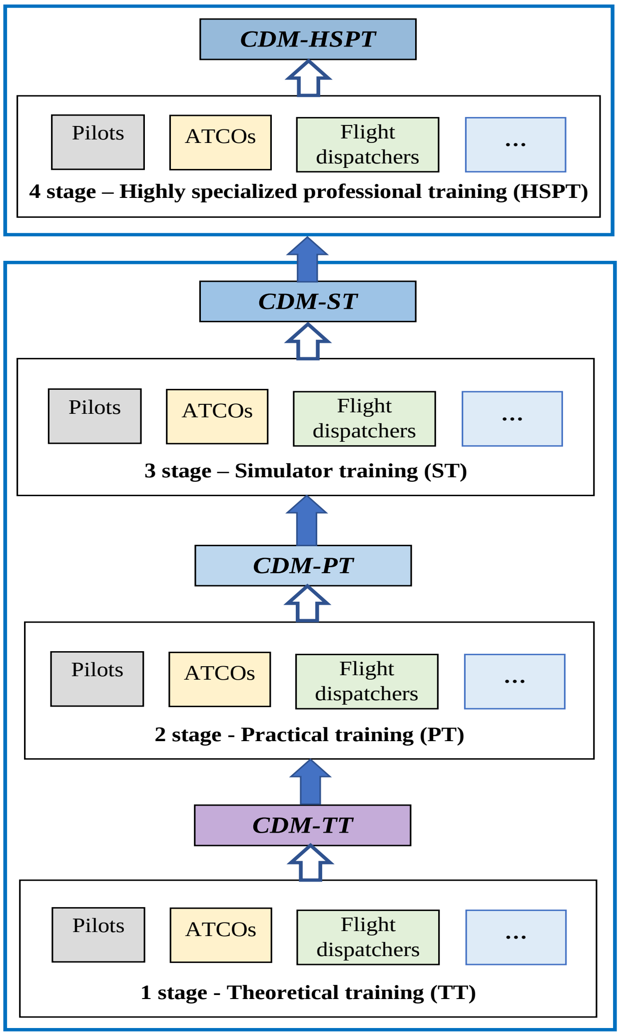

Figure 1: The formation of CDM basic competencies for aviation specialists in the conditions of a joint educational environment

- The critical time of works performance T_{cr}
- The critical path of works, list of critical works in the critical path
- Non-critical works, time reserve for each non-critical work

5. Design of the deterministic CDM model of the operators in FE:

- Optimization of *n*-network graphs – sequential redistribution of time reserves due to non-critical works to achieve the best result (minimum FE parrying time with maximum safety) (Figure 4)

- Changing the network topology due to multi-variant technologies for performing operations (integration of CDM models)
- Introduction of parallel/adjacent execution of operations with the maximum overlap in time, taking into account minimum risks and maximum safety

6. Design of the non-deterministic DM and CDM models of the operators under conditions of risk and uncertainty:

- Individual and collective DM models under risk conditions: risk assessment *R* for different alternatives of the situation development
- Individual and collective DM models under uncertainty conditions. Subjective-objective approach to optimal CDM

7. Step-by-step optimization of the deterministic DM model by integrating the obtained non-deterministic models (DM under conditions of risk and uncertainty) and the deterministic CDM model
8. Evaluation of the CDM effectiveness in FE – the results of joint practical training of aviation specialists

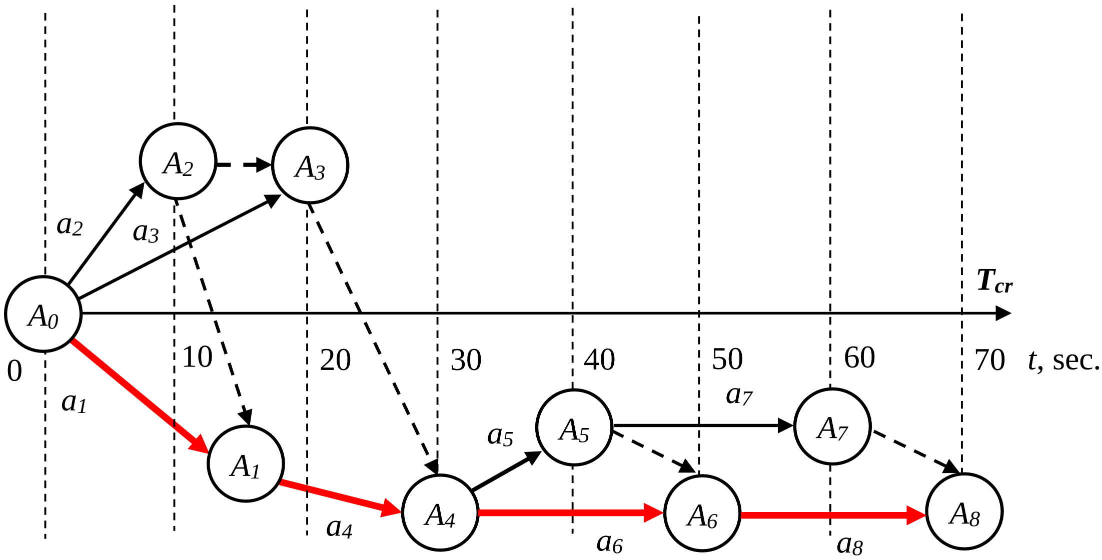

Figure 2: The deterministic DM model of the pilot in FE

The deterministic DM model of the pilot in FE.
Critical path (actions): a_1, a_4, a_6, a_8.
$T_{cr} = t_1(a_1) + t_4(a_4) + t_6(a_6) + t_8(a_8) = 15 + 15 + 20 + 20 = 70$ seconds.
Non-critical arcs: a_2, a_3, a_5, a_7.
A_0 - $\boldsymbol{a_2}$ - A_2 - A_1;
A_0 - $\boldsymbol{a_3}$ - A_3 - A_4;
A_4 - $\boldsymbol{a_5}$ - A_5 - A_6;
A_4 - $\boldsymbol{a_5}$ - A_5 - a_7 - A_7 - A_8.
Time reserves (correction of non-critical works):
$R_2 = t_1 - t_2$;
$R_3 = t_4 - t_3$;
$R_5 = t_6 - t_5$;
$R_{5\text{-}7} = t_5 + t_7 + (t_8 - t_7)$.
The deterministic DM model of the ATCO in FE.
Critical path (ASSIST): $b_1, b_3, b_5, b_6, b_9, b_{10}$.
$T_{cr} = t_1(b_1) + t_3(b_3) + t_5(b_5) + t_6(b_6) + t_9(b_9) + t_{10}(b_{10}) = 10 + 10 + 20 + 5 + 15 + 10 = 70$ seconds.
Non-critical arcs: b_4, b_7, b_8.
B_0 - $\boldsymbol{b_2}$ - B_2 - B_3;
B_3 - $\boldsymbol{b_4}$ - B_4 - B_5;
B_5 - $\boldsymbol{b_7}$ - B_7 - B_9;

B_5 - $\boldsymbol{b_7}$ - B_7 - b_8 - B_8 - B_{10}.
Time reserves (correction of non-critical works):
$R_2 = (t_1 + t_3) - t_2;$
$R_4 = t_5 - t_4;$
$R_7 = (t_6 + t_9) - t_7;$
$R7\text{-}_8 = (t_6 + t_9 + t_{10}) - (t_7 + t_8).$
Optimization of n-network graphs (pilot and ATCO).
Critical path (actions): c_1, c_2, c_4, c_5, c_6.
$T_{cr} = t_1(c_1) + t_2(c_2) + t_4(c_4) + t_5(c_5) + t_6(c_6)$ = 10 + 10 + 30 + 10 + 10 = 70 seconds.
Non-critical arcs: c_3, c_7.
C_2 - $\boldsymbol{c_3}$ - C_4;
C_4 - $\boldsymbol{c_7}$ - C_6.
Time reserves:
$R_3 = t_4 - t_3;$
$R_7 = (t_5 + t_6) - t_7.$

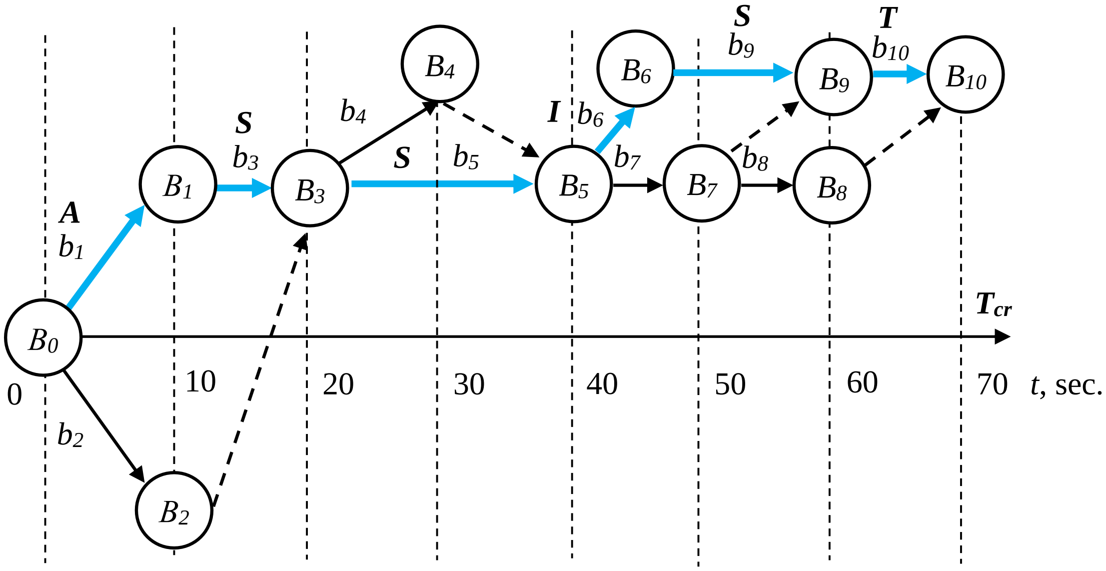

Figure 3: The deterministic DM model of the ATCO in FE

By adjusting non-critical arcs and synchronizing time reserves for each operator (member of the group), a general deterministic model is obtained – CDM certainty with general critical path (actions/time).

5. The illustrative example of collaborative decision-making (CDM) in the case of emergency landing through engine failure

Task: "Executing a training flight along the route. Visual flight rules. Emergency: engine failure. Choice of the optimal place for an emergency landing".

The aircraft flies along the route: airfield Kozelets'-Bulakhiv-Krekhaiv-Pirnove-Lebedivka (eastern coast of the Kyiv Reservoir)-Stari Petrivtsi (western coast of the Kyiv Reservoir)-Moschun-Kyiv (Antonov) (Figure 5). Magnetic flight course Kozelets'-Moschun is 250°; magnetic flight course Moschun-Kyiv (Antonov) is 150°.

The peculiarities of the flight are that from Lebedivka to Stari Petrivtsi the aircraft will fly over the Kyiv Reservoir for 11 km (about 3 minutes) (Figure 6).

Characteristics of airspace and air traffic service type [25]*:*

- Continental airspace (landing will be carried out on land outside the elements of the controlled airspace structure)
- Airspace class G (uncontrolled)

- Flight information service involves the provision of advice and information for safe and efficient flights

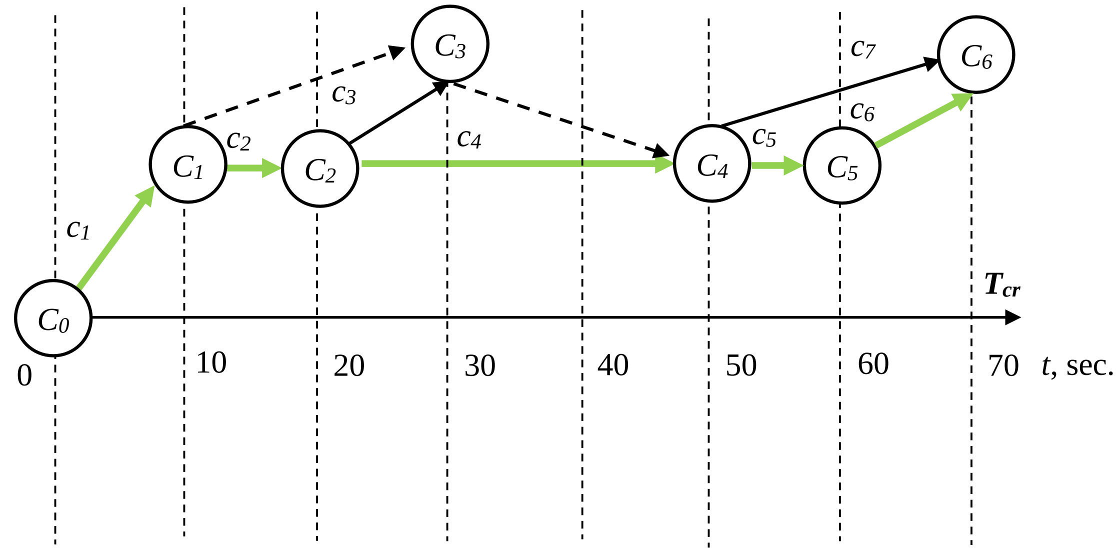

Figure 4: Optimization of *n*-network graphs (pilot and ATCO)

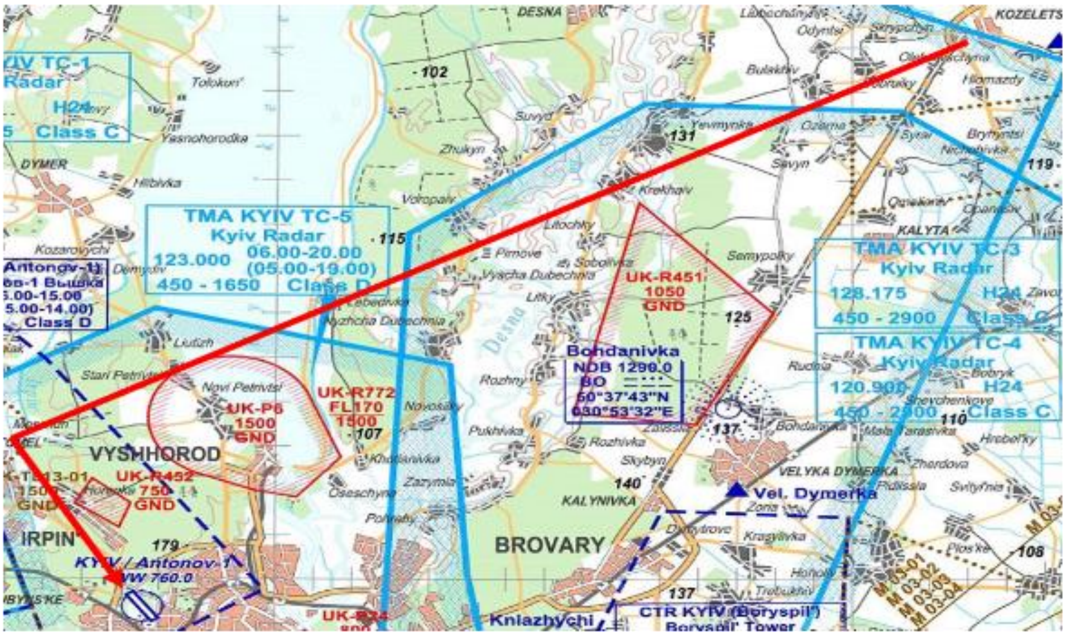

Figure 5: Flight route Kozelets'-Kyiv (Antonov)

Characteristics of air and meteorological conditions:

- The ATCO has one aircraft on radio communication
- There are no dangerous weather phenomena, calm, visibility is about 10 km
- The accident occurred in the spring, during the day

Initial data:

- Light aircraft (up to 5700 kg) with a propeller with one engine (single engine piston – SEP)
- One crew member, an amateur pilot
- The flight is performed according to visual flight rules (VFR)
- The route stage of the flight – the relative altitude of the flight H = 600 m
- Maximum aerodynamic quality of the aircraft K_{max} = 11.6
- Cruising speed W = 226 km/h
- The distance between Kozelets'-Moschun-Kyiv (Antonov) D = 77 km

- Flight time t_f = 21 minutes
- The most profitable progressive movement speed along the trajectory of the aircraft with a failed engine V = 125 km/h
- The minimum planning angle: tg $\theta_{min} = 1 / K_{max}$; θ_{min} = arctan (1 / 11.6) = arctan 0.0862 = = 4.93° ≈ 5°
- The pitch angle of an aircraft with a failed engine θ_p = 5°

Figure 6: Section of the aircraft flight route over the Kyiv Reservoir Lebedivka-Stari Petrivtsi

These are approximate calculations since in real flight speed and vertical speed depend on many factors. For example, weight, which depends on the amount of fuel on board the aircraft and its loading (passengers and cargo), flight altitude and external temperature, wind speed, and direction, other meteorological factors, the nature of the underlying surface, etc. If the flight is performed in the spring, then during the day there will usually be warm easterly air currents over the field, which can better support the aircraft and increase its time in the air, and therefore the flight range [26; 27].

Additional conditions for calculation:

- Equal time point (ETP) – a point on a route where it would take an equal amount of time to return to the departure aerodrome or to continue flight to the alternate aerodrome – is not considered
- Point of safe return (PSR) – a point on the route where the aircraft can return to the departure aerodrome with an intact fuel supply – is not considered
- The flight is performed in still air conditions (zero wind)

According to the scenario of the accident development, the engine failure on the aircraft occurs at a distance of 5.5 km from both banks of the Kyiv Reservoir. Engine failure was without fire and the propeller was automatically flared. The pilot applied the "Mayday" protocol.

Engine failure refers to emergency and abnormal situations [28]. The analysis of the pilot actions in case of engine failure and emergency landing in accordance with FMO is presented in Table 2.

The pilot will follow the instructions of the ATCO until the moment when his instructions (recommendations) do not "conflict" with the actions of the pilots in this specific situation. In any case, the final decision rests with the pilot. In case of refusal to comply with the instructions (recommendations), the pilot must report his decision to the ATCO.

According to the data in Table 2, the total time for the execution of all technological operations (T) by the pilot is 132 seconds. At the same time, according to the conditions of the problem, the planning range of the aircraft in a straight flight from a height of 600 m will be:

- Planning range in straight flight: $L_{600} = H * k$ = 600 * 11.6 = 6 960 m
- Aircraft planning time: $T_{600} = L / V$ = 200 seconds

That is, the pilot still has a time reserve of 68 seconds.

This time can be used to select the landing place by simultaneously trying to start the engine again (≈ 40 seconds on the second run).

At a lower flight height, for example at 300 m, the planning range in a straight flight will be:

- Planning range in straight flight: $L_{300} = H * k = 300 * 11.6 = 3\ 480$ m (approximately 2 000 m will remain to the coast)
- Aircraft planning time: $T_{300} = L / V = 100$ seconds

Under such conditions, the aircraft will be able to transmit the "Mayday" signal and make one attempt to start the engine.

Table 3 shows the structure-time table of the ATCO actions during an emergency landing (engine failure).

Table 2

Structure-time table of the pilot actions (p_m) during an emergency landing (engine failure) – an example

Technological operation	The sequence of the technological operations	Previous operation	Time of operation, sec.
p_1	Engine failure at H = 600 m	-	2
p_2	Immediately lower the nose of the aircraft to the planning angle ϑ_{gl}, which will ensure planning at the maximum distance	p_1	5
p_3	Check visually and by instruments whether there is no fire	p_2	5
p_4	Check that the aircraft's propeller has entered the autorotation mode	p_3	3
p_5	Move the engine control lever to the low throttle mode	p_4	3
p_6	Set the aircraft planning speed in accordance with the FMO	p_5	10
p_7	Turn the backup fuel pump switch to the "On" position	p_6	2
p_8	Check for fuel	p_7	2
p_9	Perform the steps to restart the engine again (verify that all switches on the instrument panel are on; verify that the fire hydrant of the fire extinguishing system is open; set the engine control lever to low throttle; press the "Start" button and hold it in the depressed position until the engine starts, but not more than 10 seconds. Note: If the oil pressure does not reach 2 bar within 10 seconds, immediately shut down the engine and make a forced landing	p_8	35
p_{10}	Based on the results of previous actions, make a decision (in our case, the engine did not start)	p_9	10
p_{11}	Check the spatial position of the aircraft: altitude, course, location	p_{10}	5
p_{12}	If there is communication with the ATCO, send the "Mayday" signal. Note: in the absence of communication with the ATCO, the "Mayday" signal is transmitted on the international emergency frequency 121.5 MHz Report on the nature of the FE and inform the ATCO about the decision made. Wait for confirmation from the ATCO	p_{11}	50
In total			**132**

According to Table 2 and Table 3, the network graph of the synchronized actions of the pilot and ATCO during an emergency landing is built (Figure 7).

Therefore, the question arises regarding the rapid acquisition of a large amount of data, their analysis, and the development of recommendations for a joint decision (pilot-ATCO). An intelligent system for supporting CDM by the pilot and ATCO in FE was used to obtain data. A neural network model for risk assessment of CDM by the pilot and the ATCO in the FE was built [17].

The estimates of the factors' influence (b_1 – aircraft condition (ability to maintain control of the aircraft); b_2 – availability of suitable places for safe landing; b_3 – meteorological conditions; b_4 – complexity of the approach profile to the landing place; b_5 – communication and the possibility of assistance) on the results of emergency landing according to the landing places (alternative flight routes) in case of emergency landing due to engine failure are obtained:

- a_1 – flight on a known route to the destination aerodrome
- a_2 – alternative landing place, flight on a known route to the coast
- a_3 – alternative landing place, flight on a shorter but unknown route to the coast
- a_4 – alternative landing place, turn 90° to the west coast
- a_5 – flight on a known route to the departure aerodrome, turn 180°

Table 3

Structure-time table of the ATCO actions (d_n) during an emergency landing (engine failure) – an example (ATCO begins to act from the moment of information receiving)

Technological operation	The sequence of the technological operations	Previous operation	Time of operation, sec.
p_{12}	The pilot reported on the nature of the accident and informed the ATCO about the decision made	-	25
d_1	Accept information from the pilot and confirm it	p_{12}	25
d_2	Report to the supervisor and senior navigator (senior ATCO) of the relevant control terminal area	d_1	25
d_3	Pass the information on to the relevant search and rescue unit	d_2	20
d_4	The ATCO must record all actions related to emergency service of the aircraft, laying the flight route using a remote automated workplace (taking into account its technical capabilities)	p_{12}	From the moment of information receiving
d_5	After making the decision to provide emergency service, the ATCO must use all means available to him to assist the aircraft crew	p_{12}	Until the end of the emergency state

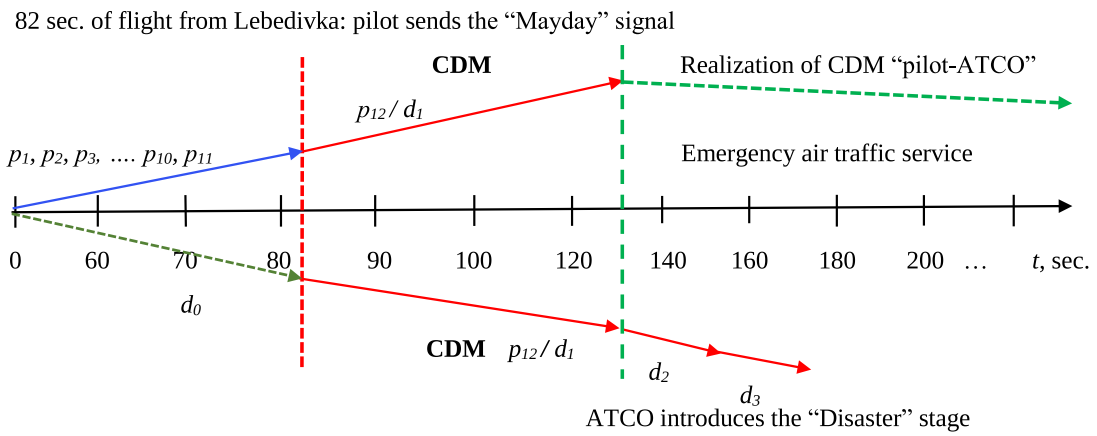

Figure 7: The network graph of the synchronized actions of the pilot and ATCO during an emergency landing of the aircraft: p_m – technological operations of the pilot; d_n – technological operations of the ATCO

To find the optimal landing place with minimal risk and maximum safety in the case of an emergency landing due to engine failure, the subjective-objective CDM optimization method based on the Wald criterion for the case of DM by three operators (pilot, ATCO, and emergency service specialist) is applied [18; 19]. According to the Wald criterion, an alternative that gives a guaranteed positive result in the worst-case scenario is selected. Table 4 shows the matrix of possible decisions from the pilot's point of view. The optimal alternative of flight completion from the pilot's point of view is a_2 – flight on a known route to the coast. Similar matrices of possible decisions from the point of view of the ATCO and emergency service specialist are obtained. Table 5 shows the CDM matrix for the pilot, ATCO, and emergency service specialist based on the Wald criterion.

Table 4
Matrix of pilot's decisions during an emergency landing (engine failure) – an example

Alternatives of flight completion	Factors influencing the results of an emergency landing					Wald criterion, W
	b_1	b_2	b_3	b_4	b_5	
a_1	1	1	5	1	1	1
a_2	4	4	5	3	4	***3***
a_3	4	2	5	2	2	2
a_4	1	1	5	2	2	1
a_5	1	1	5	1	1	1

Table 5
CDM matrix for the pilot, ATCO, and emergency service specialist – an example

Alternatives of flight completion	Results of DM by the operators			Wald criterion, W
	Pilot	ATCO	Emergency service specialist	
a_1	1	1	2	1
a_2	**3**	**3**	**4**	***3***
a_3	2	2	3	2
a_4	1	1	1	1
a_5	1	1	1	1

Optimal alternative of flight completion from the point of view of three operators (pilot, ATCO, and emergency service specialist) is also a_2 – flight on a known route to the coast.

6. Results and discussions

A concept of the formation of CDM basic competencies for aviation specialists (pilots, unmanned aerial vehicle (UAV) operators, ATCOs, flight dispatchers, ground services personnel, and other maintenance staff) in the conditions of a joint educational environment includes four stages: theoretical training, practical training, simulator training, and highly specialized professional training. The main feature of the proposed competence-oriented situational professional training in the conditions of a joint educational environment is that professionally oriented disciplines are studied based on "realistic" scenarios of the activity of pilot-ATCO that arose or may arise during flight operation and air traffic service. A significant advantage is that situational (scenario) professional training effectively helps to develop decision-making skills in conditions of uncertainty and stress, which is extremely important for a pilot and ATCO.

Method of collaborative learning in the practical training of aviation specialists based on the CDM models in the conditions of the flight situation development (normal, complicated, complex, and emergency) includes next steps: selection and analysis of FE; FE analysis as a complex situation; design of the individual deterministic DM models of the operators in FE under conditions of certainty (network planning method); optimization of the network graphs for the execution of a set of operators operations in FE; design of the deterministic CDM model of the operators in FE; design of the non-deterministic DM and CDM models of the operators under conditions of risk and uncertainty; step-by-step optimization of the deterministic DM model by integrating the obtained non-deterministic models (DM under conditions of risk and uncertainty) and the deterministic CDM model; evaluation of the CDM effectiveness in FE – the results of joint practical training of aviation specialists.

The network graph of the synchronized actions of the pilot and ATCO in the case of emergency landing through engine failure is built. The total time for the execution of all technological operations by the pilot is 132 seconds.

To find the optimal landing place with minimal risk and maximum safety in the case of an emergency landing due to engine failure, the subjective-objective CDM method based on the Wald criterion is applied. Optimal alternative of flight completion from the point of view of three operators (pilot, ATCO, and emergency service specialist) is flight on a known route to the coast.

7. Conclusion

The main active “players” in emergency and abnormal situations are the pilot and ATCO, who have quite a lot of similarities in the characteristics of the educational professional environment in terms of the formation of their basic competencies. Since the cognitive processes of joint production and decision-making are the most significant for maintaining an integrated mental “picture” concerning situational awareness and the development of the air situation, it is proposed to introduce them into the educational process, as part of the implementation of the concept of CDM in the conditions of a joint educational environment (CDM-E), collaborative work in FE for future pilots, ATCOs and other aviation personnel. The main advantages of introducing a joint educational environment in the training of future aviation specialists include the following:

1. Improved communication: joint training will help future aviation specialists to better understand each other's operational procedures, which will facilitate more effective CDM processes
2. Increased flight safety: joint training will allow for a better understanding of each other's roles and responsibilities, which in turn, by minimizing errors and increasing situational awareness, increases flight safety: “To understand the other, you need to walk in their shoes”
3. Enhanced cooperation: the joint training phase will facilitate increased professional cooperation between aviation specialists, which will contribute to the more efficient application of working procedures and operational decision-making
4. Increasing the cost-effectiveness of training: the introduction of the joint training stage will reduce the costs associated with training these categories of specialists in the case of its separate implementation. By combining human resources, training materials, and classrooms, an educational organization saves funds and simultaneously improves the quality of professional-oriented training: “the right teacher/instructor for the right discipline/topic”. This will contribute to the safety, economic, organizational, and educational effectiveness of the training system

Further research will be aimed firstly at expanding the possibilities of planning situations for CDM by a group of various aviation specialists (pilots, UAV operators, ATCOs, flight dispatchers, ground services personnel, maintenance staff, etc.) in FE, and further at situations modeling in Virtual Reality (VR) with using the Integrated Virtual Training and Education System (IVTES) for collaborative work of aviation personnel. In the future, to find a compromise between the operators’ time of DM under the influence of different factors in uncertainty and the critical time of FE parrying in certainty during the practical training in the conditions of a joint educational environment it is proposed to use Machine Learning and Big Data analyzing tools. To control Artificial Intelligence decisions by the aviation specialists it is necessary to exploit Hybrid Intelligence Systems that embrace both machine competence and operator competence.

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