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ORIGINAL SCIENTIFIC PAPER

Flying an Unmanned Aerial Vehicle: Key Factors for Risk Management

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Abstract: Only theoretical training of drone operators is not sufficient for safe integration and use of drone aircraft both in controlled and uncontrolled air space.

Based on research and analysis of incidents caused by the use of drone aircraft during 2018. The global level can conclude that most of the incidents have been performed because of unskilled handling of drones, even though the persons who managed them were theoretically trained and possessed of drone management licenses.

Purpose – for the purpose of mitigation of the risk of adverse effects of human and material resources in the work, the analysis of the Drone management.

Design/methodology/approach – decision on which of the following key factors for risk assessment achieves the greatest impact on the safe handling of drone aircraft has been carried out by using the methods of analytical hierarchical processes, i.e. “fuzzy”Expanded AHP method based on”fuzzy”triangular numbers.

Findings – Based on the results of the research, it concludes that the alternative – “a terrorist and practical training for the safe handling of drone aircraft” is essential for the safe handling of drone aircraft in the second place The ranked alternative “the need for knowledge and skills of sports pilots” in third place is the ranked alternative “only practical training is needed,” in the fourth place the alternative is “only theoretical training is needed” and the fifth match is a ranked alternative “is not Theoretical or practical training. “

Practical Implications – established frames to increase the security of flying drones through an obligatory theoretical and practical training of drone operators.

Social Implications – reduced risks of occurrence of adverse effects on human and material resources.

Keywords: drone, controlled air space, control of air space, drone operator, risk factors.

INTRODUCTION

The rise of air traffic affects the capacity of airspace, and the integration of drones in general and operational traffic implies the harmonization of knowledge, skills, procedures and technical systems used in the unique space. The European Organization for the Safety of Air Navigation has so far taken a series of measures to keep the flying of drones in the Legalist framework, while giving recommendations to Eurocontrol countries to regulate Areas.

Membership in EUROCONTROL by 2019. has 41 countries. Serbia’s a member of the EUROCONTROL from July 1, 2005.The 26 countries have regulated drone flying (regulations, laws, regulations, recommendations, etc.). The Republic of Serbia brought the rules on drones on 11. December 2015.

Of the 26 countries that have legal regulations in 12 countries or 46.15% for flying drones, it is necessary to have theoretical knowledge and practical skills (depending on the severity of the drone), in 11 countries or 42.30% it is necessary only theoretical knowledge while in 3 countries or 11.53% do not require any theoretical or practical knowledge of drone management.

The sudden rise in the development of drone industries has expanded the palette of their use in almost all spheres of human society. In addition to the initial use for military purposes today, drones are used for entertainment, sport and hobby and for film industries, Assistance in agriculture,assistance in searching and rescue, monitoring of road, rail and water At the same time are the area that is still intensive (7),(9),(10),(2).

Especially smaller drone aircraft are increasingly used in the countries of European union (EU), but under fragmented regulatory framework. Although national rules on Security, the rules differ in the EU and a number of key protection measures are not addressed in a coherent manner(11),(18),(14).

After a four-month consultation period on the proposed amendment notification, NPA 2017-05, EASA issued Opinion 01/2018, including a proposal for a new regulation for unmanned aerial vehicles in the "open", "specific" and "certified" categories.

The creation of the category is a category of Operation anddrones which, taking into account the involved risks, does not require prior approval of the competent body or the statement of the drone operator Aircraft Before the start of Operation.

With specificationcategory a category of Operation andUndoneaircraft which, taking into account the risks involved, requires approval of the competent body before the start of the operation, taking into account the mitigation measures Determined in the operational risk assessment, except for certain standard scenarios where the declaration by the operator is sufficient, or when an aircraft operator has an approval.

The Certified category is a category of Operation and drone, which, taking into account the risks involved, requiresthe certification of drones and licensedand approved by the competent body, in order to ensure the appropriate level of security.[1]

In accordance with the opinion of the Easaonly for the certified category of drones, it is necessary that the drone operator be licensedbut without the explicitly specified conditions that the drone operator must Also have practical training and check skills of drone management, especially in emergency situations.

Given that the rise in the use of drones is evident, and consequently the number of incidents caused by the use of drone aircraft, an analysis of the causes of the incidents in order to minimize risk Occurrence of the incident.

Theabilityof the operator for safe handling of drones is in correlation with the risk of using drones (1),(15),(8),(12).Risk is the probability of an event in the specific case of incidents caused by the use of drones. The key factors for assessing the risk of drone management have been analyzed.

RESEARCH METHODOLOGY

Taking into account the European Aviation Safety Agency document: "Getting to Know the Regulatory Framework for Unmanned Aerial Operations", an analysis was made of the causes of incidents caused by the use of unmanned aircraft during 2018 through key risk assessment factors for unmanned aircraft management.

[1] https://www.easa.europa.eu/easa-and-you/civil-drones-rpas

Key risk assessment factors for unmanned aircraft management:

- Area of operation and working space(hereinafter: PDRP):
- Population density,
- Areas with special protection,
- Configuration of the terrain and time of stay.
- impact on the airworthiness and control of general and operational air traffic,
- Impact on the design of air space.
- Procedures (hereinafter: PO):
- In case of an emergency situation caused by other aircraft,
- In case of an emergency situation caused by an uncontrolled malfunction of the drone.
- Unmanned aerial vehicle design and type (hereinafter: DTV):
- Features provided,
- Redundancy and safety features.
- Operational Procedures (hereinafter: OP):
- training of unmanned aerial vehicle operators,
- organizational factors.
- Environmental Impact2 (hereinafter-ZS).

Deciding which of the following key factors for risk assessment has the greatest impact on the safe management of unmanned aerial vehicles was carried out using the analytical hierarchical process or fuzzy extended AHP method based on fuzzy triangular numbers (5).

In this paper, the key factors for risk assessment are taken as criteria for analysis.

The starting basis for alternative alternatives was analysis of the causes of the incidents caused by the use of drones during 2018., wherein 54.83% of cases as the cause of the incidents identified "loss of control" or the ability to manage drone management. The common characteristic of the incident is a bad "situation response" of drone operators that did not have practical training for drone management.

The following statements have been selected as alternatives to the safe operation and operation of unmanned aerial vehicles: Requirements of terrestrial and practical training (hereinafter: PTO) for the safe operation of unmanned aircraft, knowledge and skills of sport pilots (hereinafter: CFSP) required neither theoretical nor practical training (hereinafter referred to as BPTO), only theoretical training (hereinafter: WTO) is required and only practical training (hereinafter: SPO) is required.

Research Stages

The reduction of the risk of the incidents was considered in this work by examining the aforementioned impactson the security of drone aircraftthroughthree different research phases:

[2] https://www.easa.europa.eu/sites/default/files/dfu/Introduction of a regulatory framework for the operation of unmanned aircraft.pdf

- **In the first phase of the survey,** thecause of incidents in the management of drones was being reviewed by the incident in 2018.
- **In the second phase of the survey**, an on-line survey was conducted to identify the alternative that has the greatest impact on the safe flight of drones.
- **In the third phase**, an experimental study summarized and processed the data obtained to compare the results of on-line surveys and identified incidents of drones

First phase of research

In the first phase, there was a survey of all drone-incidents at 2018. The year that were publicly published-through public information funds. The analysis found that in 26 different countries of the world were recorded A total of 124 Incidentdroneaircraft. In Figure 1. A graphic representation of the comparative analysis of the number of reported incidents in relation to the number of incidents caused by the "loss of control" was given.

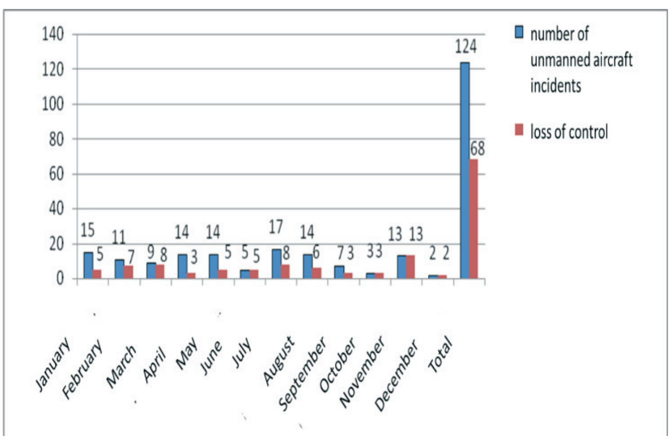

Figure 1. Comparative analysis of drone incidents

The second phase of the survey - interviewing

The online survey included 60 people, from January to April 2019, with a view to looking at attitudes toward similarity in understanding key risk assessment factors and identified alternatives. The questionnaire used in the survey was compiled according to Satie's linguistic scale for comparison by pairs (16). The respondents were divided into six groups, where each group was determined in relation to common interests: civil aviation organizations (hereinafter: CVO), academic domain experts (hereinafter: ADO), drones (hereinafter: KBV), Sports Aviation Associations (SVU), Aircraft Pilots (PA), and Helicopter Pilots (PH).

Third phase of research - experimental study

In the third phase, summation and processing of obtaineddata, methods that are more detailed in Chapter 3 of this work are realized.

Experimental study

The Order of the Linguistic scaled is played in table 1 is thecomparison phase in the few of these as shown in table 2.

Table 1. Satie's linguistic pairwise comparison scale (16).

Crips values (x)	Meaning	„fuzzy" values
1	Equal importance	(1, 1, 1 + D)
3	Weak domination	(3-D, 3, 3 + D)
5	Strong domination	(5-D, 5, 5 + D)
7	Demonstrative domination	(7-D, 7, 7 + D)
9	Absolute domination	(9-D, 9, 9)
2,4,6,8	Medium values	(x - 1, x, x+1)

Table 2. Fuzi comparison in pairs

	C1			C2			C3			C4			C5		
C1	1	1	1	1	3	5	1	3	5	1	3	5	0.09	0.11	0.14
C2	0.2	0.33	1	1	1	1	0.2	0.33	1	0.2	0.33	1	0.14	0.2	0.33
C3	0.2	0.33	1	1	3	5	1	1	1	0.2	0.33	1	0.2	0.33	1
C4	0.2	0.33	1	1	3	5	1	3	5	1	1	1	0.2	0.33	1
C5	7	9	11	3	5	7	0.09	0.11	0.14	1	3	5	1	1	1

The weights of all criteria were determined by Chang's analysis (17).First, synthetic values were calculated, based on Eq: (1)

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (1)$$

Calculated values are,

$$\sum_{j=1}^{m} M_{gi}^{j} = (23.92467532, 43.08888889, 66.61904762)$$

Based on Eq (2),

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \quad (2)$$

Calculated values are,

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = (0.04179785, 0.023207839, 0.015010722)$$

After (1) and (2) It can be calculated that the synthetic value of each factorial equation:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} * \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$$

$S_1 = (4.090, 10.111, 16.142) * (0.015, 0.023, 0.0417) = (0.061, 0.234, 0.674)$

$S_2 = (1.742, 2.2, 4.333) * (0.015, 0.023, 0.0417) = (0.026, 0.051, 0.181)$

$S_3 = (2.6, 5, 9) * (0.015, 0.023, 0.0417) = (0.039, 0.116, 0.376)$

$S_4 = (3.4, 7.66, 13) * (0.015, 0.023, 0.0417) = (0.051, 0.177, 0.543)$

$S_5 = (12.09, 18.11, 24.14) * (0.015, 0.023, 0.0417) = (0.181, 0.420, 1.009)$

The fuzzy values thus obtained were compared by Eq (3):

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2} = 1\ if\ m_2 \geq m_1, 0\ if\ l_1 \geq u_2, otherwise\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}$$

$$V(S_b \geq S_a) = 1\ if\ m_b \geq m_a, 0\ if\ l_a \geq u_b, otherwise\ \frac{l_a - u_b}{(m_b - u_b) - (m_a - l_a)} \quad (3)$$

The following values are obtained,
VSc1>=VSc2=1, VSc1>=VSc3=1 ,VSc1>=VSc4=1, VSc1>=VSc5=0.726,VSc2>=VSc4=1,VSc2>=VSc5=0,VSc2>=VSc3=0.686,VSc2>=VSc1=0.394,VSc3>=VSc1=0.895, VSc3>=VSc2=1, VSc3>=VSc4=0.840, VSc3>=VSc5=0.390,VSc4>=VSc1=1.10,VSc4>=VSc2=1,VSc4>=VSc3=1,VSc4>=VSc5=0.59,VSc5>=VSc1=1,VSc5>=VSc3=1,VSc5>=VSc2=1,VSc5>=VSc4=1.

V-Priority weightsare defined by the following,

$d(A_i) = minV(S_i \geq S_k) d(A_i) = minV(S_i \geq S_k)$, *for the* $k = 1, 2, \ldots, n: k \neq i, = 1, 2, \ldots, n: k \neq i,$

The following values are obtained,

$d(A_1) = minV\ (1, 1, 0.726526695) = 0.726526695$

$d(A_2) = minV\ (1, 0, 0.686195921, 0.394691991) = 0$

$d(A_3) = minV\ (0.89518486, 1, 0.840096923, 0.39018014) = 0.39018014$

$d(A_4) = minV\ (1.100058686, 1, 0.598867597) = 0.598867597$

$d(A_5) = minV\ (1, 1, 1, 1) = 1$

The weighting factors are calculated as follows,

$$W' = \left(d'(A_1), d'(A_2), \ldots, d'(A_n)\right)^T$$

The following values are obtained,

$$W' = (0.726526695, 0, 0.39018014, 0.598867597, 1)^T$$

Normalized weight vectors are,

$W_{factors} = (0.267540704, 0, 0.143682359, 0.220530724, 0.368246213)^T$

After comparing pairs of criteria, the comparison of the alternative to individual criteria (3). was performed. The weight of the alternative is calculated in a similar manner as the severity of the criteria.

C1	A1			A2			A3			A4			A5		
A1	1	1	1	1	3	5	7	9	11	7	9	11	0.09	0.11	0.14
A2	0.2	0.33	1	1	1	1	1	3	5	1	3	5	0.14	0.2	0.33
A3	0.09	0.11	0.14	0.2	0.33	1	1	1	1	3	5	7	0.2	0.33	1
A4	0.09	0.11	0.14	0.2	0.33	1	0.14	0.2	0.33	1	1	1	1	3	5
A5	7	9	11	0.2	0.33	1	0.09	0.11	0.14	0.2	0.33	1	1	1	1

C2	A1			A2			A3			A4			A5		
A1	1	1	1	1	3	5	5	7	9	7	9	11	0.09	0.11	0.14
A2	0.2	0.33	1	1	1	1	3	5	7	1	3	5	0.14	0.2	0.33
A3	0.11	0.14	0.2	0.14	0.2	0.33	1	1	1	3	5	7	0.2	0.33	1
A4	0.09	0.11	0.14	0.2	0.33	1	0.14	0.2	0.33	1	1	1	3	5	7
A5	7	9	11	0.14	0.2	0.33	0.09	0.1	0.14	0.14	0.2	0.3	1	1	1

C3	A1			A2			A3			A4			A5		
A1	1	1	1	1	3	5	5	7	9	7	9	11	0.09	0.111	0.14
A2	0.2	0.33	1	1	1	1	1	3	5	1	3	5	0.14	0.2	0.33
A3	0.111	0.14	0.2	0.2	0.33	1	1	1	1	3	5	7	0.2	0.33	1
A4	0.09	0.11	0.14	0.2	0.33	1	0.14	0.2	0.33	1	1	1	1	3	5
A5	7	9	11	0.2	0.33	1	0.09	0.11	0.14	0.2	0.33	1	1	1	1

C4	A1			A2			A3			A4			A5		
A1	1	1	1	1	3	5	5	7	9	7	9	11	0.09	0.11	0.14
A2	0.20	0.33	1.00	1	1	1	1	3	5	0.14	0.20	0.33	0.14	0.20	0.33
A3	0.11	0.14	0.20	0.20	0.33	1	1	1	1	0.11	0.14	0.20	0.20	0.33	1.00
A4	0.09	0.11	0.14	3	5	7	5	7	9	1	1	1	1	3	5
A5	7	9	11	0.20	0.33	1	0.09	0.11	0.14	0.20	0.33	1	1	1	1

C5	C1			C2			C3			C4			C5		
C1	1	1	1	1	3	5	7	9	11	7	9	11	0.09	0.11	0.14
C2	0.20	0.33	1	1	1	1	1	3	5	1	3	5	0.14	0.20	0.33
C3	0.09	0.11	0.14	0.20	0.33	1	1	1	1	0.11	0.14	0.20	0.20	0.33	1
C4	0.09	0.11	0.14	0.20	0.33	1	5	7	9	1	1	1	1	3	5
C5	7	9	11	0.20	0.33	1	0.09	0.11	0.14	0.20	0.33	1	1	1	1

RESULTS AND DISCUSSION

After implementing the fuzzy AHP method, as Chang's analytical method, we obtain the following results:

Criteria	Ponderized values	Alternatives				
		A1	A2	A3	A4	A5
C1	**0.26754**	0.34287	0.303967	0.319555	0.38745	0.364274
C2	**0**	0.109059	0.151158	0.130807	0.021366	0.110393
C3	**0.14368**	0.237334	0.202872	0.225072	0	0
C4	**0.22053**	0.154462	0.201578	0.148429	0.38745	0.364274
C5	**0.36825**	0.156274	0.140425	0.176136	0.203734	0.161059
weight acquired		**0.217443**	**0.206638**	**0.215428**	**0.264128**	**0.237101**

A Consensus Convergence Model – CCM) (13) is developed for the purpose of deciding which of the defined alternatives has the greatest influence on the achievement of the defined goal. It is based on the model proposed by Lehrer and Wagner (1981), which is based on the weighting of decision makers on the basis of mutual respect, that is, the competence of other participants in the decision-making process. The new model is based on determining the differences in the "weights" of decision makers based on the value assigned by each decision maker to the appropriate elements (criteria, sub criteria and / or alternatives) (6).

If the initial severity of the elements in the hierarchy that values the decision$p_1^0, p_2^0, \dots, p_n^0$-making, the determination of the weight is

$$W_{ij} = \frac{1-\left|p_i^0-p_j^0\right|}{\sum_{j=1}^{n} 1-\left|p_i^0-p_j^0\right|} \qquad (4)$$

The difficulty gained in the preceding step is used to form the Wdimension Matrix
n x n

$$W=\begin{bmatrix} W_{11} & W_{12} \dots W_{1n} \\ W_{21} & W_{22} \dots W_{2n} \\ \dots & \dots \quad \dots \\ W_{n1} & W_{n2} \dots W_{nn} \end{bmatrix} \qquad (5)$$

If Pvector is the initial weight of the hierarchy elements, the condenszous vector is obtained using the equation,

$$P_c = W P_{c-1} \qquad (6)$$

The procedures are repeated until the vector values P_c и $P_{c-1}$are equal. When two consecutive vectors have the same value, the procedure is terminated and the result is adopted as final.

Based on the evaluation results, a joint - final decision on the alternative of highest value for the safe management of unmanned aircraft - was made for all six stakeholders involved in the research. The final weight vectors for the CVO, ADO, KBV, SVV, PA, and PH interest groups are shown in Table 3. These values represent the input data for applying the consensus convergence model.

Table 3.

	WEIGHT VECTORS					
	CVO	ADO	KBV	SVV	PA	PH
A1	0,217443	0,256449	0,291121	0,276306	0,322671	0,27165
A2	0,206638	0,247448	0,278575	0,259572	0,270139	0,257494
A3	0,215428	0,239744	0,264759	0,243652	0,216346	0,249921
A4	0,264128	0,237792	0,267448	0,24323	0,226449	0,234603
A5	0,237101	0,21749	0,282413	0,238011	0,310816	0,234982

For obtaining the concentration of the vectors for alternatives, calculations have been carried out in more instrumentation (Blagojevicet al.,2016). The Consezusna weight for alternative A1 is obtained insixth Intermentation, for A2 in the fifth, for A3 in the fourth, for A4 and A5 seventh interagency. Calculation procedure with the concurrent converging model will be explained for an alternative to A1. For calculations, it is a necessary initial weight for the alternative A1 and the so-called. Respect matrix for a given alternative. Initial weight for alternatives of A1 are the difficulty that this the alternative to assigning all interest groups.

$$P_0^{A_1} = \begin{bmatrix} 0{,}250 \\ 0{,}216 \\ 0{,}244 \\ 0{,}259 \\ 0{,}265 \\ 0{,}244 \end{bmatrix}$$

Based on the formulas (4) and (5) It is calculated the matrix of respect for alternative A1, in the sixth inersion $P_6^{A_1}$and$P_5^{A_1}$are equal, which means that the resulting consesion weight for a1 and is 0.077.

The same procedure is applied for the calculation of consection weight vectors and for other alternatives and as a result of the values shown in table 4,

Table 4.

Alternatives	condensation weight vectors	Rank
A1	0,077	1
A2	0,069	2
A3	0,060	5
A4	0,061	4
A5	0,062	3

Based on the results shown in Table 4, it is concluded that Alternative A1 - "requires theatrical and practical training for the safe operation of unmanned aircraft" is of paramount importance for the safe management of unmanned aircraft; pilot "ranked third with" only practical training required "ranked, fourth with" only theoretical training required "and fifth with" no need n theoretical or practical training".

CONCLUSION

Carried out the cause of theincident in the management of free aircraft and theMulticriteria analysis of the method „fuzzy" of theexpandedAHP method thingummynumbers indicate that the safe handling of drone aircraft is necessary for theoretical and practical training of drone operatorsregardless of the category of drone aircraft.

Respecting the general laws of physics and taking into account the mass of drones, the speedand altitude on which it flies, in case of losscontrolcan be caused by serious injury of people and animals as Damage or destruction of natural resources and material goods.

This work should provide the basis for the development of regulations in the area of drone management, on the one hand, and on the other side to give the basics for drafting a plan and program for the training of drone users.

The resulting survey results can be applied in the course of increasing security in the area of drone flight management through the creation of a plan and a programmefor safe handling of drones.

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