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DEMATEL-AHP MULTI-CRITERIA DECISION MAKING MODEL FOR THE DETERMINATION AND EVALUATION OF CRITERIA FOR SELECTING AN AIR TRAFFIC PROTECTION AIRCRAFT

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Abstract: *This paper describes an approach in the determination and evaluation of the criteria and attributes of criteria for selecting the air traffic protection aircraft. After collected initial criteria and attributes, the interaction between criteria and attributes of criteria for the selection of the aircraft especially for the protection of air traffic was evaluated by 45 respondents. Data processing and criteria and attributes determination were carried out by the DEMATEL method (by eliminating less significant criteria and attributes). Furthermore, the weight values of each criterion and attribute were determined by the AHP method. Prioritization was carried out using an eigenvector method. For determination reliability the consistency ratio was checked for each result. As a result the model for the selection of the aircraft was proposed.*

***Key words**: Aircraft; Air Traffic; Attribute; Criterion;* Consistency; Protection.

1. Introduction

From an economic point of view air traffic can be one of the more profitable business activities of each country. The organization and implementation of air traffic is complex process, which includes the need for continuous improvement (Menon et al., 2004; Chen et al., 2017; Menon & Park, 2016; Steiner et al., 2010; Durso & Manning, 2008; Abbass et al., 2014). But, the issue of improving the protection of air traffic from aircraft threats has become particularly important since 9/11 (Petrović et al., 2015).

There are many approaches to address air traffic protection issues. The basic way is in the existence of duty–aircrafts (it is essentially a fighter aircraft that provide a

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rapid reaction in the case of airspace violation and other situations of violation of air traffic safety).

Some of small countries (in quantitative and qualitative terms) (Gordić & Petrović, 2014) give another countries the jurisdiction for the conducting of this mission. In the case study of the Republic of Serbia, which is a synonym for the small country, it can be noticed what are the criteria and how to prioritize them for the needs of equipping the country with the aircraft whose main purpose is to protect air traffic and intercept the aircraft that violated the airspace.

The small area of the Republic of Serbia, and unusual, elongated form of territory allow for a short flight time over the territory and a simple and rapid airspace violation (Petrović, 2013). Therefore, it is necessary to determine which criteria and attributes of criteria are significant for the needs of equipping the country with the aircraft.

The general objective of this paper is: determination and evaluation of criteria and attributes within the determinated criteria for selecting the aircraft for the purpose of air traffic protection from the airspace violation and other aviation threats using the DEMATEL and AHP methods. This multi-criteria model consists of criteria and attributes that are significant for the selection of combat aircraft.

The above stated research objective gives rise to following general hypothesis:

Using the DEMATEL and AHP methods, it is possible to determinate and to evaluate the criteria for selecting the aircraft for the purpose of air traffic protection from the airspace violation and other aviation threats.

The scientific and methodological contribution of paper is reflected in the new approach of determinating significant and eliminating less significant criteria - attributes for the needs of selecting system with special role. Also, the scientific contribution is reflected in increase of theoretical fund, which refers to the systematization of previous knowledge by the method of content analysis, and the gathering of relevant data about the criteria and attributes of criteria for the selection of the aircraft for the needs of conducting the missions during peacetime.

The practical contribution is reflected in the fact that in the paper the model was created that could improve the process of equipping the System of Defence with new equipment. Also, modification of the model (by changing of criteria) enables its application in cases of procurement a wide range of equipment for the needs of realization of various forms of human activity.

2. Materials and methodes

The research was carried out in three phases: identification of initial criteria and attributes (for selection of combat aircraft), determination of significant criteria and attributes of criteria (for selection of aircraft), and prioritization of selected criteria and attributes (Figure 1).

In the first, all measures have been identified that enable selection of the combat aircraft by analyzing the contents of the relevant scientific fund (Čokorilo et al., 2010; Kirby, 2001; Dağdeviren et al., 2009; Petrović et al., 2017). The selection and conceptual evaluation of military aircraft characteristics by applying the overall evaluation criterion (OEC) was done by Mavris and DeLaurentis (1995). The selection and evaluation of the criteria for equipping the Army with combat aircraft using the AHP method was done by Vlačić (2012). The identified measures are divided into general and specific measures using the classification method (based on the level of generality). The general measures represent criteria, and attributes are specific.

Taking into consideration the number and different significance of the identified criteria and attributes it was necessary to eliminate irrelevant and to evaluate significant criteria and attributes. It was carried out using the questionnaire, the DEMATEL and the AHP method.

Based on these results, the model that provides a multi-criteria analysis of the selection of the aircraft for the air traffic protection from the airspace violation and other aviation threats was developed.

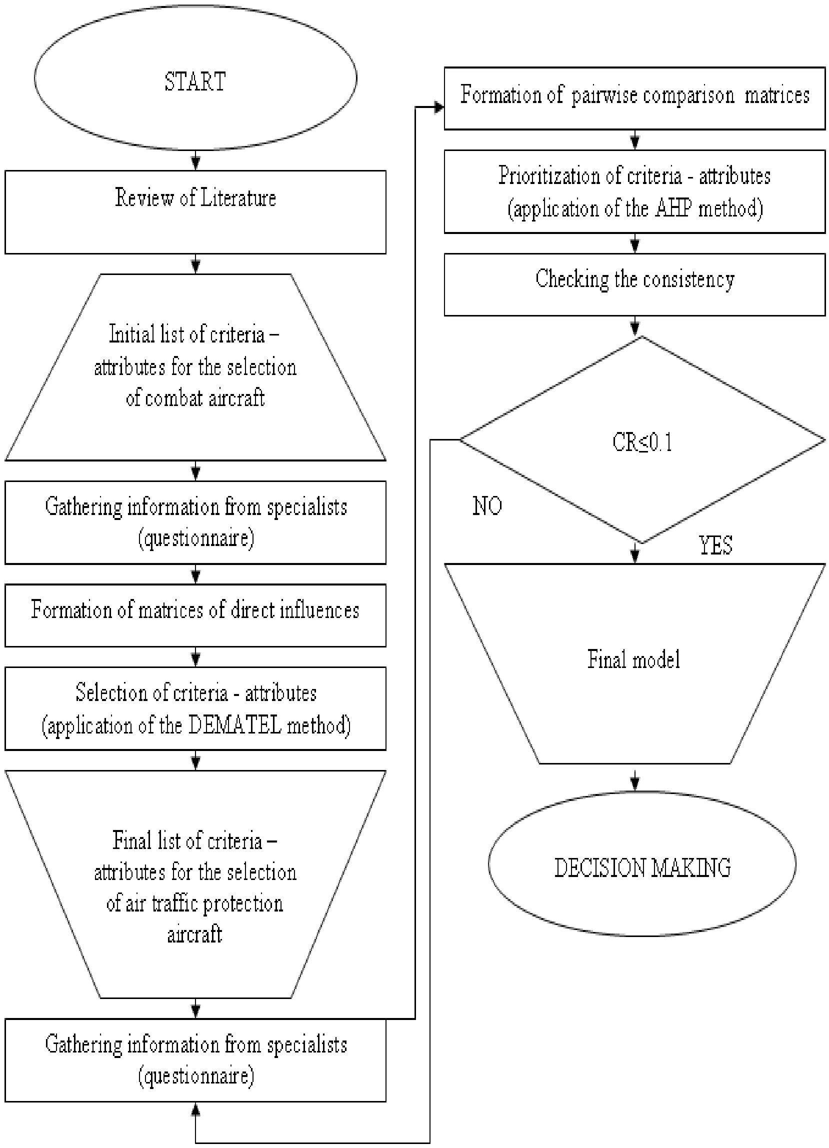

Figure 1. Algorithm of a multi-criteria selection of the aircraft

Using the questionnaire and contents analysis of literature, the criteria and the attributes of each criterion (initial criteria and attributes) for the combat aircraft were selected.

The following criteria are selected: A- aerodynamics and mechanics of the flight, B - construction and general systems, C - propulsion, D – avionics and sensors, E - integrated logistics support, F – armament, G – reconnaissance equipment, H – concept of pilot training and I – economy.

The initial attributes of criterion aerodynamics and mechanics of the flight are: A1 – weight, A2 - airspeed, A3 – acceleration performance, A4 – length of take off - landing, A5 - ceiling of flight, A6 – rate of climb, A7 – range of flight, A8 – maneuvering and stability performance, A9 – ability of supercruise and A10 – reaction time.

The initial attributes of criterion construction and general systems are: B1 - wing mechanization and flight control system, B2 – obstacle avoidance system, B3 – GPS terrain-following, B4 – voice command system, B5 – oxygen system, B6 – radar cross-section and infrared signature, B7 – potential for modernization, B8– durability, B9 – ability of aerial refueling and B10 – possibility of ejection of pilot's seat.

The initial attributes of criterion propulsion are: C1 – reliability and maintainability, C2 – maximum engine's thrust with afterburning, C3 – maximum engine's thrust without afterburning, C4 – thermal emission and C5 – maintenance system.

The initial attributes of criterion avionics and sensors are: D1 – radars and other sensors, D2 – communication equipment, D3 – fire-control radar, D4 – electronic warfare equipment, D5 – multi-function display, D6 – navigation equipment, D7 – multimedia link.

The initial attributes of criterion integrated logistics support are: E1 – reliability of aircraft, E2 - convenience of maintenance, E3 – maintenance of aircraft, E4 – maintainability, E5 – ability of maintenance staff, E6 – maintenance equipment and E7 – infrastructure.

The initial attributes of criterion armament are: F1 – capacity of locations for mounting armament, F2 – variety of armament, F3 – standardization of armament, F4 – number hardpoints of armament, F5 – under-fuselage hardpoints, F6 – possibility of using armament, F7 – safety work with armament on the ground, F8 – air – to – air missiles and rockets, F9 – bombs and other air - to - surface armament and F10 - guns (cannons).

The initial attributes of criterion reconnaissance equipment are: G1 - possibility of reconnaissance in different weather conditions, G2 - sensors range, G3 - data-processing of reconnaissance information, G4 - data-processing of reconnaissance photos and G5 - data-processing of reconnaissance video.

The initial attributes of criterion concept of pilot training are: H1 - pilot training abroad, H2 - individual training, H3 - collective training and H4 - simulators of flight.

The initial attributes of criterion economy are: I1 – acquisition cost, I2 – life cycle costs and I3 – aircraft disposal costs.

From initial criteria and attributes, the determination of criteria and attributes for the selection of the air traffic protection aircraft was preformed using the DEMATEL method (Moghaddam et al., 2010; Sumrit & Anuntavoranich, 2013).

By applying this method (Decision – Making Trial and Evaluation Laboratory), based on the determination of direct and indirect influences between each criterion (attribute) on each citerion (attribute), criteria, which mutual impact on other criteria being less significant, were eliminated (Moghaddam et al., 2010).

Each of the respondents (45 specialists – military pilots and officers of the aviation - technical service) indicated the degree of direct and indirect influences between each criterion on each citerion and each attribute on each attribute of the criterion using the questionnarie. This step was done according to DEMATEL method (Sumrit & Anuntavoranich, 2013). Pairwise comparison was done as follows. The value of each pair is ranked by a number whose value is from 0 to 4 (0 – no influence; 1 – low influence; 2 – middle influence; 3 – high influence; 4 – very high influence) The assessment of each respondent is shown by a nonnegative matrix $n \times n$ (for criterion $n = 9$). Each element of the k-matrix which is calculated by the equation 1 is a non-negative number x_{ij}^{k} , where is $1 \leq k \leq m$.

$$X^{k} = \left[x_{ij}^{k} \right]_{n \times n} \tag{1}$$

Matrices $X^{1}, X^{2}, \ldots, X^{m}$ represent individual preference (pairwise comparison) matrices of the respondents. The diagonal values are 0 because there is no influence between same criterions (Sumrit & Anuntavoranich, 2013). By calculating the means of the individual gathered values, a matrix of direct influences was created (Table 1).

Table 1. Matrix of direct influences of criteria

K	A	B	C	D	E	F	G	H	I
A	0	3.85	3.92	3.45	3.73	3.68	0.45	0.54	3.9
B	2.17	0	2.04	3.12	1.45	1.72	0.53	0.34	1.14
C	2.94	1.11	0	1.73	1.14	0.94	0.52	0.32	0.85
D	3.65	3.2	3.91	0	3.17	3.2	0.61	0.29	3.23
E	3.42	3.17	2.12	1.92	0	2.73	0.45	0.34	2.45
F	3.18	2.57	3.14	3.22	2.72	0	0.32	0.35	2.74
G	0.51	0.42	0.37	0.32	0.41	0.38	0	0.42	0.39
H	0.33	0.42	0.44	0.41	0.37	0.39	0.51	0	0.19
I	3.92	3.17	2.93	3.45	3.15	3.08	0.28	0.32	0

In the second phase, the normalization of the matrix of direct influences is calculated using the following equation:

$$D = \frac{x}{\max\left(\max_{1 \leq i \leq} \sum_{j=1}^{n} x_{ij}, \max_{1 \leq i \leq n} \sum_{i=1}^{n} x_{ij} \right)} \tag{2}$$

D – Normalized matrix of direct influences,

X – Element of the mean value matrix of estimation of mutual influence.

Each element of the matrix of direct influences of criteria is divided with the maximum value of the sum of the columns and rows of the matrix of direct influence and new matrix is formed – normalized matrix of direct influence of criteria (Table 2).

Table 2. Normalized matrix of direct influence of criteria

K	A	B	C	D	E	F	G	H	I
A	0.000	0.164	0.167	0.147	0.159	0.156	0.019	0.023	0.166
B	0.092	0.000	0.087	0.133	0.062	0.073	0.023	0.014	0.048
C	0.125	0.047	0.000	0.074	0.048	0.040	0.022	0.014	0.036
D	0.155	0.136	0.166	0.000	0.135	0.136	0.026	0.012	0.137
E	0.145	0.135	0.090	0.082	0.000	0.116	0.019	0.014	0.104
F	0.135	0.109	0.134	0.137	0.116	0.000	0.014	0.015	0.116
G	0.022	0.018	0.016	0.014	0.017	0.016	0.000	0.018	0.017
H	0.014	0.018	0.019	0.017	0.016	0.017	0.022	0.000	0.008
I	0.167	0.135	0.125	0.147	0.134	0.131	0.012	0.014	0.000

In the next phase, all the relations between each pair of the criteria are expressed by the matrix of direct influences. Elements of matrix of full direct/indirect influence of criteria were derived by the equation 3 and the matrix is shown in Table 3.

$$T = D(I - D)^{-1} \text{ in} \tag{3}$$

$$T = \left[t_{ij}\right]_{nxn}, i, j = 1, 2, \ldots n$$

T – Matrix of full influence,

I – Unit matrix of influence,

t_{ij} - Element of the matrix of full influence.

Table 3. Matrix of full influence of criteria

K	A	B	C	D	E	F	G	H	I
A	0.383	0.486	0.509	0.470	0.451	0.448	0.083	0.072	0.436
B	0.299	0.194	0.288	0.310	0.236	0.244	0.059	0.042	0.214
C	0.279	0.200	0.164	0.220	0.188	0.180	0.050	0.037	0.170
D	0.484	0.435	0.479	0.313	0.406	0.405	0.083	0.058	0.389
E	0.409	0.376	0.353	0.331	0.233	0.336	0.066	0.051	0.313
F	0.429	0.378	0.416	0.398	0.359	0.254	0.066	0.056	0.343
G	0.070	0.062	0.063	0.058	0.057	0.056	0.009	0.025	0.055
H	0.058	0.057	0.060	0.056	0.051	0.052	0.030	0.006	0.042
I	0.490	0.433	0.443	0.439	0.404	0.401	0.070	0.059	0.268

By comparing the values in the matrix of full influence of criteria with the calculated threshold value it is determined whether the criteria are significant or not. Namely, if all the values of one criterion are less than the threshold value, this criterion is not significant for the selection of the aircraft.

The threshold value is calculated using the equation 4 and is 0.232.

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left[t_{ij}\right]}{N} \tag{4}$$

α - threshold value,

N – full number of elements of matrix T.

Table 4. Comparison of the elements of matrix of full influence of criteria with the threshold values of criteria

K	A	B	C	D	E	F	G	H	I
A	0.151	0.254	0.277	0.238	0.219	0.216	-0.149	-0.160	0.204
B	0.067	-0.038	0.056	0.078	0.004	0.012	-0.173	-0.190	-0.018
C	0.047	-0.032	-0.068	-0.012	-0.044	-0.052	-0.182	-0.195	-0.062
D	0.252	0.203	0.247	0.081	0.174	0.173	-0.149	-0.174	0.157
E	0.177	0.144	0.121	0.099	0.001	0.104	-0.166	-0.181	0.081
F	0.197	0.146	0.184	0.166	0.127	0.022	-0.166	-0.176	0.111
G	-0.162	-0.170	-0.169	-0.174	-0.175	-0.176	-0.223	-0.207	-0.177
H	-0.174	-0.175	-0.172	-0.176	-0.181	-0.180	-0.202	-0.226	-0.190
I	0.258	0.201	0.211	0.207	0.172	0.169	-0.162	-0.173	0.036

By observing the obtained results it is concluded that two criteria (G and H) are not significant for the selection of the aircraft (Table 4).

In the same way attributes of selected criteria that are not relevant for the selection of the aircraft were eliminated (Table 5-11).

Table 5. Comparison of the elements of matrix of full influence of attributes of criterion aerodynamics and mechanics of the flight with the threshold values

A	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	-0.236	-0.144	-0.145	-0.213	-0.201	-0.148	-0.135	-0.133	-0.209	-0.151
A2	-0.162	0.225	0.363	-0.150	-0.148	0.159	0.371	0.421	-0.156	0.360
A3	-0.153	0.436	0.249	-0.140	-0.141	0.316	0.418	0.436	-0.152	0.401
A4	-0.214	-0.134	-0.140	-0.234	-0.208	-0.155	-0.137	-0.128	-0.208	-0.128
A5	-0.224	-0.169	-0.169	-0.221	-0.239	-0.180	-0.166	-0.164	-0.217	-0.167
A6	-0.165	0.383	0.360	-0.149	-0.148	0.135	0.364	0.399	-0.159	0.331
A7	-0.179	0.207	0.169	-0.175	-0.174	0.096	0.082	0.237	-0.182	0.069
A8	-0.165	0.248	0.181	-0.163	-0.166	0.172	0.282	0.160	-0.171	0.244
A9	-0.211	-0.121	-0.120	-0.200	-0.210	-0.142	-0.116	-0.109	-0.233	-0.120
A10	-0.147	0.443	0.425	-0.138	-0.138	0.346	0.445	0.456	-0.147	0.246

The attributes A1, A4, A5 and A9 are eliminated.

Table 6. Comparison of the elements of matrix of full influence of attributes of criterion construction and general systems with the threshold values

B	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	0.303	-0.111	-0.091	-0.092	0.390	0.442	0.174	-0.095	-0.072	0.523
B2	-0.073	-0.192	-0.162	-0.161	-0.086	-0.083	-0.106	-0.160	-0.157	-0.068
B3	-0.102	-0.174	-0.194	-0.163	-0.117	-0.114	-0.126	-0.166	-0.166	-0.097
B4	-0.085	-0.163	-0.157	-0.192	-0.103	-0.089	-0.127	-0.162	-0.171	-0.087
B5	0.532	-0.105	-0.084	-0.093	0.220	0.394	0.269	-0.093	-0.088	0.517
B6	0.335	-0.112	-0.099	-0.104	0.285	0.189	0.223	-0.114	-0.107	0.427
B7	0.494	-0.100	-0.078	-0.082	0.389	0.379	0.143	-0.091	-0.084	0.498
B8	-0.081	-0.162	-0.156	-0.156	-0.100	-0.099	-0.119	-0.191	-0.153	-0.078
B9	-0.090	-0.176	-0.171	-0.170	-0.106	-0.095	-0.111	-0.157	-0.192	-0.084
B10	0.518	-0.106	-0.089	-0.092	0.281	0.435	0.314	-0.094	-0.090	0.330

The attributes B2, B3, B4, B8 and B9 are eliminated.

Table 7. Comparison of the elements of matrix of full influence of attributes of criterion propulsion with the threshold values

C	C1	C2	C3	C4	C5
C1	0.001	0.147	0.051	0.368	0.263
C2	0.056	-0.218	-0.214	0.082	-0.140
C3	0.123	0.002	-0.172	0.184	0.015
C4	-0.070	-0.101	-0.053	-0.094	-0.009
C5	-0.051	-0.008	-0.047	0.090	-0.174

All attributes are accepted.

Table 8. Comparison of the elements of matrix of full influence of attributes of criterion avionics and sensors with the threshold values

D	D1	D2	D3	D4	D5	D6	D7
D1	-0.083	0.030	-0.001	0.011	0.028	0.070	-0.100
D2	0.006	-0.071	-0.015	-0.013	0.028	0.070	-0.048
D3	0.140	0.147	-0.034	0.146	0.162	0.188	0.099
D4	-0.065	-0.062	-0.095	-0.135	-0.088	-0.011	-0.106
D5	-0.099	-0.053	-0.134	-0.118	-0.144	-0.065	-0.111
D6	0.099	0.115	0.060	0.080	0.097	0.008	0.037
D7	0.019	0.026	-0.008	-0.006	0.028	0.081	-0.109

All attributes are accepted.

Table 9. Comparison of the elements of matrix of full influence of attributes of criterion integrated logistics support with the threshold values

E	E1	E2	E3	E4	E5	E6	E7
E1	0.114	-0.091	0.360	0.375	0.305	0.348	0.279
E2	-0.079	-0.212	-0.082	-0.085	-0.103	-0.088	-0.125
E3	0.287	-0.121	0.127	0.280	0.206	0.270	0.214
E4	0.139	-0.133	0.117	0.021	0.085	0.077	0.037
E5	0.154	-0.142	0.053	0.113	-0.020	0.064	0.022
E6	0.219	-0.134	0.201	0.187	0.131	0.058	0.102
E7	0.360	-0.102	0.328	0.333	0.281	0.307	0.102

The attribute E2 is eliminated.

Table 10. Comparison of the elements of matrix of full influence of attributes of criterion armament with the threshold values

F	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	-0.010	0.073	0.171	0.057	-0.179	0.163	0.132	0.029	-0.155	0.122
F2	0.021	-0.023	0.052	0.061	-0.176	0.037	0.094	0.087	-0.174	0.086
F3	-0.052	-0.056	-0.087	-0.044	-0.200	-0.041	-0.036	-0.065	-0.192	-0.034
F4	0.012	0.023	0.030	-0.031	-0.178	0.104	0.096	0.047	-0.181	0.134
F5	-0.174	-0.175	-0.158	-0.173	-0.243	-0.154	-0.148	-0.180	-0.222	-0.168
F6	0.089	0.125	0.193	0.158	-0.164	0.056	0.160	0.078	-0.156	0.217
F7	0.105	0.085	0.152	0.040	-0.182	0.088	0.009	0.014	-0.166	0.076
F8	0.251	0.256	0.298	0.237	-0.141	0.279	0.283	0.080	-0.129	0.253
F9	-0.181	-0.175	-0.170	-0.182	-0.227	-0.170	-0.155	-0.176	-0.242	-0.165
F10	0.189	0.214	0.218	0.151	-0.140	0.240	0.266	0.193	-0.145	0.113

The attributes F5 and F9 are eliminated.

Table 11. Comparison of the elements of matrix of full influence of attributes of criterion economy with the threshold values

I	I1	I2	I3
I1	0.075	0.275	0.317
I2	0.097	-0.332	-0.041
I3	0.055	-0.108	-0.334

All three attributes are accepted.

The evaluation of the selected criteria and attributes of criteria was performed by the AHP method (the Analytich Hierarchy Process). The gathering data was carried out using the questionnaire which was adapted to scale of relative importance (Saaty, 1980). Using the standard scale, each element of comparasion a_{ij} of matrix A can get one of 17 numerical values from a discrete interval [1/9, 9]. Prioritization is conducted using the eigenvector method – EV (Saaty, 1980). The criteria and attributes of criteria are pairwise compared by respondents. By calculating the mode of the individual gathered values, a pairwise comparison matrix was created (Table12).

Table 12. Pairwise comparison matrix (for criteria)

K	A	B	C	D	E	F	I
A	1	4	4	3	4	3	2
B	0.25	1	2	0.5	0.5	0.333	0.5
C	0.25	0.5	1	0.333	0.5	0.5	0.5
D	0.333	2	3	1	2	3	2
E	0.25	2	2	0.5	1	0.5	0.5
F	0.333	3	2	0.333	2	1	0.333
I	0.5	2	2	0.5	2	3	1

Based on values from the pairwise comparison matrix, a normalized pairwise comparison matrix was calculated by the equation 5 (Saaty, 1980).

$$a'_{ij} = {a_{ij}} \Big/ {\sum_{j=1}^{n} a_{ij}} \tag{5}$$

Table 13. Normalized pairwise comparison matrix (for criteria)

K	A	B	C	D	E	F	I
A	0.343	0.276	0.250	0.487	0.333	0.265	0.293
B	0.086	0.069	0.125	0.081	0.042	0.029	0.073
C	0.086	0.034	0.063	0.054	0.042	0.044	0.073
D	0.114	0.138	0.188	0.162	0.167	0.265	0.293
E	0.086	0.138	0.125	0.081	0.083	0.044	0.073
F	0.114	0.207	0.125	0.054	0.167	0.088	0.049
I	0.171	0.138	0.125	0.081	0.167	0.265	0.146

From the Table 13, the weight values W were calculated by the equation 6, which are shown in table 14.

$$w_i = {\sum_{j=1}^{n} a'_{ij}} \Big/ {n} \tag{6}$$

w_i - Weight value,

a'_{ij} - Element of normalized pairwise comparison matrix

Table 14. Weight values of criteria ($CR = 0.055$)

K	A	B	C	D	E	F	I	W	Rank
A	0.343	0.276	0.250	0.487	0.333	0.265	0.293	0.321	1
B	0.086	0.069	0.125	0.081	0.042	0.029	0.073	0.072	6
C	0.086	0.034	0.063	0.054	0.042	0.044	0.073	0.057	7
D	0.114	0.138	0.188	0.162	0.167	0.265	0.293	0.189	3
E	0.086	0.138	0.125	0.081	0.083	0.044	0.073	0.090	5
F	0.114	0.207	0.125	0.054	0.167	0.088	0.049	0.115	4
I	0.171	0.138	0.125	0.081	0.167	0.265	0.146	0.156	2

It can be noted (Table 14) that the highest weight value in the selection of the aircraft for air traffic protection has the criterion of aerodynamics and flight mechanics (A), while the lowest weight value has criterion propulsion (C).

Checking the consistency of the results was tested by the consistency ratio applying the following equation (Pamučar, 2017):

$$CR = {CI}/{RI} \quad (7)$$

Where is:

CI - Consistency index.

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (8)$$

$\lambda_{\max}$ - Maximum eigenvector of the matrix of comparison. This value was calculated as follows:

$$\lambda_{\max} = {1}/{n} \sum_{i=1}^{n} \lambda_i \quad (9)$$

$$\lambda_i = {b_i}/{w_i} \quad (10)$$

Value b_i was calcualted as follows:

$$\begin{bmatrix} b_1 \\ b_2 \\ b_n \end{bmatrix} = \begin{bmatrix} a_{11}a_{12}a_{1n} \\ a_{21}a_{22}a_{2n} \\ a_{n1}a_{n2}a_{nn} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ w_n \end{bmatrix} \quad (11)$$

a_{ij} - Represents the value of the element from the pairwise comparison matrix.

RI - Random index, which depends on the number of rows - columns of the matrix n (Pamučar, 2017). For example, if $n = 2$, than is $RI = 0$, if $n = 3 \Rightarrow RI = 0.52$, if $n = 4 \Rightarrow RI = 0.89$, if $n = 5 \Rightarrow RI = 1.11$, if $n = 6 \Rightarrow RI = 1.25$, if $n = 7 \Rightarrow RI = 1.35$, if $n = 8 \Rightarrow RI = 1.4$.

If $CR \le 0.10$ then the result is consistent. In this case, the consistency ratio is 0.055 and it is lower then 0.1, so the result is consistent (there is no need for corrections of the comparison).

The weight values for attributes are determined in the same way. Weight values for the attributes of each criterion are shown in the following Tables 15-21.

Table 15. Weight values for attributes of criterion aerodynamics and mechanics of the flight ($CR = 0.03$)

A	A2	A3	A6	A7	A8	A10	W1	Rank
A2	0.185	0.222	0.273	0.222	0.254	0.147	0.217	2
A3	0.046	0.056	0.045	0.037	0.028	0.088	0.050	6
A6	0.092	0.167	0.136	0.148	0.169	0.147	0.143	3
A7	0.061	0.111	0.068	0.074	0.042	0.088	0.074	5
A8	0.061	0.167	0.068	0.148	0.085	0.088	0.103	4
A10	0.554	0.278	0.409	0.370	0.423	0.441	0.413	1

Table 16. Weight values for attributes of criterion construction and general systems ($CR = 0.01$)

B	B1	B5	B6	B7	B10	W2	Rank
B1	0.404	0.412	0.316	0.343	0.490	0.393	1
B5	0.058	0.059	0.053	0.057	0.061	0.057	5
B6	0.134	0.118	0.105	0.086	0.082	0.105	4
B7	0.202	0.176	0.211	0.171	0.122	0.177	3
B10	0.202	0.235	0.316	0.343	0.245	0.268	2

Table 17. Weight values for attributes of criterion propulsion ($CR = 0.02$)

C	C1	C2	C3	C4	C5	W3	Rank
C1	0.162	0.222	0.222	0.176	0.147	0.186	2
C2	0.081	0.111	0.148	0.118	0.117	0.115	3
C3	0.054	0.056	0.074	0.118	0.084	0.077	4
C4	0.054	0.056	0.037	0.059	0.065	0.054	5
C5	0.649	0.556	0.519	0.529	0.587	0.568	1

Table 18. Weight values for attributes of criterion avionics and sensors ($CR = 0.03$)

D	D1	D2	D3	D4	D5	D6	D7	W4	Rank
D1	0.152	0.133	0.170	0.190	0.194	0.100	0.218	0.165	3
D2	0.076	0.067	0.068	0.095	0.129	0.067	0.036	0.077	5
D3	0.304	0.333	0.339	0.286	0.258	0.400	0.327	0.321	1
D4	0.038	0.033	0.057	0.048	0.032	0.067	0.036	0.044	7
D5	0.051	0.033	0.085	0.095	0.065	0.067	0.055	0.064	6
D6	0.304	0.200	0.170	0.143	0.194	0.200	0.218	0.204	2
D7	0.076	0.200	0.113	0.143	0.129	0.100	0.109	0.124	4

Table 19. Weight values for attributes of criterion integrated logistics support ($CR = 0.03$)

E	E1	E3	E4	E5	E6	E7	W5	Rank
E1	0.374	0.261	0.357	0.350	0.329	0.462	0.355	1
E3	0.124	0.087	0.036	0.100	0.082	0.077	0.084	5
E4	0.075	0.174	0.071	0.100	0.055	0.058	0.089	4
E5	0.053	0.043	0.036	0.050	0.041	0.058	0.047	6
E6	0.187	0.174	0.214	0.200	0.164	0.115	0.176	3
E7	0.187	0.261	0.286	0.200	0.329	0.231	0.249	2

Table 20. Weight values for attributes of criterion armament ($CR = 0.04$)

F	F1	F2	F3	F4	F6	F7	F8	F10	W6	Rank
F1	0.032	0.024	0.031	0.029	0.025	0.023	0.053	0.024	0.030	8
F2	0.065	0.049	0.125	0.114	0.041	0.023	0.053	0.043	0.064	5
F3	0.065	0.024	0.063	0.114	0.062	0.034	0.074	0.071	0.063	6
F4	0.065	0.024	0.031	0.057	0.062	0.034	0.074	0.071	0.052	7
F6	0.161	0.146	0.125	0.114	0.124	0.136	0.122	0.107	0.130	3
F7	0.097	0.146	0.125	0.114	0.062	0.068	0.074	0.043	0.091	4
F8	0.226	0.341	0.313	0.286	0.373	0.341	0.368	0.428	0.334	1
F10	0.290	0.244	0.188	0.171	0.249	0.341	0.184	0.214	0.235	2

Table 21. Weight values for attributes of criterion economy ($CR = 0.02$)

I	I1	I2	I3	W7	Rank
I1	0.621	0.600	0.692	0.638	1
I2	0.310	0.300	0.231	0.280	2
I3	0.069	0.100	0.077	0.082	3

3. Results

On the basis of the first two phases of the research, less significant criteria and attributes are eliminated. These criteria are: reconnaissance equipment and concept of pilot training. In the same way attributes of criterion aerodynamics and mechanics of the flight are eliminated: weight, length of take off - landing, range and ceiling of flight and ability of supercruise. Eliminated attributes of criterion construction and general systems are: obstacle avoidance system, GPS terrain-following, voice command system, durability and ability of aerial refueling. Also, attribute convenience of maintenance of criterion integrated logistics support is eliminated. The following attributes of criterion armament are eliminated: under-fuselage hardpoints and bombs and other air - to - surface armament. Other attributes of selected criteria are significant for selection the air traffic protection aircraft. Their determination was the objective of the first part of the research.

Determining differences in significance between criteria and attributes of criteria was the objective of the second part of the research (using the AHP method). Prioritization of the criteria determined that the most significant criterion (Table 14 and Figure 2) is aerodynamics and mechanics of the flight (rank 1, weight 0.321), while the least significant is the criterion propulsion (rank 7; 0.057).

Attributes are also evaluated by prioritizing. The the most significant attribute of the criterion aerodynamics and mechanics of the flight (Table 15) is reaction time, and the least significant attribute is acceleration performance. Furthermore, for criterion construction and general systems the most significant attribute is wing mechanization and flight control system, and least significant is oxygen system.

The most significant attribute of the criterion propulsion (Table 17) is maintenance system and the least significant attribute is thermal emission. For the criterion avionics and sensors the highest weight value (Table 18) has fire-control radar and the lowest weight value has electronic warfare equipment. For the integrated logistics support the most significant is reliability of aircraft and the least significant is ability of maintenance staff (Table19). The air – to – air missiles and rockets are most significant for the criterion armament and the least significant attribute for the same criterion is capacity of locations for mounting armament (Table 20). Prioritization for the criterion economy is determined (Table 21) that highest weight value has acquisition cost, in the middle is life cycle costs and the lowest weight value has aircraft disposal costs.

For each weight value calculation, the consistency of the results was checked. Since all consistency ratio were less than 0.1, it is concluded that there is consistency for all results of prioritization.

Considering all aforementioned, it is concluded that the objective of the research is achieved and the general hypothesis is proven and the model is proposed (Figure 2).

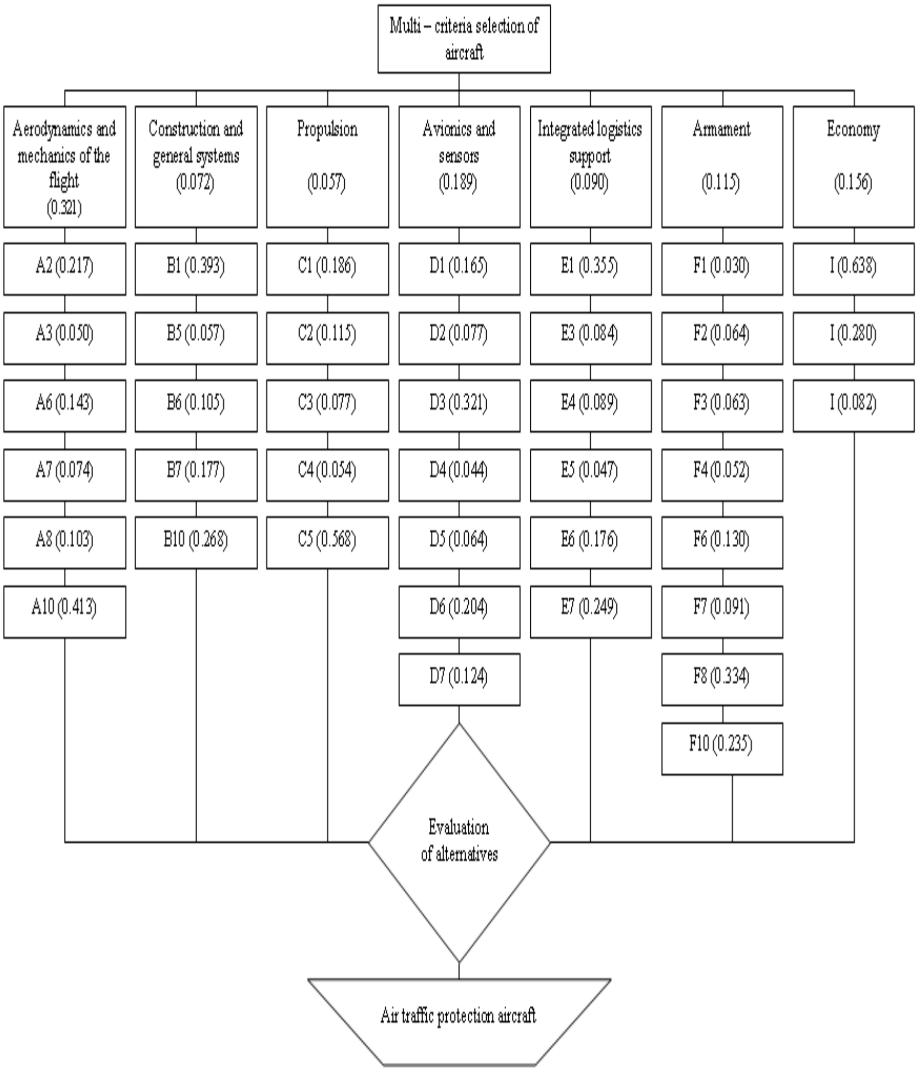

Figure 2. Proposed model for selection of the air traffic protection aircraft with weight values for criteria and attributes of criteria

4. Discussion

On the basis of the results it can be concluded that there are criteria and attributes which are significant for equipping the Army with the combat aircraft (Vlačić, 2012), but which are irrelevant in peacetime for the purpose of air traffic protection in the case of airspace violation.

For example, the most significant criterion for the combat aircraft is aerodynamics and mechanics of the flight, but also because of the multi roles, very significant is criterion reconnaissance equipment. The need for equipping two or three squadrons with the combat aircraft is the reason for the significance of the criterion concept of pilot training. Despite the aforementioned, the criterion economy is less significant for equipping with the combat aircraft than in the case of equipping with the air traffic protection aircraft (Vlačić, 2012). This difference as well as the difference in the significance of the selected criteria and attributes is a consequence of the overall picture of the organization and functioning of air traffic over the territory of the Republic of Serbia. Small area, elongated form of territory, high frequency of traffic, geostrategic position, number of air routes, financial capabilities of the country, availability and classes of airports are only several factors that have an impact on the determination and evaluation of criteria for selecting the aircraft (for example, it is easy to notice that due to the form of the territory and the area of the country, the reaction time is very significant for aircraft - the time required by duty - aircraft to take prescribed measures on the ground after receipt of an airspace endagering warning, to take off to be navigated and to intercept an aviation threat). The differences in the significance of the factors are also a consequence of the fact the combat aircraft conducts a wide range of tasks such as: air-to-air combat, aerial reconnaissance, forward air control, electronic warfare, air interdiction, suppression of enemy air defence and close air support. These missions would be conducted by aircraft in extremely specific conditions. Therefore, for selection of the aircraft are significant the following four overall evaluation criteria: affordability, mission capability, operational readiness and operational safety (Mavris & DeLaurentis, 1995).

It might be concluded that there are a lot of factors which impact on the determination and evaluation of criteria and attributes of criteria for selecting the air traffic protection aircraft. Also, those criteria are specific due to mission that is conducted by air traffic protection aircraft, although it is essentially the aircraft designed for use both in peacetime and wartime.

5. Conclusion

Air traffic is not immune to numerous security threats, including aviation threats. In the modern age, the possibility of occurrence of the airspace violation and other aviation threats is a reality. Therefore, the protection of air traffic from aviation threats is a very important security mission all around the world. In small countries, this task is conducted by their own aviation or aviation of some other countries. There is no doubt that for each country it is better to conduct this mission with its own aviation. It is also important to know that the aircrafts whose mission is to protect the air traffic from aviation threats have to meet the relevant international standards and technological criteria. Bearing in mind aforementioned and price of modern military aircrafts, the small countries usually make the decision to equip only a few aircrafts for the conducting of this mission. Therefore, it is necessary to determine very precisely according to the criteria of equipping, which depend on the set of factors mentioned in this paper and because of it precise determination and evaluation of the criteria for the selection of the air traffic protection aircraft on the example of the Republic of Serbia was the subject of this research.

For the purposes of this paper, traditional multi-criteria decision making methods are used and the model is proposed that can be applied in practice (and for the purpose of other countries that have simmilar teritorial characterics). By determining the mutual influence of the criteria (attributes) using the DEMATEL method, the final definition of the criteria (atributtes) and their weights are calculated by AHP. The applied methods, the obtained results and the proposed model make this research scientifically and methodologically justified.

Furthermore, it is possible to propose similar models for the needs of equipping the system of defence with other types of equippment. Above mentioned makes this research practical justified.

In the future research, it is possible to select a specific aircraft using some other the multi-criteria decision making methods (TOPSIS, MABAC, VIKOR, MAIRCA, etc.). Also, the models for designing certain technological solutions according to user requirements can be created. Furthermore, the application of similar models is possible for the purpose of implementing organizational changes in some organizational systems. Future research can also focus on the development of similar models using traditional methods in combination with methods that take into account uncertainty – fuzzy numbers tipe one-two or rough or interval-valued rough fuzzy numbers, intuitionistic fuzzy numbers, etc (Vahdani et al., 2013; Sizong & Tao, 2016; Zywica et al.,2016; Pamučar et al., 2018), which would significantly improve the field of multi-criteria decision making.

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