SELECTION OF AGRICULTURAL AIRCRAFT USING AHP AND TOPSIS METHODS IN FUZZY ENVIRONMENT

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Abstract

Considering the difficulty and complexity involved in choosing an agricultural aircraft, it is proposed to rank agricultural aircraft based on linguistic evaluations of their qualities. Aiming this, it is used an algorithm based on the Analytical Hierarchy Process (AHP) method and in the Technique of Order of Preference by Similarity to Ideal Solution (TOPSIS). The linguistic parameterization is made by using triangular fuzzy numbers. The method can be also used in other selection problems and in conceptual design phase in order to choose aircraft configurations.

1 Introduction

The use of aircraft in agriculture is very important. The application of pesticides, fertilizers and seeds with the use of aircraft is widely used in Brazil. Furthermore, this market has a great growth potential.

Considering the difficulty and complexity involved in choosing an agricultural aircraft, it is proposed applying a mathematical model that has as inputs linguistic variables, to select the best performance agricultural aircraft taking into account various relevant criteria. One important aspect of this method is its simplicity of usage that is obtained based on linguistic criteria of evaluation of the qualities.

The algorithm used in this work is based on the Analytical Hierarchy Process (AHP) method and in the Technique of Order of Preference by Similarity to Ideal Solution (TOPSIS). The linguistic parameterization is made using triangular fuzzy numbers. The usage of simple linguistic variables and comparisons allows inputs considering particularities of the mission profile that the aircraft will perform.

The same algorithm has already been used to a weapon selection problem and good results were achieved [1], demonstrating the effectiveness and feasibility of the method. Also, the selection of aircraft was already tested using TOPSIS under a fuzzy environment, emphasizing the capabilities of these method [2].

2 Objectives

This work aims proposing a solution to a selection problem of agricultural aircraft, considering important criteria related to its mission, and achieve the best aircraft. Specific objectives are shown below.

1. Evaluate the weights of relevant criteria considered in the selection problem using the Analytical Hierarchy Process (AHP).
2. Evaluate the quality of the competitors considering each criterion separately, using linguistics parameters established by fuzzy triangular numbers.
3. Order the competitors using the Technic of Order of Performance by Similarity to Ideal Solution (TOPSIS).
4. Analyze the results and the applicability of the method.

3 AHP

The AHP, developed by Saaty (1980) [3], provides a powerful tool to deal with multi-criteria decision problems. With this method, it is possible to attribute weights to different relevant criteria in a selection problem and to evaluate criteria using simple quantitative comparisons.

The first step of the method is to structure a hierarchy of elements of decision based on the problem. These elements are the criteria and the competitors that compose the analysis.

The establishment of the hierarchy allows decomposing a complex problem in a convenient structure to analyze. This way the problem is represented in a tree structure with at least three levels: problem goal, choice criteria and competitors.

Considering the hierarchy established, the next step is to proceed with pairwise comparisons of the criteria. The comparison is done since the highest levels of the hierarchy until the lower ones. This pairwise comparison is done following some standardized comparison scale. In this work the considered scale is shown in Tab.1.

Tab. 1 - Scale used in pairwise comparisons

Importance Intensity	Definition
1	Same importance
2	Slightly more important
3	More importante
4	Much more important
5	Absolutely more important

Considering $C = \{c_1, c_2, ..., c_n\}$ the set of n adopted criteria, the matrix A is then established as the result of the pairwise comparisons between them.

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \qquad (1)$$

$$a_{ii} = 1, a_{ij} = \frac{1}{a_{ji}} \qquad (2)$$

Where a_{ij} is the comparison value of the criteria c_i and c_j.

The weights of each criterion are obtained by calculating the eigenvector corresponding to the highest eigenvalue of the matrix A.

In order to measure if the evaluations are sufficiently consistent, it is necessary to calculate the consistency index (CI). This index is important to represent the quality of the comparisons, considering that some comparison mistakes can compromise the quality of the results.

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (3)$$

The ratio between the consistency index and the random index (RI) results in the consistency relation.

$$CR = \frac{CI}{RI} \qquad (4)$$

The values of RI depends on the number of criteria adopted in the comparison and were determined by Saaty. In order to satisfy the consistency requirement it is necessary to have $CR<0.1$.

3 Technique of Order of Performance by Similarity to Ideal Solution

The TOPSIS was developed by Hwang & Yoon (1981) [4], and consists in a method to order competitors according to their performance.

TOPSIS consists in establishing two idealized competitors, the positive ideal competitor (IC^+) and the negative ideal competitor (IC^-). The positive ideal competitor is the one that has the best possible performance attributes, while the negative ideal competitor has the worst ones. Following the technique, the best competitor is the one that is closer to the ideal positive competitor and most distant from the negative ideal competitor.

In order to calculate these distances it is necessary to evaluate the competitors according to each criterion in order to establish the evaluation matrix V.

$$V = \begin{bmatrix} v_{11} & \cdots & v_{1m} \\ \vdots & \ddots & \vdots \\ v_{n1} & \cdots & v_{nm} \end{bmatrix} \quad (5)$$

The evaluation matrix V is composed by elements v_{ij}, which are defined as the performance value of the j^{th} competitor in respect to the i^{th} criterion in a problem of n criteria and m competitors.

Then, it is necessary to calculate the matrix Q, result of the normalization of the matrix V. The element q_{ij} of the matrix Q is calculated following the Eq. 6.

$$q_{ij} = \frac{v_{ij}}{\sqrt{\sum_{i=1}^{n} (v_{ij})^2}} \quad (6)$$

On this step the criteria weights, if applicable, are introduced to the problem by multiplying each line by the respective criterion weight. The element p_{ij} of the weighted matrix P can be calculated by the following equation, where w_i is the weight of the i^{th} criterion.

$$p_{ij} = q_{ij}\ x\ wi \quad (7)$$

Then, it is necessary to determine the positive ideal competitor vector A^+, and the negative ideal competitor vector A^-.

$$A^+ = \{a_1^+, \ldots, a_j^+, \ldots, a_m^+\} \quad (8)$$

$$A^- = \{a_1^-, \ldots, a_j^-, \ldots, a_m^-\} \quad (9)$$

The values of a_j^+ and a_j^- are established by evaluating each criterion and assuming the absolute best and worst values, respectively, concerning its influence in performance.

Finally, it is calculated the distance between each competitor and the positive ideal competitor D_j^+.

$$D_j^+ = \sqrt{\sum_{i=1}^{n} (p_{ij} - a_i^+)^2} \quad (10)$$

Analogously, the distance between each competitor and the negative ideal D_j^+ competitor is calculated.

$$D_j^- = \sqrt{\sum_{i=1}^{n} (p_{ij} - a_i^-)^2} \quad (11)$$

The relative distance from the ideal solution (CC_j) can be then calculated and used to order the competitors.

$$CC_j = \frac{D_j^-}{D_j^+ + D_j^-} \quad (12)$$

Therefore, the competitor with the highest value of CC_j has the best combined performance according to TOPSIS.

5 TOPSIS Technique parameterized linguistically with triangular fuzzy numbers

The TOPSIS technique is widely used in order to evaluate and order competitors in real problems. However, it is difficult to apply this technique to some problems, such as an aircraft choice, due to some difficulties when using absolute numbers. It is not simple to establish the ideal solutions and the calculation of the distances using absolute number not necessarily fits the imprecisions and tolerances of these problems.

Using the Fuzzy Set Theory, by Zadeh, (1965)[5],(1975)[6] together with the TOPSIS method, it is possible to introduce the ability of handling uncertainties in the problem and facilitates the establishment of the ideal solutions and the calculation of the distances. Furthermore, fuzzy numbers have simple relations and operations, avoiding the problem to become excessively complex.

Some important definitions concerning fuzzy triangular numbers are introduced bellow.

Definition 1 – A fuzzy set A is defined on a base set X, and it is characterized by its pertinence function $\mu_A(x)$. The function $\mu_A(x)$ associates each element of X with a real value in the range [0,1].

$$A: X \rightarrow [0,1] \quad (13)$$

Definition 2 – A triangular fuzzy number a can be defined by a triple (a_1, a_2, a_3). The pertinence function $\mu_A(x)$ is defined in Eq. 14 and is shown in Fig. 1.

$$\mu_A(x) = \begin{cases} 0, & x < a_1 \\ \frac{x - a_1}{a_1 - a_2}, & a_1 \leq x \leq a_2 \\ \frac{x - a_2}{a_2 - a_3}, & a_2 \leq x \leq a_3 \\ 0, & x > a_3 \end{cases} \quad (14)$$

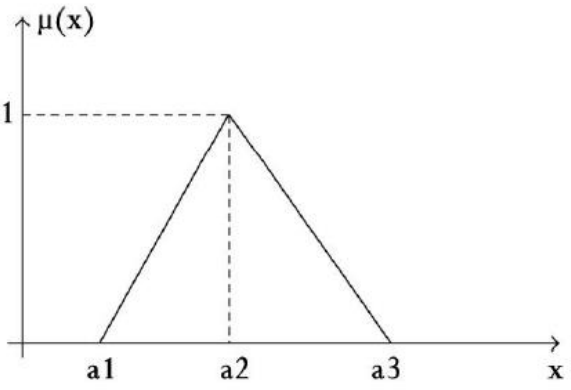

Fig. 1 - Pertinence function for $a = (a_1, a_2, a_3)$

The operational laws of fuzzy triangular numbers are shown below, considering two fuzzy numbers $a = (a_1, a_2, a_3)$ and $b = (b_1, b_2, b_3)$.

$$a + b = (a_1, a_2, a_3) + (b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3) \quad (15)$$

$$a - b = (a_1, a_2, a_3) - (b_1, b_2, b_3) = (a_1 - b_1, a_2 - b_2, a_3 - b_3) \quad (16)$$

$$a \times b = (a_1, a_2, a_3) \times (b_1, b_2, b_3) = (a_1 b_1, a_2 b_2, a_3 b_3) \quad (17)$$

$$a \div b = (a_1, a_2, a_3) \div (b_1, b_2, b_3) = (a_1/b_1, a_2/b_2, a_3/b_3) \quad (18)$$

$$k \times a = k \times (a_1, a_2, a_3) = (k\, a_1, k\, a_2, k\, a_3) \quad (19)$$

Definition 3 – The vertex method to calculate the distance between two fuzzy triangular numbers $a = (a_1, a_2, a_3)$ and $b = (b_1, b_2, b_3)$ is defined as:

$$d(a,b) = \sqrt{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2} \quad (20)$$

Definition 4 – A linguistic variable is a variable which value is a word or sentences in a natural or artificial language. For example, 'range' is linguistic variable and can assume the values 'low', 'medium' or 'high'.

Definition 5 – Considering that each criterion receives a different weight in the evaluation, the normalized weighted fuzzy matrix is structured in the following way.

$$P = \left[p_{ij}\right]_{nxm} \quad (21)$$

Where:

- $p_{ij} = x_{ij} \times wi$
- A set of values of performance of the competitor A_j ($j=1,2,\ldots,m$) with respect of the criteria C_i($i = 1,2,\ldots,n$) defined by $X = \{x_{ij}, i=1,2,\ldots,n; j=1,2,\ldots,m\}$
- A set of criteria weight w_i ($i=1,2,\ldots,n$)

Considering these definitions concerning fuzzy theory, the following steps describe the TOPSIS-fuzzy methodology.

First it is necessary to determine the evaluations matrix, composed by linguistic values, $X = [x_{ij}]_{nxm}$, where x_{ij} is the linguistic variable result of the evaluation of the j^{th} competitor in respect to the i^{th} criterion. The normalized weighted matrix is determine by replacing the linguistic variables by its respective fuzzy triangular numbers and apply the weights to each criterion.

The second step consists in establishing the fuzzy positive ideal solution (*FPIS*) and the fuzzy negative ideal solution (*FNIS*). These solutions are determined analogously as in TOPSIS technique, but in this case, the ideal solutions are determined as the absolute fuzzy triangular numbers in respect to each criterion.

On the third step, the distances between each competitor and the *FPIS* and *FNIS* are calculated analogously as TOPSIS distances, but using the vertex method, described in Eq. 20, considering that now theses distances are between fuzzy triangular numbers.

The calculation of the relative distance to ideal solution (*CC*) is done on the fourth step for all competitors. Finally, the competitors can be rank by its distance to ideal solution.

6 Proposed Algorithm

The proposed algorithm to be used in the selection of agricultural aircraft is composed by five basic steps. Establishing the competitors and hierarchy (1), pairwise comparison of the criteria and determinations of its weights (2), evaluate each competitor characteristics according to each criterion (3), establish the normalized weighted fuzzy matrix (4) and order the competitor by performance (5).

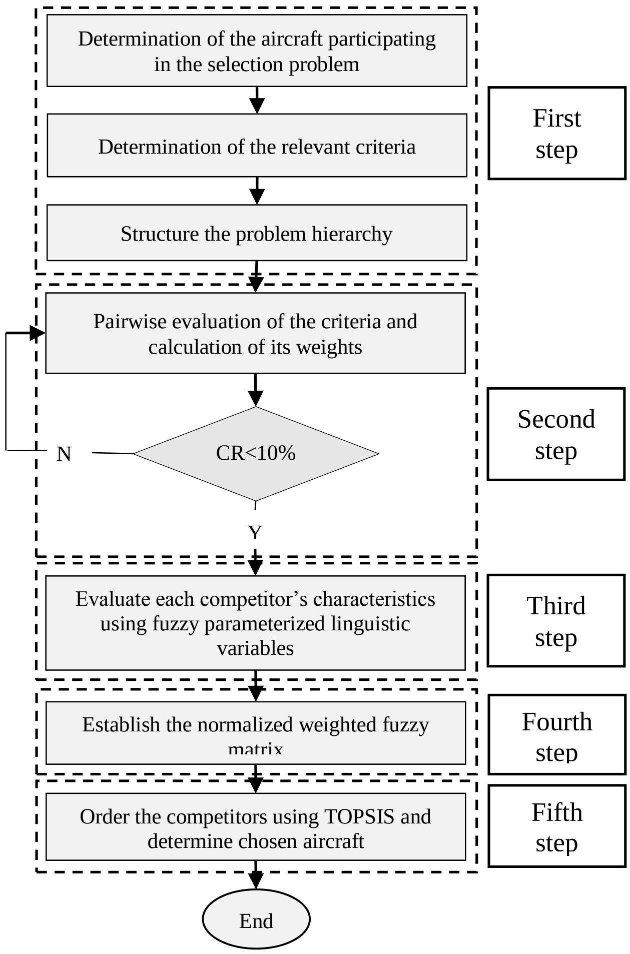

Fig. 2 - Diagram of the method

The steps of the proposed algorithm can be seen at Fig. 2 and are described.

1 – First step – Establishing the competitors, the criteria and hierarchy

It is necessary establish the aircraft that will compose the analysis. At the same time, the criteria that will be used in the process must be chosen.

Determined the elements composing the analysis, the hierarchy can be established. In the first level the objective of the process is introduced, in this case, choosing the best agricultural aircraft. On the second level, the criteria used in the analysis are inserted. On the third level, the lower one, there is the set of aircraft that are considered in the analysis.

2 – Second step – Pairwise comparison of the criteria and determinations of its weights

On this step, it is necessary to evaluate the relevancy of the criteria by a pairwise comparison. Using as reference for this comparison the values from Tab. 1, the weights for each criterion are determined using the AHP calculations. The analysis proceed if the value of *CR* for the evaluations is inferior than *0.1*. Else, it is necessary to perform another evaluation in order to reach a lower value of *CR* and, consequently, a satisfactory consistency.

3 – Third step – Evaluate each competitor characteristics according to each criterion

Tab. 2 Linguisic values and respective fuzzy numbers

Linguistic Values	Fuzzy Numbers
Very Low	(0.0, 0.0, 0.2)
Low	(0.0, 0.2, 0.4)
Medium	(0.2, 0.4, 0.6)
High	(0.4, 0.6, 0.8)
Very High	(0.6, 0.8, 1.0)
Excellent	(0.8, 1.0, 1.0)

Now it is necessary to evaluate each competitor's characteristics for each criterion. This evaluation is done using linguistic values that are then converted to triangular fuzzy values according to Tab. 2.

4 – Fourth step – Establish the normalized weighted fuzzy matrix

Since the evaluation is done in the previous step, now the matrix is constructed using the triangular numbers. Considering that the fuzzy number are already normalized in Tab. 2, it is only necessary to introduce the weights of each criterion. Using the AHP weights, it then possible to establish the normalized weighted fuzzy matrix.

5 – Fifth step – Order the competitor by performance

In order to order the competitors it is necessary to calculate the distances between each competitor and the positive and negative ideal solutions. With these values it is possible to calculate each competitor final performance.

Finally, the competitors can be ordered and, consequently the best one is determined.

7 Application

The method was applied in an agricultural aircraft selection problem involving four competitors and nine criteria. The application of the method follows the steps detailed before and is described below.

7.1 Establishing the competitors, criteria and hierarchy

The aircraft participating in the selection problem were selected because they are the most common in the market and it is easy to its find performance data. These aircraft are shown in the Tab. 3

Tab. 3 - Aircraft competitors in the selection problem

Manufacturer	Aircraft
Embraer	EMB-202 Ipanema
AT-401B	Air Tractor
AT-502	Air Tractor
510P	Thrush

The criteria were chosen considering its influence on agricultural aircraft performance. They are listed and described below.

C1 – Hopper capacity. The hopper is the container in which the agricultural chemical products are stored. Therefore, it represents an important indicator of the aircraft operational capability.

C2 – Takeoff distance. It is an important performance value considering that an agricultural mission has restricted runways. As the runway minimal length is limited by the takeoff distance it was decided to insert this parameter in the analysis instead of the landing distance.

C3 – Fuel capacity. Indicates the maximum amount of fuel carried by the aircraft and reflects on the duration and efficiency of the mission.

C4 – Engine power – It is the criterion directed related to the aircraft power plant. It is important due to the necessity of the aircraft of operating near the maximum takeoff weight, even when the atmospheric conditions are not the best.

C5 – Aspect ratio – It is the relation between the square of the wing spam and the wing area. It is directly related to the quality of the deposition of chemical products on the ground. An aircraft with higher aspect ratio has fewer losses by wing tip vortex and can perform a better deposition of the products.

C6 – Maximum climb ratio – It is important in an agricultural aircraft due to the necessity of a fast climb while maneuvering, to avoid obstacles and in the end of an application path.

C7 – Dihedral – It is the angle between the transversal axis of the aircraft and the wing plan. Analogously as the rate of climb, it is related to the maneuver capability of the aircraft. The dihedral angle can provide more maneuverability and facilitate the detour of obstacles. It is also related to the lateral-directional stability of the aircraft.

C8 – Wing spam – It is an important factor in the aircraft performance and in the quality of the deposition of chemical products

C9 – Fuel consumption – It allows introducing the economical factor to the operation of the aircraft. It is important to note that two competitors are powered by Jet fuel while the other two use Avgas. In order to compare the economic factor with the fuel consumption, the price of the two fuel were considered in the evaluation.

Having the competitors defined and the criteria established, the next step is to determine the hierarchy of the problem.

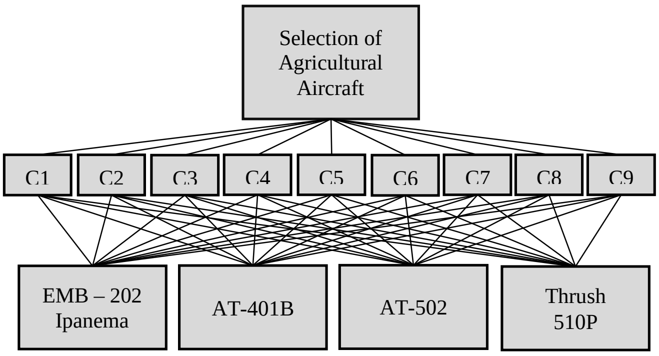

Fig. 3 - Hierarchy of the problem

7.2 Pairwise comparison of the criteria and determinations of its weights

In order to determine the weights of the nine criteria, it is necessary to proceed with the pairwise criteria comparison required by the AHP. The comparison was done using the reference values provided by Tab. 1. The criteria were analyzed by the author according to their importance for an agricultural aircraft selection. The matrix result of the pairwise comparison of the criteria is summarized in Tab. 3.

Tab. 3 - Pairwise criteria evaluation

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1.00	0.50	0.33	0.50	0.50	3.00	0.50	0.50	3.00
C2	2.00	1.00	0.33	1.00	0.50	2.00	0.50	0.33	2.00
C3	3.00	3.00	1.00	2.00	1.00	3.00	1.00	1.00	4.00
C4	2.00	1.00	0.50	1.00	0.50	2.00	1.00	1.00	3.00
C5	2.00	2.00	1.00	2.00	1.00	3.00	2.00	1.00	4.00
C6	0.33	0.50	0.33	0.50	0.33	1.00	0.50	0.33	1.00
C7	2.00	2.00	1.00	1.00	0.50	2.00	1.00	0.50	3.00
C8	2.00	3.00	1.00	1.00	1.00	3.00	2.00	1.00	2.00
C9	0.33	0.50	0.25	0.33	0.25	1.00	0.33	0.50	1.00

After the determination of the matrix above, its eigenvector associate to its higher eigenvalue was calculated to represent the weights. The results of AHP are shown in Tab. 4.

Criteria	Weights	CI	CR
C1 - Hopper Capacity	0.08048	0.0472	0.0326
C2 - Takeoff Distance	0.08474		
C3 - Fuel Tank Capacity	0.17705		
C4 - Engine Power	0.11110		
C5 - Aspect Ratio	0.17382		
C6 - Climb Ratio	0.04833		
C7 - Dihedral Angle	0.11999		
C8 - Wing Spam	0.16048		
C9 - Fuel Consumption	0.04399		

The criteria with the higher weight are Fuel Tank Capacity (C3), Aspect Ratio (C5) and Wing Spam (C8), respectively.

The value of CR obtained is lower than 0.1, what demonstrate the consistency of the pairwise comparison.

7.3 Evaluate each competitor characteristics according to each criterion

Since the criteria's weights were already determined by the AHP method, it is now necessary to evaluate each competitor characteristics in respect to each one of the nine criteria.

The evaluation of the aircraft was done by the author considering the aircraft data. The linguistic variables chosen for each aircraft's characteristic, as well as its respective fuzzy number are shown in Tab. 4.

Tab. 4 - Evaluation of each aircraft for each criterion

	EMB-202 Ipanema	AT-401B	AT-502	Thrush 510P
C1	Low (0.0, 0.2, 0.4)	High (0.4, 0.6, 0.8)	Excellent (0.8, 1.0, 1.0)	Excellent (0.8, 1.0, 1.0)
C2	Low (0.0, 0.2, 0.4)	High (0.4, 0.6, 0.8)	Very Low (0.0, 0.0, 0.2)	Very High (0.6, 0.8, 1.0)
C3	Low (0.0, 0.2, 0.4)	Medium (0.2, 0.4, 0.6)	Very High (0.6, 0.8, 1.0)	Excellent (0.8, 1.0, 1.0)
C4	Low (0.0, 0.2, 0.4)	High (0.4, 0.6, 0.8)	Very High (0.6, 0.8, 1.0)	Very High (0.6, 0.8, 1.0)
C5	Medium (0.2, 0.4, 0.6)	Very High (0.6, 0.8, 1.0)	Very High (0.6, 0.8, 1.0)	Low (0.0, 0.2, 0.4)
C6	Alto (0.4, 0.6, 0.8)	Very High (0.6, 0.8, 1.0)	Medium (0.2, 0.4, 0.6)	Very Low (0.0, 0.0, 0.2)
C7	Excellent (0.8, 1.0, 1.0)	Medium (0.2, 0.4, 0.6)	Medium (0.2, 0.4, 0.6)	Medium (0.2, 0.4, 0.6)
C8	Low (0.0, 0.2, 0.4)	Very High (0.6, 0.8, 1.0)	Very High (0.6, 0.8, 1.0)	High (0.4, 0.6, 0.8)
C9	Very Low (0.0, 0.0, 0.2)	High (0.4, 0.6, 0.8)	High (0.6, 0.8, 1.0)	Very High (0.8, 1.0, 1.0)

7.4 Establish the normalized weighted fuzzy matrix

On this step, the criteria weights calculated by AHP are introduced in the matrix result of the evaluation of the aircraft. The normalized weighted fuzzy matrix is then obtained and is shown in Tab. 5.

Tab. 5 - Normalized weighted fuzzy matrix

	EMB-202 Ipanema	AT-401B	AT-502	Thursh 510P
C1	(0.0000, 0.0161, 0.0322)	(0.0322, 0.0483, 0.0644)	(0.0644, 0.0805, 0.0805)	(0.0644, 0.0805, 0.0805)
C2	(0.0000, 0.0169, 0.0339)	(0.0339, 0.0508, 0.0678)	(0.0000, 0.0000, 0.0169)	(0.0508, 0.0678, 0.0847)
C3	(0.0000, 0.0354, 0.0708)	(0.0354, 0.0708, 0.1062)	(0.1062, 0.1416, 0.1770)	(0.1416, 0.1770, 0.1770)
C4	(0.0000, 0.0222, 0.0444)	(0.0444, 0.0667, 0.0889)	(0.0667, 0.0889, 0.1111)	(0.0667, 0.0889, 0.1111)
C5	(0.0348, 0.0695, 0.1043)	(0.1043, 0.1391, 0.1738)	(0.1043, 0.1391, 0.1738)	(0.0000, 0.0348, 0.0695)
C6	(0.0193, 0.0290, 0.0387)	(0.0290, 0.0387, 0.0483)	(0.0097, 0.0193, 0.0290)	(0.0000, 0.0000, 0.0097)
C7	(0.0960, 0.1200, 0.1200)	(0.0240, 0.0480, 0.0720)	(0.0240, 0.0480, 0.0720)	(0.0240, 0.0480, 0.0720)
C8	(0.0000, 0.0321, 0.0642)	(0.0963, 0.1284, 0.1605)	(0.0963, 0.1284, 0.1605)	(0.0642, 0.0963, 0.1284)
C9	(0.0000, 0.0000, 0.0088)	(0.0176, 0.0264, 0.0352)	(0.0264, 0.0352, 0.0440)	(0.0352, 0.0440, 0.0440)

7.5 Order the competitor by performance

The last step of the algorithm is done by calculating the distances of each competitor to the positive and negative ideal solution. The positive (*FPIS*) and negative (*FNIS*) ideal competitors are defined on this step as having the best and worst characteristics, respectively, in terms of linguistic variables.

The positive and negative ideal solutions are shown in Tab. 6**.**

Tab. 6 - FPIS and FNIS

	FPIS	FNIS
C1	(1.0, 1.0, 1.0)	(0.0, 0.0, 0.0)
C2	(0.0, 0.0, 0.0)	(1.0, 1.0, 1.0)
C3	(1.0, 1.0, 1.0)	(0.0, 0.0, 0.0)
C4	(1.0, 1.0, 1.0)	(0.0, 0.0, 0.0)
C5	(1.0, 1.0, 1.0)	(0.0, 0.0, 0.0)
C6	(1.0, 1.0, 1.0)	(0.0, 0.0, 0.0)
C7	(1.0, 1.0, 1.0)	(0.0, 0.0, 0.0)
C8	(1.0, 1.0, 1.0)	(0.0, 0.0, 0.0)
C9	(0.0, 0.0, 0.0)	(1.0, 1.0, 1.0)

The values of the distances are calculated and shown in Tab. 7, together with the performance values of the competitors.

Tab. 7 - Distances to ideal solution and performance values

	EMB-202 Ipanema	AT-401B	AT-502	Thrush 510P
D+	6.712	6.542	6.407	6.600
D-	2.335	2.483	2.616	2.426
CC	**0.258**	**0.275**	**0.290**	**0.269**

The final rank of the competitors is shown in Tab. 8.

Tab. 8 - Final rank

Rank	CC	Aircraft
1	0.290	AT-502
2	0.275	AT-401B
3	0.269	Thrush 510P
4	0.258	EMB-202 Ipanema

8 Conclusions

The AHP combined with TOPSIS-fuzzy provides a useful tool to order competitors by performance. As most of the times agricultural aircraft data cannot be found easily, the evaluation of the competitors using linguistic characteristics provides an important alternative to the process.

The model proposed on this work applies the method to an agricultural selection problem, considering some relevant operational performance criteria. The method provides satisfactory results considering only the chosen criteria. It is necessary to point that the chosen criteria were selected in order provide a test-case where it was possible to find aircraft data. The main purpose of this test case was to evaluate the applicability of the method considering a set of relevant criteria which are not necessarily the main ones in such problem.

This way, in a real selection problem, the algorithm must be used considering other relevant criteria that were not considered on this analysis. Also, in a real scenario, the evaluation using linguistic variables must be done using fieldwork in order to get more realistic data and, consequently, find best results.

Future work will be done in order to find the main criteria involved in an agricultural aircraft selection, including maintenance characteristics, operational costs, and another relevant parameters that were not taken into account. It is also necessary to search for pilots and operators evaluations and opinions concerning the agricultural aircraft selection process.

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