MULTICRITERIA SELECTION OF AN AIRCRAFT WITH NAIADE

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Abstract: This article deals with the problem of multicriteria selection of an aircraft. The problem has eight alternatives to be evaluated under eleven different criteria, whose measurements can be exact, stochastic, or fuzzy. The technique chosen for analyzing and then finding a solution to the problem is the multicriteria decision aiding method named NAIADE (Novel Approach to Imprecise Assessment and Decision Environments). The method used allows tackling the problems by working with quantitative as well as qualitative criteria under uncertainty and imprecision. Another considerable advantage of NAIADE over other multicriteria methods relies in its characteristics of not requiring a prior definition of the weights by the decision maker. As a conclusion it can be said that the use of NAIADE provided for consistent results to that aircraft selection problem.

1 PROBLEM DEFINITION

Decisions form part of our day-to-day routine. Some are simple and do not require great developments, others are more complex, requiring a greater degree of expertise and a methodology which is coherent with the approach to the problem. This work essentially deals with a decision making problem of the more complex type, whose importance requires a theoretically structured approach.

The problem presented in this article is faced by a non-regular aerial transport company. The company under study is a start-up company, derived from an economic group whose principal activity is logistics. Founded in 1969, the group is noted for its capacity for diversification, in 2005, possessing 12 companies acting in diverse sectors, varying from hotel services to agro-business. During the process of qualifying as an airline operator, the managers of the company studied analyzed the opportunity of acting in the market of non-regular public flights, known as charter flights, within routes typically characterized as regional. In this modality, the public are generally offered seats to destinations which may or may not be attended by regular airline companies. Among the analyses necessary for the formatting of the new product to be offered, the managers identified a factor of vital importance to the success of the new service, the correct choice of airplane to be used in this type of operation.

The company under study came into being in 1983 with the aim of producing ultra-light planes for the practice of aerial sports. Since its foundation, the company has been based at the Maricá aerodrome in the Brazilian State of Rio de Janeiro. After being acquired by a highly diversified group in 1991, the organization suffered from lack of investment, later ceasing its activities. The company remained inactive until 2007, maintaining its assets by means of renting its facilities. At the end of that year, studies were initiated to reactivate the company with a view to making use of the buildings available to install a company in the aeronautic sector; the decision being made for an air-taxi company. The regulations for the creation of an air-taxi service permit the exploitation of passenger flights on demand, a modality known as charter flights. Based on this, the managers of the company proposed an evaluation, with the aim of formulating an economic plan for the addition of this type of operation.

The critical problem encountered in this evaluation was the choice of an aircraft, as this

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represents the main part of the investment necessary, surpassing even the initial investment calculated for the operations. This amount can be vital for a company of the scale of the one studied (Bercovitz and Mitchell, 2007). In addition to this, the selection process was also shown to be complex at the beginning, given the number of criteria and their variations of measurement as well as the quantity of alternatives to be chosen.

The adoption of a multicriteria decision aiding tool, providing the managers with well-grounded decision making, is justified therefore by the importance for the company and the complexity of the decision making problem. As it belongs to an economic group, the decision was the responsibility of the president of the group. The information passed on to the decision analyst originates above all from internal research, with the director of operations also responsible for the evaluation of the value of the qualitative variables necessary to the process and which would be treated by means of fuzzy logic (Zadeh, 1975).

It fell to these two agents, assisted by the decision analyst, to make the definition of the set of alternatives and the family of criteria. To help in solving the problem, a multicriteria decision aiding method was chosen with qualities more aligned to those which the problem required. The actors that participated in the process were the managers of the company. The multicriteria method chosen is the NAIADE method, created by Munda (1995). This method encompasses, to a greater or lesser degree, characteristics of resistance to trade-offs – in contrast, for example, to MAUT, in which there is an explicit exchange between values in a multiattribute utility function (Keeney and Raiffa, 1976) – and the possibility of the application of variables of diverse types. According to Munda (1995), the application of the NAIADE method consists of three steps: pair comparison, aggregation of the criteria and the analysis of the alternatives.

For the application of the first step, the difference of values between the alternatives must be obtained. The way in which this difference is obtained constitutes the larger part of the foundation of the method. For this reason, even before knowing how each one of the three steps is executed, attention must be given to the functioning of this mechanism.

In the literature there are already some uses of MCDA in Air Transportation. For instance, a high density route, the Belgrade – Zagreb air shuttle service was evaluated by Teodorović (1985) using the TOPSIS method, and another high density route, the Rio de Janeiro – São Paulo was evaluated by Soares de Mello et al (2003) using the MACBETH method (Bana e Costa and Vansnick, 1994).

2 METHODOLOGY

ANAC – the National Agency of Civil Aviation is the Brazilian authority responsible for the regulation of air transport. Constituted by Law no. 11.182, ANAC regulates the sector supported by the Brazilian Aeronautical Code and specific regulations, called the Brazilian Regulations of Aeronautic – RBHA. According to the RBHA 119 and 135, aircraft permitted for regional charter operations are those with a capacity equal to or less than 30 passengers, which already significantly limits the viable alternatives. Also according to these regulations, some advantages can be obtained by companies which opt to use aircraft with a capacity equal to or less than 19 passengers. The main advantage can be found in RBHA 135.3(b), where the company is dispensed from more detailed training of the crew. Another significant advantage can be found in RBHA 135.107, which dispenses the company from the need for a qualified steward on board its flights, which significantly reduces the operational costs, of training, and of the preparation and maintaining of the documents necessary for operations.

With this new cut-off, the universe of choices was reduced even more. According to the managers of the company, the alternatives to be evaluated are: Cessna Caravan, Fairchild Metro, Beechcraft 1900, Embraer EMB-110 Bandeirante, LET 410, De Havilland DHC 6, Dornier 228 and the CASA 212. In relation to the criteria, one of the ways of working with the definition of the criteria is by creating a hierarchy in the form of a tree, in this way becoming very similar to the AHP method (Saaty, 2005). At the higher levels are the more wide ranging criteria which are subdivided in other more detailed criteria until a sufficiently specific family of criteria is formed which can be evaluated effectively.

At the first level the criteria are divided into three groups. In the financial group, there are the criteria which result in direct expense or which produce some impact on the financial or economic administration of the institution. In the group of criteria linked to logistics are listed the criteria which are most significant for the operation of the aircraft and their limitations. Lastly, in the group linked to quality, the criteria reflect, either directly or indirectly, the level of relative satisfaction on the part of the users of the alternative.

The criteria which will effectively be evaluated are on the second level. For a better understanding of the importance of each criterion inside the model, there follows a list of each of these criteria: Acquisition Cost; Liquidity; Operating Costs; Range; Flexibility; Cruising Speed; Replacement Parts Availability; Landing and take-off distance; Comfort; Avionics; Availability; Safety (Figure 1).

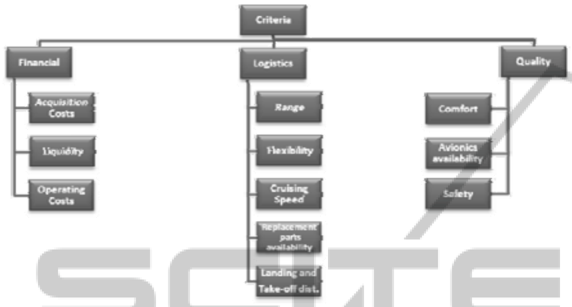

Figure 1: Subdivision in levels of the Criteria.

3 APPLICATION AND RESULTS

The Impact Matrix summarizes the problem, showing what is relevant for the application of the methodology. Munda (2006) suggests that the most useful information must be present in the impact matrix and that they should include the alternatives analysed, accompanied by all the criteria and their values, as well as the weights practiced for each criterion.

For the purposes of organization, the impact matrix for this problem was broken down into two matrices. The first is a matrix of the information on the criteria (Table 1), which brings information on measurement, weights and intersection for each criterion. The second matrix is the impact matrix itself (table 2), bringing the values collated for each alternative in each criterion.

The following stage consists of calculating the distance of the values and the pair comparison of the distances calculated, in order to, in this way, construct a matrix of indices of intensity of preference for each criterion.

Munda (1995), as previously mentioned, presents two possibilities for comparing the alternatives. The first analyses the degree of truth in relation to the statement “according to the majority of the criteria ...” with the variants “... a is better than b”, “...a is indifferent to b” or “... a is worse than b”.

Table 1: Impact Matrix – Information on the criteria.

	Type	Units	Sense	Weights	$c_{\gg}$	$c_{>}$	$c_{\cong}$	$c_{=}$
Aq. Costs	Stoch.	$	min	0.129	400000	250000	200000	100000
Liquidity	Fuzzy	N/A	max	0.086	0.37	0.26	0.19	0.12
Op costs	Crisp	$/nmPax	min	0.100	0.1	0.05	0.02	0.01
Range	Crisp	nm	max	0.071	200	101	100	50
Flexibility	Fuzzy	N/A	max	0.086	0.37	0.26	0.19	0.12
Cruise Sp.	Crisp	knots	max	0.086	30	15	10	5
Avail. Parts	Fuzzy	N/A	max	0.100	0.37	0.26	0.19	0.12
Land. Dist	Crisp	meters	min	0.057	300	201	200	100
Comfort	Crisp	m^3	max	0.114	6	4	3	2
Avionics	Fuzzy	N/A	max	0.071	0.37	0.26	0.19	0.12
Safety	Fuzzy	N/A	max	0.100	0.37	0.26	0.19	0.12

In order to aggregate the criteria, a table of size N x M is used, where N is half of the number of pairs of alternatives and M the number of relations of preference considered. Table 3 presents the result of the aggregation of the criteria.

Table 2: Impact Matrix – Values for the Criteria.

	Cessna 208 (a_1)	DHC-6 (a_2)	LET 410 (a_3)	Metro (a_4)
Aq. Costs	μ=1000K σ=150K	μ=1900K σ=400K	μ=700K σ=200K	μ=1000K σ=200K
Liquidity	Perfect	Moderate	Very Good	Reasonably Bad
Op. Costs	0.2475	0.3116	0.2574	0.2911
Range	917	775	755	595
Flexibility	Very Good	Good	Good	Reasonably Good
Cruise Sp.	184	182	208	242
Avail. Parts	Very Good	Moderate	Good	Reasonably Bad
Land. Dist.	738	366	935	625
Comfort	9.60	10.87	17.90	17.92
Avionics	Very Good	Good	Very Good	Reasonably Bad
Safety	Good	Very Good	Very Good	Good
	Beech 1900 (a_5)	**EMB 110 (a_6)**	**Dornier 228 (a_7)**	**CASA 212 (a_8)**
Aq. Costs	μ=2000K σ=250K	μ=1000K σ=200K	μ=1250K σ=250K	μ=900K σ=200K
Liquidity	Moderate	Good	Reasonably Bad	Good
Op. Costs	0.2995	0.3011	0.2889	0.2953
Range	1100	980	560	820
Flexibility	Good	Good	Reasonably Good	Very Good
Cruise Sp.	248	190	271	180
Avail. Parts	Perfect	Perfect	Reasonably Bad	Reasonably Bad
Land. Dist.	1050	980	450	675
Comfort	16.20	12.94	14.63	24.35
Avionics	Very Good	Good	Reasonably Bad	Very Good
Safety	Very Good	Very Good	Good	Very Good

The second possibility is the ranking of the alternatives by means of the intersection of two flows adapted from the PROMÉTHÉE method. As the first case is related by Munda (1995) merely as a complement, the analysis will be carried out by means of the flows, presented in table 4.

The order of preference of the alternatives for the pilot application is, according to the flows is presented in table 5.

Both by the positive flow and the negative flow, alternative a3 is the optimum alternative, according to the data supplied by the company and its managers.

4 CONCLUSIONS AND LIMITATIONS

The NAIADE method is capable of formatting and aiding in the solution of decision problems which involve criteria of various types. In this problem it was possible to apply mechanisms of the method which allowed this property to be used.

In meeting the primary objective of this work, it was possible to apply the NAIADE method to the problem, even though the usual applications of this method do not correspond to the profile of this work. Therefore, it was possible to define the alternative which best reflects what was being sought by the administration of the company under analysis.

The option for the LET-410 aircraft was therefore recommended to the decision maker, as this stood out as the one which best met the specifications and values sought in the equipment for the carrying out of the intended activities.

Table 3: Aggregation of the Criteria.

	μ>>	μ>	$\mu\pm$	μ==	μ<	μ<<
a_1,a_2	0.3132	0.5058	0.5193	0.2874	0.0585	0.0330
a_1,a_3	0.0000	0.0855	0.7262	0.3249	0.2940	0.1049
a_1,a_4	0.3425	0.4796	0.2361	0.0330	0.2665	0.1830
a_1,a_5	0.2543	0.3675	0.3959	0.2159	0.2973	0.1712
a_1,a_6	0.0000	0.0832	0.8672	0.2107	0.0050	0.0000
a_1,a_7	0.3929	0.5916	0.1522	0.0518	0.2301	0.1387
a_1,a_8	0.1018	0.1911	0.6456	0.3559	0.1860	0.1428
a_2,a_3	0.0581	0.0722	0.4284	0.2716	0.5931	0.3707
a_2,a_4	0.0793	0.2490	0.3180	0.0167	0.3774	0.2995
a_2,a_5	0.0752	0.1700	0.5246	0.2703	0.3954	0.2758
a_2,a_6	0.0615	0.0755	0.6056	0.3259	0.4298	0.2823
a_2,a_7	0.0863	0.2001	0.4508	0.0493	0.3207	0.2410
a_2,a_8	0.0184	0.0519	0.6174	0.3192	0.4099	0.3081
a_3,a_4	0.3049	0.5374	0.4502	0.2010	0.1379	0.0591
a_3,a_5	0.2185	0.3115	0.5362	0.3702	0.2066	0.1318
a_3,a_6	0.0241	0.3117	0.6695	0.2899	0.0849	0.0328
a_3,a_7	0.3870	0.6435	0.2290	0.0232	0.1750	0.1427
a_3,a_8	0.0977	0.2965	0.6163	0.2727	0.1450	0.0501
a_4,a_5	0.1908	0.2324	0.4831	0.1743	0.3632	0.2721
a_4,a_6	0.1262	0.2328	0.3369	0.0411	0.4733	0.3269
a_4,a_7	0.0040	0.1303	0.8557	0.5018	0.0930	0.0190
a_4,a_8	0.0926	0.1189	0.5280	0.2666	0.4972	0.2736
a_5,a_6	0.0977	0.1841	0.7219	0.5423	0.2235	0.1726
a_5,a_7	0.2727	0.3638	0.4039	0.1313	0.2930	0.2046
a_5,a_8	0.2519	0.3093	0.4449	0.3453	0.4024	0.3047
a_6,a_7	0.3506	0.4973	0.3901	0.1034	0.1913	0.1588
a_6,a_8	0.1087	0.1945	0.6651	0.3338	0.2603	0.1529
a_7,a_8	0.1145	0.1529	0.3956	0.1381	0.5453	0.3702

One of the weak points detected during the application of the methodology is the lack of simplicity when approaching variables of diverse types. Although conceptually the method is simple, when the component of uncertainty of the variables is added, the mathematical calculations begin to acquire undesirable levels of complexity, which could compromise the transparency of the recommendations of this work to the decision maker.

Table 4: Analysis of the Alternatives.

	φ^+	φ^-
a_1	0.3306	0.1728
a_2	0.1022	0.4833
a_3	0.4376	0.1083
a_4	0.2026	0.4184
a_5	0.3040	0.2902
a_6	0.2730	0.1598
a_7	0.1982	0.4623
a_8	0.3793	0.1700

In relation to the results obtained, it is also important to comment on the difference between the rankings supplied by the negative and positive flows. Although some inversion is expected, the rankings in the greater part were very different. This phenomenon simply demonstrates how close the alternatives are, according to the values practiced by the decision maker. Nevertheless, it can be observed by the value of the positive and negative flows that the optimum alternative is found to have a comfortable difference in relation to the other alternatives. Therefore, observing this phenomenon, the recommendation becomes clear for the choice of this aircraft as the best placed in the ranking of the alternatives.

Table 5: Ranking of the Alternatives.

φ^+	φ^-
a_3	a_3
a_8	a_6
a_1	a_8
a_5	a_1
a_6	a_5
a_4	a_4
a_7	a_7
a_2	a_2

In relation to the alternatives, as an option for these, the decision was made to select aircraft with a maximum capacity of nineteen passengers, which significantly reduced the universe of possible alternatives. The choice of this cut arose solely due to the strategy adopted by the company, therefore, no study in greater depth was carried out on the alternatives which exceed this level of cut. It is possible that a wider ranging study in terms of the number of alternatives would point to greater viability with larger aircraft.

The criteria were defined according to the values of the managers of a pre-operational company. Even though they have been defined with the greatest rigor possible, it is possible that the cast of important criteria is modified when the operation becomes effective. Obviously, the same would occur with the weights and intersection points. A valid suggestion for a future study is to repeat this analysis after the operations have begun, so that it becomes a useful tool when the decision is made to increase the fleet.

The method used was the fruit of a choice oriented by some characteristics observed above all by the decision analyst. This does not mean that no other method can be used to attempt to solve the same type of problem. The comparison of this work with another which seeks to solve the same problem with another methodology would be interesting, as it would make it possible to verify the mathematical model practiced in this work.

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