SELECTING AN IT SERVICE PROVIDER THROUGH AN INTERVAL SMART / SWING WEIGHTING DOMINANCE ANALYSIS

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Abstract

Decisions must oftenly be made, quickly and with precision, in complex, high risk scenarios, in corporations. This article presents the use of the MAUT approach, combined with the INTERVAL SMART/SWING WEIGHTING method, for dealing with uncertainty, through the application of the WINPRE software as a support tool for the calculation of dominance. An application is made to the case of a firm selecting IT service providers. This case study confirms that the approach can successfully aid the decision process, being able to treat questions of uncertainty that are practically always present.
Keywords: Multicriteria Decision Aiding. Uncertainty. Conjoint Measurements. Interval Smart/Swing Weighting Method.

Resumo

Decisões devem freqüentemente ser tomada rapidamente e com precisão nas corporações, em cenários complexos e de alto risco. Este artigo apresenta o uso da MAUT, combinada com o método INTERVAL SMART/SWING WEIGHTING, para lidar com incerteza, através da aplicação do software WINPRE, como ferramenta de suporte no cálculo da dominância. Faz-se uma aplicação ao caso de uma empresa selecionando um provedor de servisços de Tecnologia da Informação. O estudo de caso aqui abordado confirma que essa abordagem pode apoiar com sucesso o processo de decisão, permitindo o tratamento de questões que envolvem incerteza e que estão sempre presentes.
Palavras-chaves: Apoio Multicritério à Decisão. Incerteza. Medições Conjuntas. Método Interval Smart/Swing Weighting.

1. Introduction

In the 1990s the outsourcing of operational services to specialised companies was the solution found for many companies to cut costs through large contracts and economies of scale, in this way maintaining the focus of the company on the business. The search for partners who could supply a quality service and the capillarity that a multinational requires, with long term contracts, has made the choice complex with important impacts and consequences.

In order to solve one of the management problems in IT, namely its printing service, the company whose case study we present in this article, here called W-Cosmetic, opted for the outsourcing of this service. The executives of W-Cosmetic decided to choose the supplier using the decision aiding methods known as *MAUT* (or Multiattribute Utility Theory) (KEENEY and RAIFFA, 1976) and *INTERVAL SMART/SWING WEIGHTING* (MUSTAJOKI, HÄMÄLÄINEN, and SALO, 2005), developed to deal with uncertainty in the definition of the values of the alternatives and the weights of the attributes. The software WINPRE (2009), which is available for academic use on an Internet page, will be used to determine dominance.

The printing service includes numerous operational activities, consequently generating non-productive work, as is called work which is not directly linked to the company strategy. The following could be cited as examples: Management of Assets and Contracts; Management of Hardware Problems and Support Calls; and Management of Costs by Department. Brazilian legislation requires a large quantity of documents to be printed. Some of these documents are critical and are directly linked to the distribution of the products, as is the case of sales receipts. Without sales receipts there is no distribution, and consequently, this directly affects sales.

Currently, the company has a plant of 25 printers of its own, seven of them being dot matrix and the others multifunctional laser machines, installed in the cities of Rio de Janeiro, Duque de Caxias, São Paulo, Guarulhos, and Salvador.

The management of maintenance, backup parts and consumables, as well as the management of support calls are the responsibility of W-Cosmetic. Various companies are contracted to carry out the maintenance of these printers, depending on the location where they are installed. There is no satisfactory control of the volume printed by department, with some departments which spend less receiving greater costs than they should due to sharing the costs of other departments. The annual cost of the current solution was estimated at 500,000 reais. The plant installed is already obsolete in relation to the current printing needs as regards volume, confidential printing resources, A3 coloured printing, A3 black and white copies and scanner.

For all the problems described, W-Cosmetic decided to open a project of outsourcing the printing service with the following as the main objectives: i. To reduce printing costs as a result of part of the economies of scale obtained by the contracted party being passed to the contractor; ii. To meet the new needs of printing volume resources, paper size, confidential printing, printing restrictions as well as the copy, fax and scanner functions; iii. To permit the accounting of printing per cost centre in order to evaluate the expenses by department, facilitating actions to reduce printing volume, and consequently, reductions in costs; iv. To guarantee the operational continuity of the printers and multifunctional printers, including the sales receipt dot matrix printers, considered critical to the business; v. To reduce the operational load of the IT staff as regards the management and maintenance of equipment, requests for consumables and maintenance of backups. This objective can bring cost reductions, as well as free IT staff from purely operational activities for planning and execution of projects essential to the business.

2. Methodology

2.1. The MAUT approach

MAUT was introduced by Keeney and Raiffa (1976) as an extension of Utility Theory, largely developed by Fishburn (1970). It is concerned with the construction of a mathematical function called "Multiattribute Utility Function", which presupposes that it is possible to give a value to every attribute. Many pieces of research have been written recently which work with utility theory (GOMES and RANGEL, 2009; MEIRELLES and GOMES, 2009; RANGEL and GOMES, 2009). MAUT does not accept "Incomparability", in other words, it assumes that all the alternatives can be compared according to the defined attributes. The decision maker must choose one and only one from among the statements below when comparing two alternatives: "a" is preferable to "b" $\leftrightarrow$ aPb; "b" is preferable to "a" $\leftrightarrow$ bPa; "a" is indifferent to "b" $\leftrightarrow$ aIb $\vee$ bIa. MAUT requires transitivity in the following way: if alternative "a" is preferable to "b"; and alternative "b" is preferable to "c", then "a" is preferable to "c" (preference transitivity); and if alternative "a" is indifferent to "b"; and alternative "b" is indifferent to "c", then "a" is indifferent to "c" (indifference transitivity). Once the scoring of each alternative has been calculated, as well as the marginal rates of substitution for each criterion, the aggregate value can be calculated through the linear additive value function given by the expression (1):

$$V(a) = \sum_{j=1}^{n} W_j V_j(a) \tag{1}$$

where, "W_j" is the weight of the criterion "j", and "$V_j(a)$" is the performance of the alternative in relation to the criterion "j", resulting in the aggregate value of the alternative "a". This must be done for each of the alternatives, and, at the end, they are ranked from highest score (best alternative) to the lowest score (worst alternative). In order to use this function it is necessary for all criteria to be mutually independent, in terms of preference, in other words, that the evaluation of one alternative in relation to one criterion does not have any influence from another criterion. It is said that the criteria are independent among themselves, if any subset of criteria is independent regarding the preferences in relation to its complementary subset. If there is not independence between the criteria, it is recommended that the family of criteria is redefined through the grouping of dependent criteria, or even the redefinition of the criteria (CLEMEN and REILLY, 2001). During the evaluation the concept of dominance can still be used. This concept is based on the definition that if alternative "a" is as good as alternative "b" for all the criteria and has Strict Preference for at least one of the criteria, then it is said that "a" dominates "b". The set of alternatives not dominated is called the "Pareto Optimal Set". The use of this concept is important to restrict the alternatives and facilitate the decision (BELTON and STEWART, 2002). The definition of the weights is a fundamental part of MAUT, and it needs special attention from the decision makers. Some techniques have been developed to facilitate this decision so that the weights defined represent the preferences given by the decision makers. Some more sophisticated methods are presented as follows:

- SMART (Simple Attribute Rating Technique)

Published by Edwards in 1971 (EDWARDS, 1971), this technique carries out the definition of the weights in two stages: firstly, all the attributes are ranked in order of importance, considering their best performance. In the second stage, the least important attribute is given the value 10, the other attributes are then evaluated with more than 10 points according to the degree of importance in relation to the least important attribute, all being normalised to a total sum of 1.

- SWING WEIGHTING

This method was published in 1986 by von Winterfield and Edwards (VON WINTERFELD and EDWARDS, 1986), and consists of the idealisation of a hypothetical alternative where the attributes are taken to their worst level, and which will be used as a comparison (benchmark).

At a second stage, the attributes are classified in order of importance, responding to the following question: which attribute which when changing from the worst level to the best level has the most positive impact on the hypothetical alternative? This is carried out for each attribute until all are ranked. The value 0 is attributed to the benchmark alternative. The most important attribute is attributed the value 100. The other attributes are valued through a direct comparison, which can be thought of as a value, or as a percentage in relation to the change of the attribute from its worst to its best level. Finally, the weights are normalised to 1.

2.2. The *SMART/SWING WEIGHTING* Method – Judgements by Intervals

In a process of multicriteria decision analysis, uncertainty is always present, principally as regards the scoring of the alternatives in relation to the criteria, and the definition of the weights of each criterion. The uncertainty can be caused by the company culture, by the individual experience of each participant of the decision making process, by personal priority or that of the respective area, or even due to the lack of complete information. The highly competitive market and the consequent need to launch new products and make important decisions in a short time can bring significant impacts in financial terms, including negative impacts. Decisions must be made quickly and with incomplete information.

Judgements using intervals is one of the suitable ways of dealing with imprecision (WEBER, 1987), substituting a single score by an interval which identifies the possible points that a determined alternative or criterion may assume. The *SMART* and *SWING WEIGHTING* methods are much used in multicriteria decisions, and the use of judgements by intervals in these methods is an important tool to work with imprecision.

While the least important or most important attribute is commonly chosen as the reference attribute in the application of the *SMART* and *SWING WEIGHTING* methods, when making judgements by intervals, the reference attribute can be any one. In this way, an attribute which is easy to measure, which is best understood by all and score with precision can be chosen.

This attribute is given a single score, in other words, it is not judged by intervals of points. From this, the other attributes are scored in intervals which represent the possible variation that an attribute can have in relation to the reference attribute. The number of judgements will be calculated by the expression (2):

$$2.(n-1) \qquad (2)$$

that is, each attribute will be judged twice in relation to the reference attribute so that maximum and minimum values be defined. Different methods of scoring can arrive at different results (WEBER and BORCHERDING, 1993; POYHONEN and HÄMÄLÄINEN, 2001).

When an interval of values is defined for a determined alternative in relation to a determined attribute, only this alternative is affected by this variation of points, that is, the judgement of one alternative is independent of the judgement of another alternative in relation to the attributes. On the other hand, the judgement of an attribute is defined through the comparison of this with the other attributes. Differently from the judgement of the alternative, a variation in the weight of an attribute affects all the alternatives in a linear fashion (KEENEY and RAIFFA, 1976). In this way, the calculation of dominance uses linear programming to model uncertainties and proceeds towards the maximum and minimum aggregate values. This is accomplished by using the concept of feasible region for the weights, which, by definition, is the region that meets the limits of the weights. It is not the objective of this article to examine linear programming in depth, but solely for better understanding, the following example is presented:

Supposing a situation with 3 attributes: “W_a” [reference attribute = 1]; “W_b” [0.5;2]; “W_c” [1;3]. The limits of the relation between the attributes are calculated by the equation (3):

$$\frac{ref}{max_i} \leq \frac{W_{ref}}{W_i} \leq \frac{ref}{min_i} \qquad (3)$$

With W_{ref} being the score given for the reference attribute, max_i the maximum limit of the non-reference attribute, and min_i the minimum limit of the non-reference attribute.

Substituting the values of the intervals in the equation (3), there is:

$$\frac{1}{2} \leq \frac{W_a}{W_b} \leq 2 \qquad \frac{1}{3} \leq \frac{W_a}{W_c} \leq 1 \qquad \frac{1}{6} \leq \frac{W_b}{W_c} \leq 2$$

As there are three variables, it is represented graphically as a polyhedron with the vertices in 1, as in the *INTERVAL SMART/SWING* method the weights are normalised to 1. Signalling the limits in the plane formed by the three vertices and tracing the vectors from each vertex to the limits on the opposite side, the feasible region “S” is reached at the intersection of the areas as shown in figure 1:

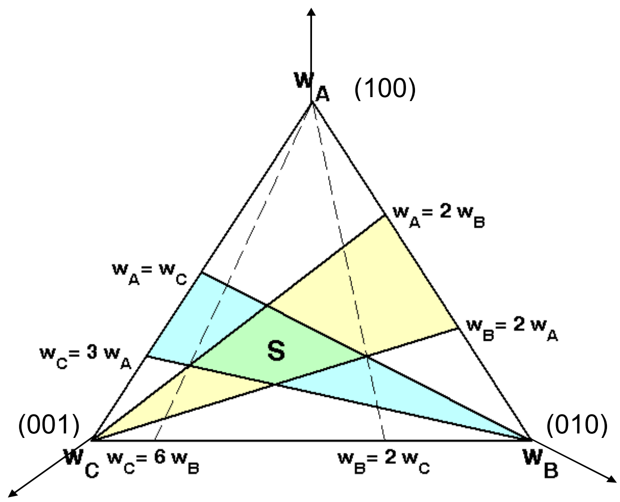

Figure 1: Example of feasible region

The aggregate values are calculated considering the *feasible region*, in accordance with the equations (4) and (5), minimum aggregate value and maximum aggregate value respectively:

$$\underline{V}(a) = \min_{w \in S} \sum_{j=1}^{n} W_j V_j(a_j) \tag{4}$$

$$\overline{V}(a) = \max_{w \in S} \sum_{j=1}^{n} W_j V_j(a_j) \tag{5}$$

where, "W_j" is the weight and "$V_j(a_j)$" is the scoring of the alternative for each of the criteria, resulting in the maximum and minimum aggregated values of the alternative "a".
The solution of the problem consists of determining which alternative dominates all the others. It is said that alternative "a" dominates alternative "b", if the aggregated value of "a" is greater than the aggregated value of "b", for any combination within the feasible region. The mathematical representation is given by the equation (6):

$$\min_{w \in S} \sum_{j=1}^{n} W_j(\underline{V}_j(a_j) - \overline{V}_j(b_j)) \geq 0 \tag{6}$$

that is, if the aggregate value of alternative "a" calculated by its respective minimum values is greater than the aggregate value of alternative "b" calculated by its respective maximum values, for any combination inside the feasible region, then the expression will have a result greater than zero, meaning that alternative "a" dominates alternative "b".
The choice of the reference attribute is the first step in developing the method, and is fundamental in order to obtain the dominant alternative. According to Mutajoki, Hämäläinen and Salo (2005), the recommended sequence for the choice of the reference attribute is: i. If it is possible to identify the attribute with the least imprecision, then this must be chosen as the reference attribute; ii. If the imprecision cannot be differentiated among the attributes, then the most important attribute must be chosen.
The identification of the most precise or most important attribute points to the need for a wide-ranging discussion among the participants in the decision making process during the criteria defining phase, with the objective of seeking alignment in the understanding of what each of them signifies. The intervals represent the imprecision in the judgement of an alternative in relation to each attribute, or the imprecision in the definition of the weight of each attribute. Each of these judgements can have different levels of uncertainty from the judge, which consequently defines different intervals. The larger the interval, the greater the imprecision and consequently, the greater the number of non-dominated alternatives.
Even if the best choice for the reference attribute has been made, it is still possible that not all of the alternatives are dominated. In this case, it is necessary to use other decision rules to be able to rank them (SALO and HÄMÄLÄINEN, 2001). Some techniques can be applied to reduce the number of non-dominated alternatives: i. Pre-Analysis of Alternatives: To define the minimum values for the main attributes, and eliminate the alternatives which do not accord with these values. This stage is very useful in the evaluation of information technology services, as normally there are a large number of suppliers of these services, though some of them are found to be without the structure to carry them out; ii. Variation of the Intervals: after the first result of dominance, the decision maker can carry out a 'what-if' analysis, varying the intervals until a single dominant alternative is obtained. This can be done by a more detailed study of each maximum and minimum value attributed, seeking to reduce the imprecision, or even to correct values attributed to the alternatives and to the attributes.
After a single dominant alternative has been identified, it is good to check the attributed intervals to ensure that they represent the imprecision of each attribute and/or alternative. This

can be done, for example, using one of the methods below: i. Centralization of the Minimum and Maximum Aggregate Values: after calculating the maximum and minimum aggregate values, the central value of each alternative can be calculated, adding these aggregate values and dividing by two. In this way, all the alternatives will have a single aggregate value (central), and the dominant value will be that which has the highest value; ii. Minimum or Maximum Aggregate Value: the ranking of the alternatives can be made by choosing the maximum or minimum value as the reference. The dominant alternative will be that which has the highest value in the reference chosen.
The use of the MAUT and *INTERVAL SMART/SWING WEIGHTING* methods is therefore efficient in dealing with uncertainty in situations of medium and high risk, permitting a quick and precise decision even with incomplete information. However, all due care must be taken in the evaluation of the alternatives, weights and choice of the reference attribute.

3. Case Study

3.1. Evaluation Criteria

Figure 2 presents, through a “Value Tree”, the criteria which shall be used in the evaluation of the alternatives.

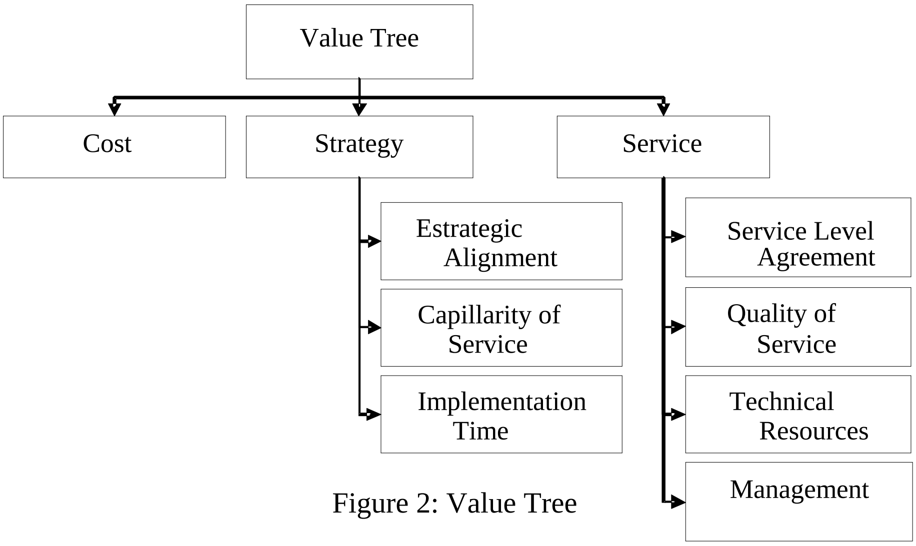

Figure 2: Value Tree

The criteria are described as follows: i. Service Level Agreement: this measures the time taken to resolve a problem from receiving the call, considering Customer Service 24x7 (7 days a week, 24 hours a day). The less time taken, the greater the score in this requirement. Time periods above 24 hours for Duque de Caxias or Guarulhos should be scored zero, as these are the most important distribution centres. This is defined as a precise criterion because its values are well-defined and clear to the decision maker; ii. Service Capillarity: this evaluates which locations are serviced by the company itself, and which are serviced by sub-contracted companies. It is understood that the greater the number of locations that are serviced directly, the better the quality of service and technical empowerment. Companies which do not provide service directly in the São Paulo area should be scored zero. It is defined as an imprecise criterion as there is some disagreement over the true importance which should be attributed to this criterion. iii. Technical resources: this evaluates the printing, copy, fax and scanner resources available. The greater the resources available within those described in the specifications, the higher the score. It is defined as a precise criterion, as the main companies have all or almost all of the resources; iv. Cost: this evaluates the annual cost of each solution. In the first phase, it is important that the alignment of the proposals with the specification is carried out well in order to avoid large differences due to the lack of a clear understanding. Following the recommendation for the choice of a reference attribute according to Mutajoki, Hämäläinen and Salo (2005), this attribute was identified as the attribute with the greatest degree of precision in the definition of the corresponding weight. The attribute will be given the value one and will be the reference attribute in the evaluation of the other attributes. It is common to find cost to be the most important attribute, but in this case, it was not very clear for the decision makers. If it were, one would have the ideal situation where the reference attribute is at the same time the most precise and the most important; v. Strategic Alignment: this evaluates the capacity of the company to participate in a global alignment, establishing a standard for Latin America. It evaluates the possibilities of servicing companies in the same group beyond Brazil: Mexico, Argentina, Chile, Venezuela and Colombia. It is defined as an imprecise criterion, as there is not sufficient information defining how the service will be effected; vi. Management: this evaluates how much operational work will be taken away from the contracting company. It also evaluates the capacity to issue accompanying management reports which will make it possible to carry out cost analysis by cost centres with the aim of reducing the volume of printing. The use of a system via Web in which it is possible to consult and carry out these evaluations is considered as a positive point. This is defined as an imprecise criterion due to the subjectivity of the evaluation; vii. Quality of Service: this is evaluated based on a questionnaire sent to three clients indicated by each of the competing companies. The objective is to check if even a client indicated by the company would not evaluate the service provider well. viii. Time of Implementation: this is the time taken to implement the project, counting from the signing of the contract. The maximum acceptable period is two months.

3.2. Results

3.2.1. Prior Analysis

A first analysis was performed to check whether all of the suppliers were within the maximum implementation period. Two suppliers were eliminated as shown in table 2, as the period was above 2 months, the maximum period defined by the company. In this research, the suppliers are the alternatives considered in the evaluation.

Alternatives	Period of Implementation (Months)
Alternative 1	1.5
Alternative 2	2.0
Alternative 3	2.0
Alternative 4	***3.0***
Alternative 5	2.0
Alternative 6	1.0
Alternative 7	***3.0***
Alternative 8	1.5
Alternative 9	2.0
Alternative 10	2.0

Table 2: Evaluation of the alternatives according to the minimum criteria

3.2.2. Dominance Analysis

The WINPRE software (2009), which is available for academic use, was used to determine dominance. The suppliers 4 and 7 were not considered as they had been eliminated in the previous stage. In this way, the research was carried out considering the remaining eight suppliers, A_1, A_2, A_3, A_5, A_6, A_8, A_9, A_{10}. Figure 3 presents the “Value Tree” captured through the WINPRE system, with the evaluation criteria and the alternatives.

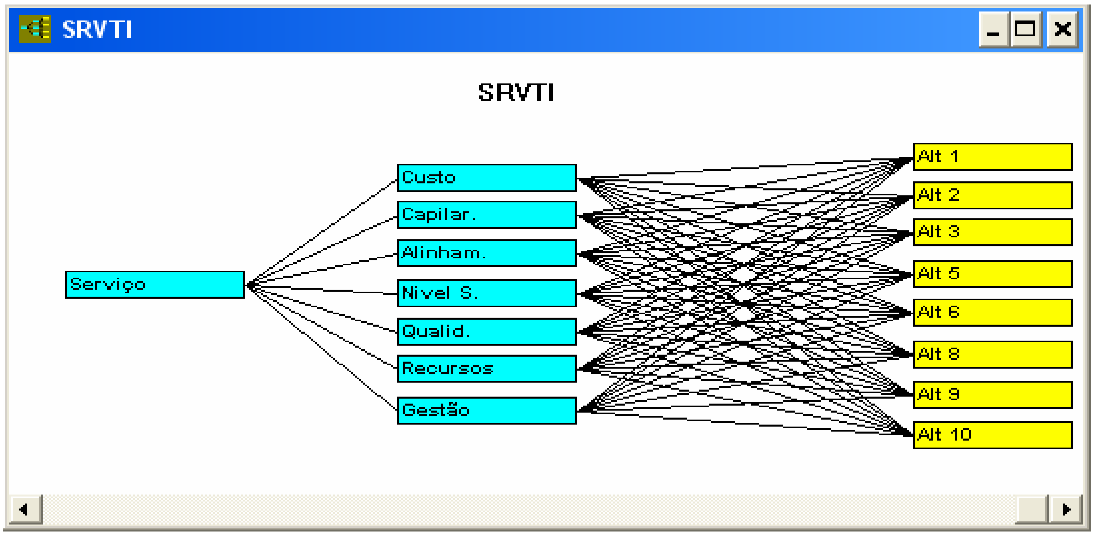

Figure 3: Value Tree captured by the WINPRE software

The evaluation of the alternatives according to the criteria established in the analysis is presented in the evaluation matrix in table 3.

Alternatives	Criteria						
	Annual Cost (Reais)	Capillarity.	Strategic Alignment.	SLA	Quality of Service	Technical resources	
Alt. 1	400,000	Brazil	Brazil	6h	7.7	All	V. Good
Alt. 2	450,000	RJ and SP	L.A.	4h	6.3	All	Good
Alt. 3	420,000	RJ and SP	L.A. except for Colombia	8h	6.0	All	V. Good
Alt. 5	390,000	Brazil	Brazil	6h	6.3	Without Colour Scanner Copy	Regular
Alt. 6	425,000	Brazil	Brazil	24h	6.0	All	Good
Alt. 8	415,000	RJ and SP	L.A. except for Colombia and Venezuela	48h	8.3	Without confidential printing	V. Good
Alt. 9	430,000	RJ and SP	L.A. except for Colombia and Venezuela	6h	7.0	All	V. Good
Alt. 10	470,000	Brazil	L.A.	8h	6.7	All	Regular

Table 3: Evaluation of the alternatives according to the established criteria

Considering table 3 with the responses to each of the alternatives, already discounting alternatives 4 and 7 eliminated in the previous phase (table 2), it is possible to create table 4 where the minimum and maximum values for the alternatives in relation to each attribute are presented.

Alter-natives	Criteria													
	Annual Cost		Capillarity		Strategic Alignment		SLA		Quality of Service		Technical resources		Manage-ment	
	min	max	min	max	min	max	min	max	min	max	MiN	max	min	max
Alt. 1	0.9	0.9	1.0	1.0	0.5	0.5	1.0	1.0	0.7	0.8	1.0	1.0	0.7	1.0

Alt. 2	0.3	0.3	0.5	0.7	1.0	1.0	1.0	1.0	0.6	0.7	1.0	1.0	0.5	0.7
Alt. 3	0.6	0.6	0.5	0.7	0.7	0.8	0.8	0.8	0.6	0.7	1.0	1.0	0.7	1.0
Alt. 5	1.0	1.0	1.0	1.0	0.5	0.5	1.0	1.0	0.5	0.7	0.6	0.6	0.1	0.4
Alt. 6	0.5	0.5	1.0	1.0	0.5	0.5	0.5	0.5	0.6	0.6	1.0	1.0	0.5	0.7
Alt. 8	0.8	0.8	0.5	0.7	0.7	0.8	0.0	0.0	0.8	0.9	0.6	0.6	0.7	1.0
Alt. 9	0.5	0.5	0.5	0.7	0.7	0.8	1.0	1.0	0.7	0.8	1.0	1.0	0.7	1.0
Alt. 10	0.0	0.0	1.0	1.0	1.0	1.0	0.8	0.8	0.6	0.7	1.0	1.0	0.1	0.4

Table 4: Maximum and minimum values of the alternatives in relation to the attributes

Figure 4 presents the minimum and maximum values of each alternative in relation to the criterion “Management”, inserted in the WINPRE software.

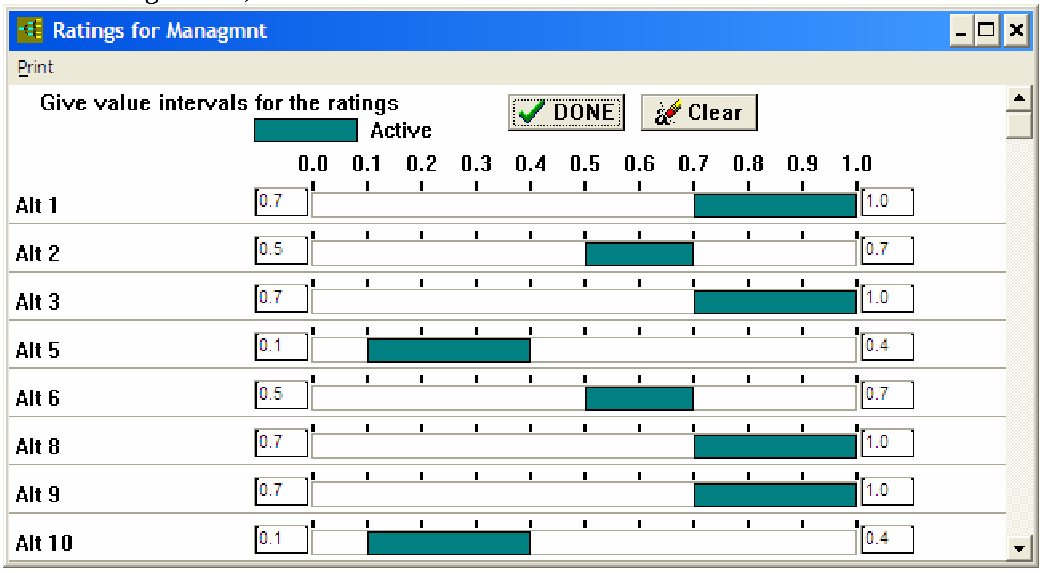

Figure 4: Scoring of the alternatives in relation to the attribute “Management”

We proceed to the calculation of the intervals of the weights in relation to the reference attribute. Figure 5 presents the maximum and minimum values attributed to each of the criteria, in relation to the attribute reference “Cost”.

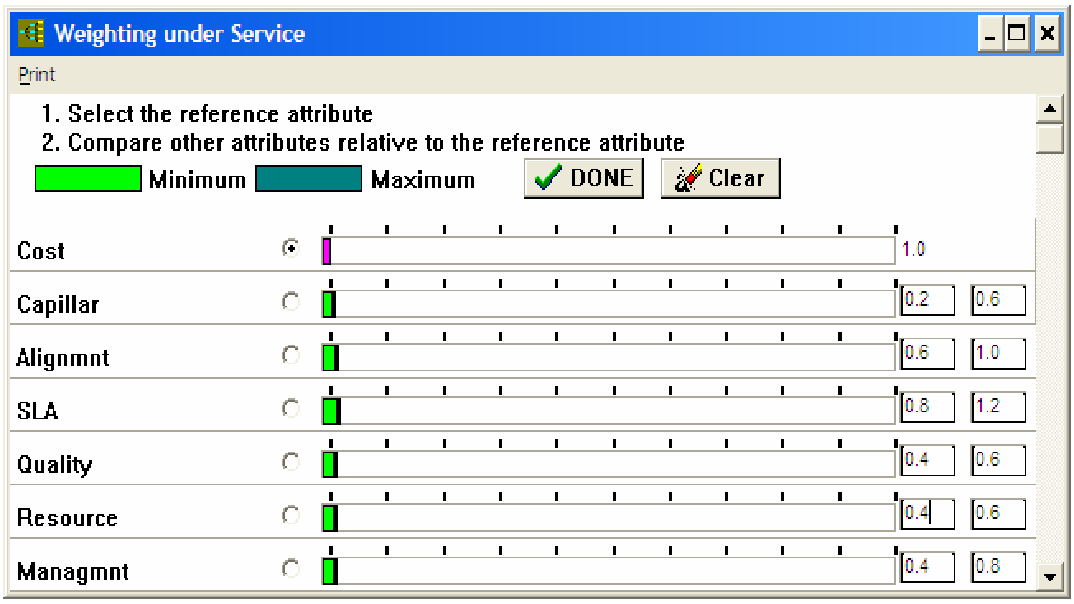

Figure 5: Weights captured by the WINPRE software.

Figure 6 presents the dominance existing between the alternatives according to the data given in figure 5. The dominant alternative appears on the left side and the dominated alternative on the right.

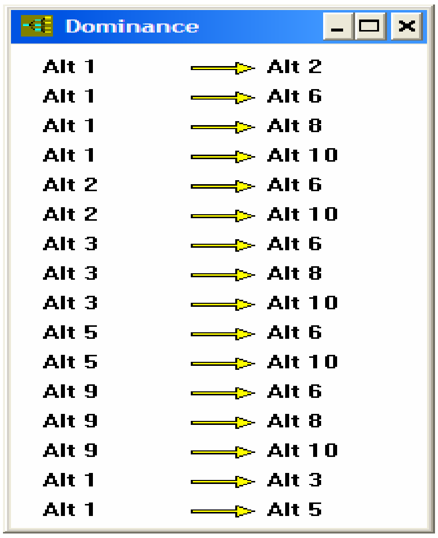

Figure 6: Dominance captured by the software WINPRE

It becomes clear that the alterna tives 1 and 9 are the only ones not dominated. This demonstrates that the reference attribute was chosen well, providing a high percentage of dominated alternatives. However, it was still necessary to define whether alternative 1 or alternative 9 should be recommended.
Returning to table 3, and evaluating the differences between these alternatives, it can be seen that alternative 1 is better in the attribute “Cost” (400,000 x 430,000), and that alternative 9 is best in the attribute “Strategic Alignment” (Latin America apart from Colombia and Venezuela x Brazil). These attributes, in conjunction with the attribute “SLA” are the ones which carry the most weight among all the attributes evaluated.
The question which must be answered is: Is it worth paying 30,000 reais more per year to have strategic alignment including the main countries (Brazil, Mexico, Argentina and Chile)? On the other hand, it can also be asked: Is it worth paying 30,000 reais less per year to have a solution which only serves Brazil?
Evaluating the description of the problem, and the objectives which must be reached with this project, and considering that a sensitivity analysis will still be made, at this moment alternative 9 is recommended based on the following arguments: i) Alternative 9, in spite of having a higher cost than alternative 1, still reduces the current cost by 70,000 reais, which corresponds to approximately 14%; and ii) The cost difference to alternative 1 can be achieved later, with a renegotiation including the other countries in Latin America, considered in the alternative 9 solution.

3.2.3. Sensitivity Analysis

In this analysis, the result encountered in the dominance analysis stage shown in figure 19 will be compared to the result of a new analysis which will rank the alternatives by the aggregate value, calculated using the minimum, maximum and central values respectively, based on the formula number “1”. The minimum aggregate value will be calculated using the minimum values defined in the intervals of the values of the weights and the values of the alternatives in relation to the weights. The maximum aggregated value will be calculated using the maximum values defined in the intervals of the values of the weights and the values of the alternatives in relation to the weights. The central aggregated value will be calculated using the mathematical average of the maximum and minimum values defined in the intervals of the values of the weights and the values of the alternatives in relation to the weights respectively.

Table 5 shows the aggregate values calculated according to the scoring of the alternatives in relation to the attributes presented in table 4, and the weights given using the reference attribute “Cost”, as shown in figure 5.

Alternatives	Minimum		Maximum		Central	
	Aggregate Value	Classification	Aggregate Value	Classification	Aggregate Value	Classification
Alt. 1	3.14	1	14.88	1	9.01	1
Alt. 2	2.58	5	13.53	3	8.06	4
Alt. 3	2.66	4	13.48	4	8.07	3
Alt. 5	2.76	2	11.12	8	6.94	7
Alt. 6	2.22	6	12.26	6	7.24	6
Alt. 8	2.10	8	11.67	7	6.89	8
Alt. 9	2.76	2	14.22	2	8.49	2
Alt. 10	2.13	7	13.18	5	7.65	5

Table 5: Classification considering the minimum, maximum and central values.

The result presented in table 5, shows that the alternatives 1 and 9 are always classified as first and second respectively. The sensitivity analysis confirms that the alternatives 1 and 9 are the best alternatives. As a consequence, the choice of alternative 9 will be maintained as the alternative recommended to provide the printing service according to the criteria defined.

4. Conclusion

The use of a multicriteria decision aiding approach was shown to be of great importance, as it generates well-founded, transparent recommendations in an organised way, capable of keeping the discussions on technical criteria, not permitting the process to get lost in irrelevant discussions with little objectivity in relation to the decision process in question. The MAUT method was shown to be a method which is easy to understand and use, and, at the same time, one which provides results which are easy to defend, principally when it involves various decision makers from the company. The use of the *INTERVAL SMART/SWING* method contributed towards covering any imprecision in the judgements, leaving the decision makers in a more comfortable position. It also allows the intervals to be revised throughout the study to represent a reality which had not been perceived before. However, the fact that the decision makers feel more comfortable, may generate a failure in the search for more complete information, in other words, if the decision maker can judge via an interval, this judgement does not require such precision in the information. It is possible to get around this problem in the sensitivity analysis phase, narrowing the intervals through the search for more complete information.

The choice of the reference attribute was also shown to be fundamental, confirming that the choice of the most precise attribute is most recommended (MUTAJOKI, HÄMÄLÄINEN and SALO, 2005). The choice of the attribute “Cost” generated an analysis of dominance where only two dominant alternatives remained. The current market requires decisions to be made in a quick and precise way, and consequently, with incomplete information. This scenario contributed to generating uncertainty in the analysis of the criteria and alternatives. The use of these methods permits interactivity during the whole of the decision making process, keeping the discussions focused on the problem in question, and presenting the solution in a transparent way which is easy for the participants to understand. In this way it strongly minimises the possibility of financial loss through the choice of an inappropriate alternative. As a result of the process being documented at all stages, it can be used for consultation in other similar processes.

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References

Belton, V. and Stewart, T.J. (2002) *Multiple criteria decision analysis: an integrated approach.* Boston: Kluwer Academic Press.
Clemen, R. T. and Reilly, T. (2001) *Making Hard Decisions with Decisions Tools*. 2. ed. Pacific Grove: Duxbury.
Edwards, W. (1971) *Social utilities*. Engineering Economist, Summer Symposium Series, 6, p. 119-129.
Fishburn, P. (1970) *Utility Theory for Decision Making*. New York: John Wiley e Sons.
Gomes, L.F.A.M. and Rangel, L.A.D. (2009) *Determining the utility functions of criteria used in the evaluation of real estate*. International Journal of Production Economics, v. **117**, p.420-426.
Keeney, R. L. and Raiffa, H. (1976) *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. New York: John Wiley e Sons.
Meirelles, C.L.A. and Gomes, L.F.A.M. (2009) O apoio multicritério à decisão como instrumento de gestão do conhecimento: uma aplicação à indústria de refino de petróleo. Pesquisa Operacional, v. **29**, n. 2, p. 451-470.
Mustajoki, J.; Hämäläinen, R.P. and Salo, A. (2005) *Decision support by interval SMART/SWING – Incorporating imprecision in the SMART and SWING methods*. Decision Sciences, v. **36**, n. 2, p. 317-339.
Poyhonen, M. and Hämäläinen, R.P. (2001) *On the convergence of multiattribute weighting methods.* European Journal Operational Research, v. **129**, p. 569-585.
Rangel, L.A.D. and Gomes, L.F.A.M. (2009) *Emprego dos métodos Utilité Additive e Utilité Additive – CRiteria na avaliação de imóveis: um estudo de caso.* Gestão & Produção, v. **16**, n. 2, p.222-231.
Salo, A. and Hämäläinen, R.P. (2001) *Preference Ratios in Multiattribute Evaluation (PRIME) – Elicitation and Decision Procedures under Incomplete Information.* IEEE Transactions on Systems, Man, and Cybernetics Journal, v**. 31**, p. 533-545.
Von Winterfeldt, D. and Edwards, W. (1986) *Decision Analysis and Behavioural Research.* New York: Cambridge University Press.
WINPRE (2009) *Decision analysis with imprecise ratio statements* **-** *preference programming, PAIRS.* Disponível em <http://www.sal.hut.fi/Downloadables/winpre.html>. Access in: July 7th.