A Multicriteria Decision Aid Software Application for selecting MCDA Software using AHP

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Abstract
In the business world, a good decision may be the success of an organization. To decide, sometimes, is not an easy task, mainly when we have multiple criteria. A bad decision can mean the collapse of an organization. In the current climate of turbulence, the companies, in order to become competitive in an increasing demanding market, have to know how to make decisions right.
This work begins to present a review of the literature on the main techniques proposed in multicriteria decision making. Then it presents the results of a research on the software tools available in this field. These software tools were then characterized and classified and their main characteristics summarized.
The next step was to construct a software application to help organizations in the selection of the right multicriteria Decision Aid (MCDA) software available, among the ones previously collected. The multicriteria technique used for the selection was the Analytic Hierarchy Process (AHP) from Saaty. The programming language used to develop the application was Microsoft Visual Basic 2008 Express Edition. The software tool developed allows the user to access all the information about the software tools available, showing the web page of each application and allowing one to view other related information. The criteria selected were: "Compatibility between Operating Systems", "Cost of a License", "Interaction with user", "User Manual and Tutorials", "Application Examples", "Online Help" and finally "Free Version". After inserting the pairwise comparisons required by the AHP between pairs of criteria, the software is able to select the best alternative software tool among the ones available. An example application of the algorithm is presented to illustrate the use of the program.
Keywords: Multicriteria Decision Making, Multicriteria Decision Aid Software, Analytic Hierarchy Process.

1. Introduction

Over time it has been observed that the requirements of the process of decision making in industry and in the business world have increased. Competition among organizations is ever present. This means that companies increasingly pay more attention to the decisions that have to be made. For example, in the context of the choice of a new product to be introduced in the market, a wrong choice may represent a significant financial loss for the company.

Currently there are several software packages on the market to help make decisions. The problem is to choose the best software that an organization should use to solve a specific problem.

The goal of this paper is to help on that choice. In particular, we present a tool that allows comparing the main multicriteria decision analysis software tools available in the market, in order to make the decisions under multiple criteria easier, for a specific company.

The paper is organized in five sections, beginning with this introduction. Section 2 gives the necessary background to multicriteria decision aid. Section 3 presents the main MCDA software available. Section 4 presents the software developed and the algorithm used, and the paper concludes with and an outlook on future research in section 5.

2. Multicriteria Decision Aid

Whenever a problem has more than one solution and a choice must be made on which one to adopt, we have a decision problem [1]. According to Zeleny [2], the decision is an effort to solve problems of conflicting objectives, which presence prevents the existence of the optimal solution and leads to demand the best compromise. A multicriteria decision problem is a complex problem which, as the name suggests, involves several criteria and the evaluation of several alternatives [3][4][5][6][7]. Many authors do not distinguish between multicriteria and multiattribute; in this work we consider these two terms to be synonymous.

2.1 Basic Concepts of the Decision Theory
In a multicriteria problem several agents act simultaneously. The following presents some basic definitions.
Decision-makers: It is a group of individuals that carry out choices and make preferences as a whole. The decision

process depends on the decision makers, who may have different values and are influenced by culture, religion, technical training, among other factors.

Analyst: According to Rogers et al. [8], the analyst is the agent that has the role of selecting the model to be used, the information necessary to model and interpret the results and explain the decision mechanism of the model chosen.

Model: It is a set of mathematical operations that represent the tastes and views of the decision makers, leading to the achievement of the desired result. Models can be classified into descriptive and normative: descriptive models represent what the decision makers do, and the normative models represent what the decision makers should do.

Actor: Roy [9] and Bana e Costa [10] define actor as a person or group of persons who, in a decision-making process, directly or indirectly influence the decision.

Alternatives: A set of alternatives is a set of choices. Sometimes the definition of the set of alternatives is the most difficult task of decision making. The alternatives are the entities that have the power to change the nature of the problem.

Criteria: According to Roy [11], criteria are viewed as tools that allow comparing the actions in relation to views of each decision maker.

Objectives: According to Keeney [12] an objective is the demonstration of something that somebody wants to reach. He defines two types of objectives: the fundamental objectives and intermediate objectives.

2.2 Classification of Multicriteria Methods

According to Vincke [13], most of the researchers or authors divide the MCDA in three families of approaches:
• American school or school of the MultiAttribute Utility Theory (MAUT).
• French school or European school or methods of outranking and synthesis.
• Interactive methods or multiobjective mathematical programming models.

The interactive methods usually apply to interactive systems, which have the objective of supporting and improving decision-making processes. Vanderpooten [14] argues that the French school directs his study to methodologies where the personal preferences of decision makers have less influence on the alternative chosen. To cite some methods of this school, we have the ELECTRE family methods (ELimination Et Choix Traduisant la REalité) which stems from the pioneering work of Roy [9], and the PROMETHEE (PReference ranking Organization METHod for Enrichment Evaluations) method developed by Brans and Vincke [15] from the ELECTRE method, in order to create a simpler method whereas ELECTRE requires many parameters that may not be meaningful to the decision maker. The American school seeks methods to better explain the preferences of the decision maker, which can have a major influence on the final choice. In this school we can cite the Multiattribute Utility Theory of Keeny and Raiffa [6], that explicitly addresses the value tradeoffs in multiobjective decisions and the AHP (Analytic Hierarchy Process) method, developed by Thomas Saaty in the mid 1970s, that is based in pairwise comparisons between alternatives [16]. To our thinking a good decision will only be possible if there is balance between these two influences. There are software tools developed for all of the methods cited above, in many cases by the scientific communities. In this work we will focus our study on the multiattribute methods that deal with multiple discrete alternatives; noting that in general, multiobjective methods consider a continuous space of alternatives. We will be using AHP [16].

3. Main MCDA Software

In the literature there are many methods for solving multicriteria decision analysis problems, and a wide range of software to implement them. Many of the tools are still in experimental phase, combined with academic research. So to do a survey of software in this area is a difficult task, not only because of the rapid developments in computer science, but also because its commercialization is associated with its author or the university that developed it. The MCDA software reaches several levels of the decision making process, starting at the structure of the problem, continuing to the modeling of the preferences, and finally providing the solution. In this study the software analyzed to help solve MCDA problems was divided into six categories: Qualitative Problem Structuring, General Multiple Attribute Decision Making, General Multiple Objective Decision Making, Multiple Criteria Sorting Problems, Specific Applications Software and Group Decision Support. A similar approach was used in [17].

3.1 Qualitative Problem Structuring

The software in this category implements the initial stages of the decision making process: exploration and formulation of the problem. In this category we have DECISION EXPLORER [w1].

3.2 General Multiple Attribute Decision Making

The software in this category deals with any problem of decision, where it is necessary to choose a finite set of alternatives, characterized by a set of attributes. In this category we have CRITERIUM DECISION PLUS [w2], DAM (Decision Analysis Module) [18], DECISION DECK [w3], DECISION LAB [w4], ELECTRE IS [w5], ELECTRE III-IV

[w6], EQUITY [w7], EXPERT CHOICE [w8], GMAA (Generic MultiAttribute Analysis) [w9], GRIP [19], HIVIEW [w10], IDS [w11], LOGICAL DECISIONS [w12], MACBETH [w13], MACMODEL [w14], M&P (MAPPAC [20] and PRAGMA [21]), MIIDAS [22], MINORA [23], MUSTARD [24], NAIADE [w15], ON BALANCE [w16], PREFCALC [w17], PRIAM (PRogramme utilisant l'Intelligence Artificielle en Multicritère) [25], PRIME DECISIONS [w18], REMBRANDT [26], RPM (Robust Portfolio Modeling) [w19], SANNA [w20], SMAA.fi [w21], TOPSIS [w22], UTA PLUS [w23], VIP ANALYSIS [w24], VISA [w25], WEB-HIPRE [w26] and WINPRE [w27].

3.3 General Multiple Objective Decision Making
In models with multiple objectives, decision criteria are expressed in the form of mathematical objective functions that must be optimized. These models may involve linear or nonlinear objective functions and continuous or discrete variables. In this category we have ADBASE [27], TEC ADVISOR [w28], FGM (Feasible Goals Method) [w29], GUIMOO [w30], KAPPALAB [w31], MULTIGEN [28], MULTISTAT [w32], PARADISEO [w33], SOLVEX [w34], TRIMAP [29], TOMMIX [30] and WWW-NIMBUS [w35].

3.4 Multiple Criteria Sorting Problems
The software in this category classifies the alternatives into predefined groups or classes. In this category we have ELECTRE TRI [w36], IRIS [w37], PREFDIS [31] and TOMASO [w38].

3.5 Specific Applications Software
In this category we cite some applications developed for specific areas, namely AUTOMAN [w39], BANKADVISOR [32], CASTART [33], DIDASN++ [34], ESY [35], FINCLAS [36], INVEX [37], LPA VISIRULE [w40], MARKET EXPERT [38], MEDICS [39], MOIRA [w41], PROAFTN [w42], SANEX [w43], SKILLS EVALUATOR [w44], TELOS [40] and WATER QUALITY PLANNING DSS [w45].

3.6 Group Decisions Support
The software in this category serves primarily to deal with problems where there is more than one decision-maker. In this category we have AGAP [41], ARGOS [42], ATHENA [w46], GMCR [43], HIPRIORITY [w47], MEDIATOR [w48], OPINIONS-ONLINE [W49], SCDAS [44] and WINGDSS [w50].

4. Multicriteria Decision Aid Software Application Development
The procedure for the selection of the MCDA software was based on the work developed by Saaty [16]. AHP is especially suitable for complex decisions involving the comparison of decision elements which are difficult to quantify. It involves building a hierarchy of decision elements and then making comparisons between each possible pair, for each level of the hierarchy. This gives a weighting for each element within each level and also a consistency ratio, useful for checking the consistency of the data.

4.1 Criteria used for the selection of MCDA software
The use of criteria for software evaluation is essential for selecting the best option available.
The criteria for evaluating MCDA software proposed was inspired on the work of Banks [45], for the selection of simulation software. The following table presents the criteria considered for selection MCDA software.

Table 1: Criteria used for the selection of MCDA software

Compatibility between Operating Systems
Cost of a license
Interaction with user
User Manual and Tutorials
Application Examples
Online Help
Free Version

The compatibility between operating systems, allows the user to install the software on any version of Microsoft Windows, Linux, Mac OS, Solaris, etc., so it may be an important feature. The cost of a license is normally an important criteria as well. It should be carefully analyzed because it may involve several components. The interaction with the user is also an important factor because in decision problems the amount of information is normally high and the interface may help on structuring it in a convenient way. Moreover an user friendly interaction may facilitate the use of the model or models available in the software to help the user to arrive to practical solutions in a faster way. The availability of the user manual and detailed information on how to install and uninstall the software, as well as reference guides to commands and functions and/or tutorials that explore the characteristics of the tools, are also important criteria that should be considered in evaluating the tool. The existence of simple examples of application of the tool helps to better understand the functions and commands.

Technical support via e-mail messages is a criterion to be considered for allowing the clarification of doubts and facilitate the contact between the user and the supplier. Another criterion to consider is the availability of a free, limited version, which allows the construction of simple models, which facilitates learning and the initial contact with the tool.

There must be a comprehensive analysis of the features offered by the tool to facilitate the creation of the model to evaluate the time needed for its construction, thereby increasing efficiency and productivity.

4.2 The choice of the programming language

For the development of MCDAS we wanted a relatively simple language. More precisely, we seek a language with which to produce an application that relies greatly on database accessing while providing a suitable graphical interface.

Among the usual programming languages, those being object-oriented seem easier to learn as they provide much functionality while staying robust enough to be used by a non-advanced programmer. On this regard, we considered Java and the subset of Microsoft Visual Studio family: C# and Visual Basic.

The Java language is powerful but for database programming and graphical interface, the Microsoft languages are more appealing as they rely on .Net Framework on Windows. This platform provides features for database manipulation (like ADO.Net). Also, the design of graphical interfaces is easier with the provided tools of the Visual Studio.

Between, C# and Visual Basic, we chose the Microsoft Visual Basic, version 2008 Express Edition, which is freely available and because it seems a language easier to learn than C#.

4.3 MCDAS Tool

MCDAS was the tool developed in Microsoft Visual Basic Express Edition, in order to help decision makers in the selection of multiciteria decision aid software. Because it is a simple tool, this software is very easy to learn.

Its interface allows access to four menus: File, Software, Language, and Help. In the File option the user has four options: New, Open, Save and Exit. In the "New" option the user can insert pairwise comparison values between criteria, in a scale from 1 to 9. According to Saaty [16] this scale is sufficient to quantify the preference of decision makers. With the "Save" option the user may save this information. The "Open" can be used to open a previously saved pairwise comparison matrix, and finally using the option "Exit", the user can leave the tool.

On the menu Software the user can "Edit" the software information. This option opens a form that allows viewing the software information already in the database, as well as inserting new software tools or removing existing ones. He can also "View" the software web-page. Finally he can "Select" a subset of software tools to perform the analysis and run the analysis, using AHP. The result will be a rating of the software tools previously selected. On the menu Language the user can select between Portuguese and English. And finally on the Help menu the user has two options: "What is MCDAS?" which explains how MCDAS works and "Tutorial" with an explanation of how to use MACDAS. In figure 1 we can see some print screens of the application.
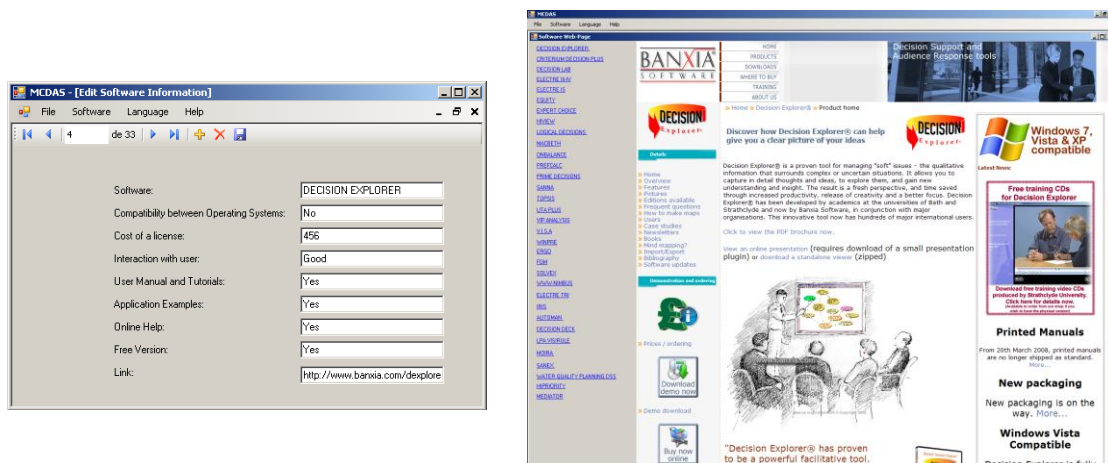

Figure 1: Print Screens of the application developed

4.4 The algorithm

MACDAS is based on AHP. This methodology divides a decision problem into its constituent parts, using a hierarchical structure. The main goal is placed on the top of the hierarchy and criteria, sub-criteria and alternatives in the next levels. The relative importance of each criterion is determined by a pairwise comparison of preferences made by the decision makers. According to Saaty [16] the preference between two items can be measured on a

scale of 1 to 9, as follows (see table 2).

Table 2: Saaty's Scale

Comparison	Preference to be given
If x is as important as y	1
If x is a little more important than y	3
If x is much more important than y	5
If x is far more important than y	7
If x is absolutely more important than y	9

So, the first step is to build a matrix with the preferences of decision makers comparing all the elements. The number of comparisons needed to fill a matrix of n options is:

$$\text{Number of comparisons required } = \frac{(n^2 - n)}{2} \tag{1}$$

To illustrate the algorithm used in MCDAS, we are going to consider only 3 software tools from the database tool: SANEX, IRIS and MACBETH, and three criteria (cost of a license, compatibility between operating systems and user interaction). The hierarchical structure is represented in figure 2. In this case we have to make $(3^2 - 3)/2 = 3$ comparisons. So, we have to fill, for example, the values in bold, in table 3. The others can be derived from these ones as the inverse of the correspondent pair already inserted. For example, if the cost of a license is a little more important than the compatibility between operating systems (3), the second criterion will be a little less important than the first one (1/3).
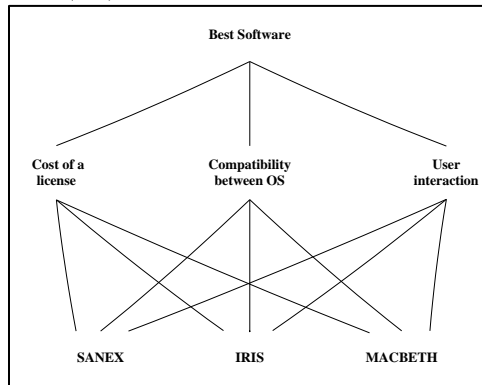

Figure 2: AHP hierarchical structure

Table 3: Pairwise comparison matrix between criteria and normalized matrix

	CL	COS	UI	CL	COS	UI	Sum of lines	Average
CL: Cost of a license	1	**3**	**5**	0.65	0.69	0.56	1.9	0.63
COS: Compatibility between Operating Systems	1/3	1	**3**	0.22	0.23	0.33	0.78	0.26
UI: User Interaction	1/5	1/3	1	0.13	0.08	0.11	0.32	0.11
∑=	1.53	4.33	9	1.00	1.00	1.00	3	1.00

After introducing the pairwise comparison values, we have to sum the values on each column, as shown in table 3, and divide each element of the matrix by this sum, in order to obtain the normalized matrix. Then we sum up the lines, evaluate the total sum for all the criteria and finally the weight of each criteria. This weight is close to the desired eigenvector, and represents the priority weights of the criteria. The next step is to verify that the matrix is consistent. To do this, we calculate the Consistency Ratio (CR), which according to Saaty, should not be greater than 0.10, and can be evaluated as follows:

$$CR = \frac{CI}{RI} \tag{2}$$

Where CI is the consistency index of an array of size N, given by:

$$CI = \frac{\lambda_{max} - N}{N - 1} \tag{3}$$

λ_{max} is an approximation to the largest eigenvalue.

And RI is the random index evaluated by Saaty, using simulation. This index was evaluated for different array

sizes, as shown in table 4.

Table 4: Saaty's Random Index

N	1	2	3	4	5	6	7	...
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	...

To evaluate CI first we multiply the comparison matrix with the eigenvector calculated above.

$$\begin{bmatrix} 1 & 3 & 5 \\ 0.33 & 1 & 3 \\ 0.2 & 0.33 & 1 \end{bmatrix} \times \begin{bmatrix} 0.63 \\ 0.26 \\ 0.11 \end{bmatrix} = \begin{bmatrix} 1.96 \\ 0.80 \\ 0.32 \end{bmatrix} \tag{4}$$

Then divide each element of the new vector by the corresponding element of the eigenvector, obtaining a new vector.

$$\begin{bmatrix} \dfrac{1.96}{0.63} & \dfrac{0.80}{0.26} & \dfrac{0.32}{0.11} \end{bmatrix} = [3.11 \quad 3.08 \quad 2.91] \tag{5}$$

Then evaluate the average of this new vector, obtaining λ_{max}, the approximation to the maximum eigenvalue.

$$\lambda_{max} = \frac{3.11 + 3.08 + 2.91}{3} = 3.03 \tag{6}$$

Knowing λ_{max} we can evaluate CI:

$$CI = \frac{\lambda_{max} - N}{N - 1} = \frac{3.03 - 3}{3 - 1} = 0.015 \tag{7}$$

Knowing CI, we can calculate CR:

$$CR = \frac{CI}{RI} = \frac{0.015}{0.58} = 0.02 \tag{8}$$

We can conclude that the matrix is consistent since CR is ≤ 0.10. If the result was not smaller or equal to 0.10, we could still apply an interactive method to improve the consistency rate.

The next step of the algorithm is the assignment of weights to the alternatives when compared by each of the criteria. This assignment is made in the same way as before, using the comparison matrices. Next we present the matrices for the comparison of the alternatives when compared by each of the three criteria:

Cost of a license

Table 5: Pairwise comparison matrix and normalized matrix between alternatives considering the criterion cost of a license

	S 0€	I 1000€	M 1750€	S 0€	I 1000€	M 1750€	Sum of lines	Average
S: SANEX 0€	1	7	9	0.8	0.84	0.69	2.33	0.78
I: IRIS 1000€	1/7	1	3	0.11	0.12	0.23	0.46	0.15
M: MACBETH 1750€	1/9	1/3	1	0.09	0.04	0.08	0.21	0.07
∑=	1.25	8.33	13	1	1	1	3	1

CR was evaluated as before, and the result was CR = 0.07, which is good. So for the criterion cost of a license, the relative priority weights of the alternatives are:

Table 6: Relative priority weights considering the criterion cost of a license

SANEX	0.78
IRIS	0.15
MACBETH	0.07

Compatibility between Operating systems

Table 7: Pairwise comparison matrix and normalized matrix between alternatives considering the criterion compatibility between operating systems

	S No	I No	M yes	S No	I No	M Yes	Sum of lines	Average
S: SANEX No	1	1	1/9	0.09	0.09	0.09	0.27	0.09
I: IRIS No	1	1	1/9	0.09	0.09	0.09	0.27	0.09
M: MACBETH Yes	9	9	1	0.82	0.82	0.82	2.46	0.82
∑=	11	11	1.22	1	1	1	3	1

CR = -0.07, which is good. So for the criterion compatibility between operating systems, the alternatives relative weights of priority are:

Table 8: Relative priority weights considering the criterion compatibility between operating systems

SANEX	0.09
IRIS	0.09
MACBETH	0.82

Interaction with the user

Table 9: Pairwise comparison matrix and normalized matrix between alternatives considering the criterion interaction with the user

	S Very Good	I Good	M Good	S Very Good	I Good	M Good	Sum of lines	Average
S: SANEX Very Good	1	5	5	0.72	0.72	0.72	2.16	0.72
I: IRIS Good	1/5	1	1	0.14	0.14	0.14	0.42	0.14
M: MACBETH Good	1/5	1	1	0.14	0.14	0.14	0.42	0.14
∑=	1.4	7	7	1	1	1	3	1

CR = -0.07, which is good. So for the criterion compatibility between operating systems, the relative weights of priority of the alternatives are:

Table 10: Relative priority weights considering the criterion interaction with the user

SANEX	0.72
IRIS	0.14
MACBETH	0.14

In figure 3 we present the hierarchy of decision with the weights evaluated:

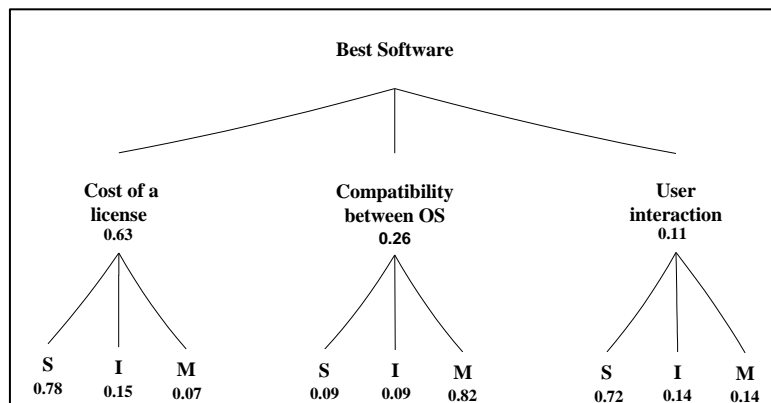

Figure 3: AHP hierarchical structure with the priority weights

The final priorities can be obtained in the following way:

$$Priority\ Weight\ of\ S = (0.78 \times 0.63) + (0.09 \times 0.26) + (0.72 \times 0.11) = 0.59 \tag{9}$$

$$Priority\ Weight\ of\ I = (0.15 \times 0.63) + (0.09 \times 0.26) + (0.14 \times 0.11) = 0.13 \tag{10}$$

$$Priority\ Weight\ of\ M = (0.07 \times 0.63) + (0.82 \times 0.26) + (0.14 \times 0.11) = 0.27 \tag{11}$$

The final result of this process is a ranking of the alternatives on a scale, allowing the decision maker to choose the best option, considering the comparisons made (see table 11).

Table 11: Final priority weights and ranking of the alternatives

SANEX	0.59	1°
IRIS	0.13	3°
MACBETH	0.27	2°

5. Conclusions and future research

Several authors maintain that decision-making is a vast and difficult problem: there are many types of decisions and numerous ways to deal with them. There are various methods and decision making processes, with each being unique in context and consequences. Thus there is no single model that fits all circumstances. Decision analysis presents rational methods to select an alternative (the best) or a group of alternatives from among a set of possible alternatives.

In this context, the use of a decision support methodology can be seen as a comprehensive approach since it considers the various factors surrounding the decision making process from the vantage point of the decision maker.

Most of the software referenced in this paper has characteristics of more than one category. We chose to put it in the category where the most prominent feature resides.

Some of the tools presented in section 3 of the paper are not available on the open market; others have a web page where one can download a free version for testing the product and learn of purchasing information.

When purchasing MCDA software, one needs not only to be concerned with the technology (i.e., hardware and software), but also with the role of the decision maker in the process and the ease of use of the tool. In this context we developed a simple software tool to help on the selection of the best MCDA software, among the ones available on the database.

In the future we intend to keep updating the software database as well as improving the tool with more flexibility in inserting data and include a new module to for sensitivity analysis, which is so important in this type of decision making, namely due to the uncertainty normally presented when decision makers have to assign weights to criteria or alternatives. So, it is very important to be able to investigate how the solution is influenced by the changing of weights assigned to criteria.

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