Using an Outranking Method Supporting the Acquisition of Military Equipment

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ABSTRACT

We overview the desirable features of a ranking and a selection methodology, taking several criteria into account. We show to what extent the class of PROMETHEE methods is presenting these features. We summarize the recommendations which were formulated a few years ago, in order to adapt these methods to their use for military equipment acquisition.

These adaptations are primarily related to the choice of the criteria hierarchy, the determination of weights, the transformation and rescaling functions, the indifference and preference thresholds and some other technical parameters.

Then we discuss the capabilities of the PROMETHEE methods to perform stability analysis of the ranking with respect to the weights and its relevance for the acquisition process of military equipment.

Finally we discuss the interpretation of the results given by these PROMETHEE methods.

INTRODUCTION

Outranking methods for multicriteria decision aid belong typically to the so-called European School of Multicriteria Decision Making (MCDM), which came into existence with the stimulating work of B. Roy ([13],[14],[15],[16]). The outranking approach is based on a fundamental partial comparability axiom where incomparability is a key concept ([5], p.80). In contrast with this approach there is the so-called American School in which Th. Saaty plays an important role with his “Analytical Hierarchy Process” (AHP Method) in which there is no place for incomparabilities [17]. In the European School we think that incomparabilities between alternatives to be ranked or to be selected, are a natural aspect of any MCDM problem, in which criteria evaluating the performance of these alternatives are conflicting – meaning that for instance two different criteria can have inversed preferences between couples of the same alternatives. If this happens on a large set of couples of criteria, then we claim that neglecting these conflicts, is leading to decisions which are often far from the original data of the MCDM problem. Although the final objective in practice is to decide about a ranking or about a selection of a subset of the alternatives, we claim that the decision maker should be supported by methods which are warning about the presence of incomparabilities. We even claim that it should be possible to assess the importance (the intensity) of these incomparibilities in order to fully inform the decision maker about it, before the final decision is made.

Many different methods belong to the outranking class. For overviews we refer to [5], [18] and [19]. For a detailed description of industrial applications with the oldest member (ELECTRE) of this class we refer to [11]. In this paper we will concentrate on the well-known PROMETHEE methods. In other contributions to the NATO SAS-080 Specialist Meeting (Brussels, 22-23 October 2009) we will focus on the ORESTE method ([10],[12]) which is complementary to the PROMETHEE methods. There are other methods belonging to the European School like MACBETH [1] which in SAS-080 is the subject of a keynote address by C. Bana e Costa.

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We overview the desirable features of a ranking and a selection methodology, taking several criteria into account. We show to what extent the class of PROMETHEE methods is presenting these features. We summarize the recommendations which were formulated a few years ago, in order to adapt these methods to their use for military equipment acquisition. These adaptations are primarily related to the choice of the criteria hierarchy, the determination of weights, the transformation and rescaling functions, the indifference and preference thresholds and some other technical parameters. Then we discuss the capabilities of the PROMETHEE methods to perform stability analysis of the ranking with respect to the weights and its relevance for the acquisition process of military equipment.

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The PROMETHEE methods are sufficiently well-known by System Analysis specialists, to skip in this paper all mathematical aspects. For details we refer to [4],[8] and [9]; for some more philosophical considerations see [3].

The PROMETHEE methods have been extensively used in the eighties and nineties of last century by teams of Belgian MoD equipment acquisition services. These (and other) MCDM methods are taught in the curriculum of the High Staff College for Military Administrators of the Belgian MoD. Currently personnel involved with equipment acquisition can use these methods on an individual basis. For other areas in Defence where these methods were used, we refer for instance to [6].

In this paper we concentrate on practical features of PROMETHEE, the typical use for military equipment acquisition, and we illustrate the discussion primarily by an implementation we called MCDMTool [7].

MILITARY EQUIPMENT ACQUISITION CRITERIA

Criteria to assess or evaluate military equipment to be acquired by the MoD are to a large extent the same as those used in logistics engineering and management. Therefore we refer to [2] (Appendix B) for a very detailed checklist of criteria, and to [2] (Appendix C) for a very detailed checklist of criteria for the evaluation of suppliers. In Figure 1 is shown an example of 10 alternative equipments assessed on a hierarchy of typical criteria.

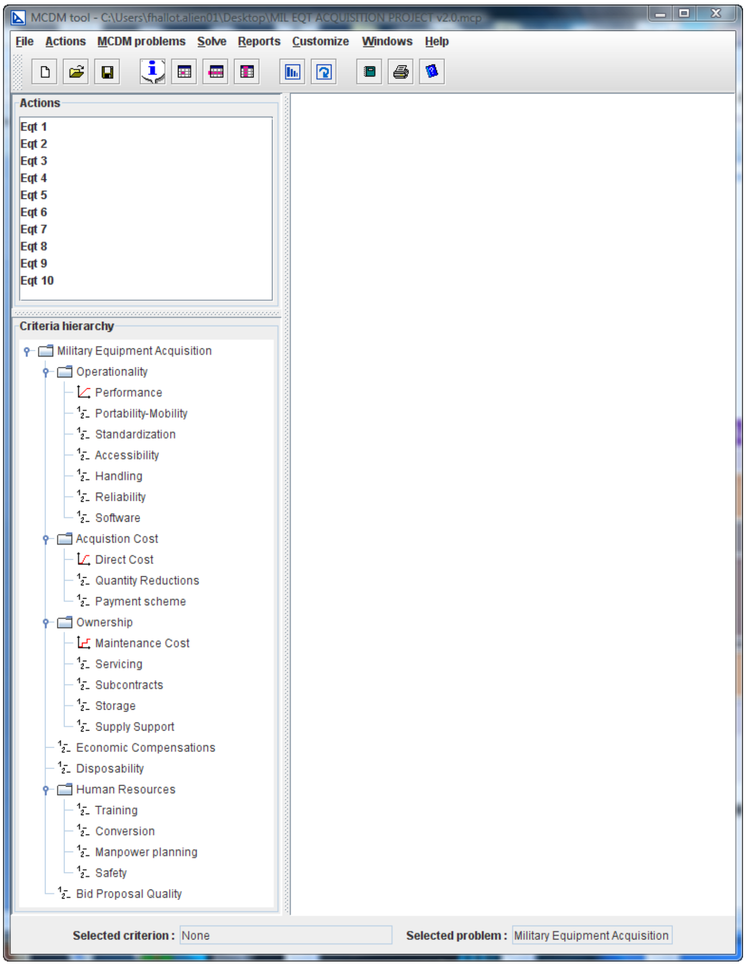


Figure 1: MCDMTool criteria hierarchy

DESIRED FEATURES OF AN MCDM METHOD

Cardinal assessments have to be fully exploited. Loss of information has to be avoided. Information about deviations of evaluations between alternatives for each criterion has to be used.

Scale effects due to different units in which different criteria are measured are to be eliminated in the calculations.

Pairwise comparisions between alternatives have to lead to partial ranking (with incomparabilities) or to complete ranking (without incomparabilities).

The method (and calculations) has to be transparent (as "simple" as possible) to the decision maker.

Technical parameters need to have an interpretation in world of the decision maker.

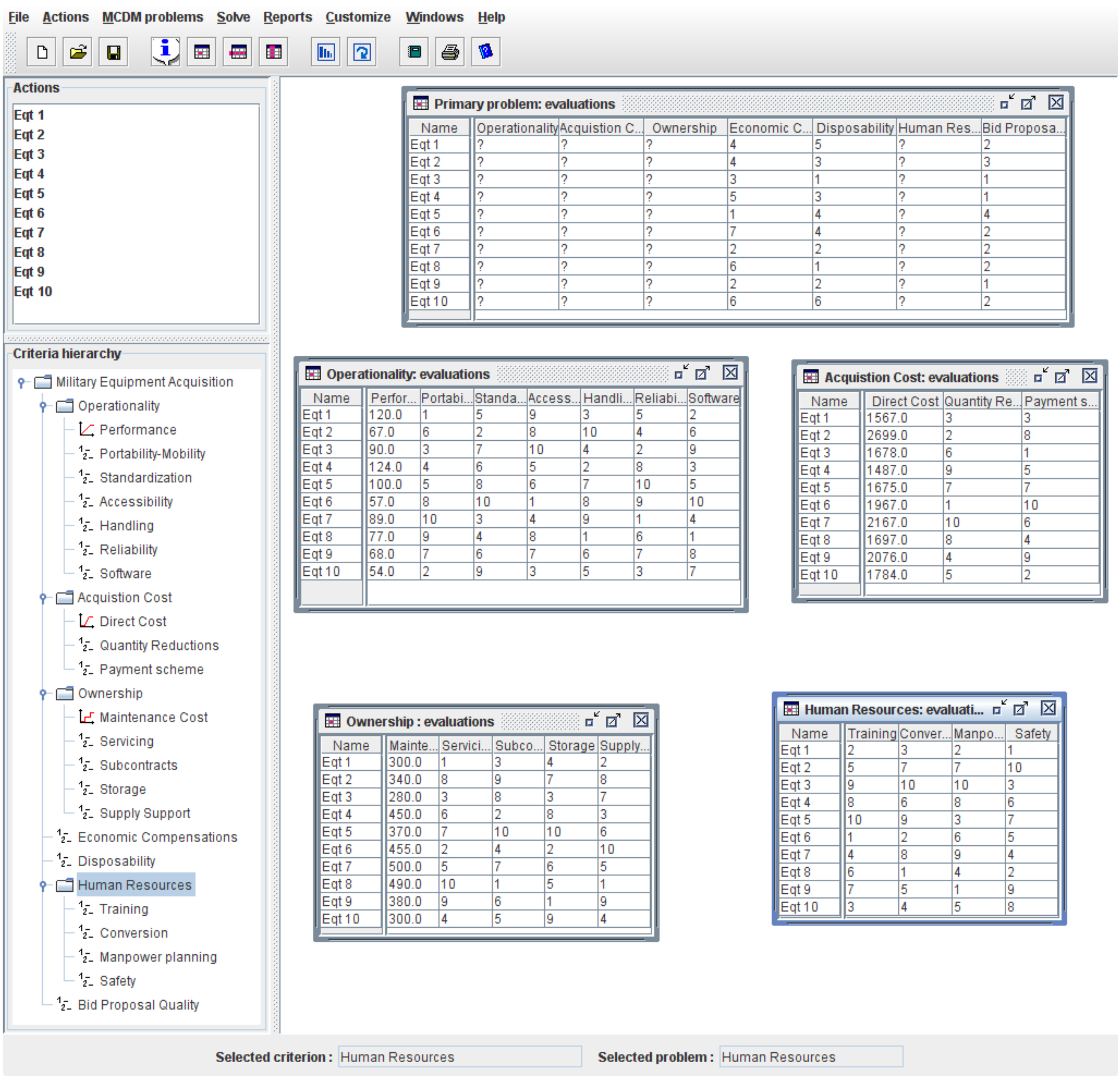
Weights allocated to criteria should have a clear role a straightforward interpretation in the data aggregation procedure of the MCDM method, leading to a ranking or a selection of alternatives.

Incomparability (conflict) analysis should be integrated in the method.

These features are all present in the PROMETHEE methods.

PROMETHEE INPUT

Here is an illustration with MCDMTool in Fig. 2 .



Primary problem: evaluations

Name	Operationality	Acquistion C...	Ownership	Economic C...	Disposability	Human Res...	Bid Proposa...
Eqt 1	?	?	?	4	5	?	2
Eqt 2	?	?	?	4	3	?	3
Eqt 3	?	?	?	3	1	?	1
Eqt 4	?	?	?	5	3	?	1
Eqt 5	?	?	?	1	4	?	4
Eqt 6	?	?	?	7	4	?	2
Eqt 7	?	?	?	2	2	?	2
Eqt 8	?	?	?	6	1	?	2
Eqt 9	?	?	?	2	2	?	1
Eqt 10	?	?	?	6	6	?	2

Operationality: evaluations

Name	Perfor...	Portabi...	Standa...	Access...	Handli...	Reliabi...	Software
Eqt 1	120.0	1	5	9	3	5	2
Eqt 2	67.0	6	2	8	10	4	6
Eqt 3	90.0	3	7	10	4	2	9
Eqt 4	124.0	4	6	5	2	8	3
Eqt 5	100.0	5	8	6	7	10	5
Eqt 6	57.0	8	10	1	8	9	10
Eqt 7	89.0	10	3	4	9	1	4
Eqt 8	77.0	9	4	8	1	6	1
Eqt 9	68.0	7	6	7	6	7	8
Eqt 10	54.0	2	9	3	5	3	7

Acquistion Cost: evaluations

Name	Direct Cost	Quantity Re...	Payment s...
Eqt 1	1567.0	3	3
Eqt 2	2699.0	2	8
Eqt 3	1678.0	6	1
Eqt 4	1487.0	9	5
Eqt 5	1675.0	7	7
Eqt 6	1967.0	1	10
Eqt 7	2167.0	10	6
Eqt 8	1697.0	8	4
Eqt 9	2076.0	4	9
Eqt 10	1784.0	5	2

Ownership : evaluations

Name	Mainte...	Servici...	Subco...	Storage	Supply...
Eqt 1	300.0	1	3	4	2
Eqt 2	340.0	8	9	7	8
Eqt 3	280.0	3	8	3	7
Eqt 4	450.0	6	2	8	3
Eqt 5	370.0	7	10	10	6
Eqt 6	455.0	2	4	2	10
Eqt 7	500.0	5	7	6	5
Eqt 8	490.0	10	1	5	1
Eqt 9	380.0	9	6	1	9
Eqt 10	300.0	4	5	9	4

Human Resources: evaluati...

Name	Training	Conver...	Manpo...	Safety
Eqt 1	2	3	2	1
Eqt 2	5	7	7	10
Eqt 3	9	10	10	3
Eqt 4	8	6	8	6
Eqt 5	10	9	3	7
Eqt 6	1	2	6	5
Eqt 7	4	8	9	4
Eqt 8	6	1	4	2
Eqt 9	7	5	1	9
Eqt 10	3	4	5	8

TRANSFORMATION FUNCTIONS

Transformation functions are used to transform deviations of cardinal evaluations on a (0,1)-interval. This avoids later scale effects in the calculations.

It is recommended to use continuous transformations for data known with a high degree of accuracy. This avoids unnecessary loss of information. For less accurately known data or data known with some degree of uncertainty, discontinuous level-type transformations are recommended.

Parameters are chosen in order to avoid loss of information on the one hand (preference threshold [4]) and in order to take into account uncertainty on the other hand (indifference threshold [4]).

Here are some examples illustrated with MCDMTool.

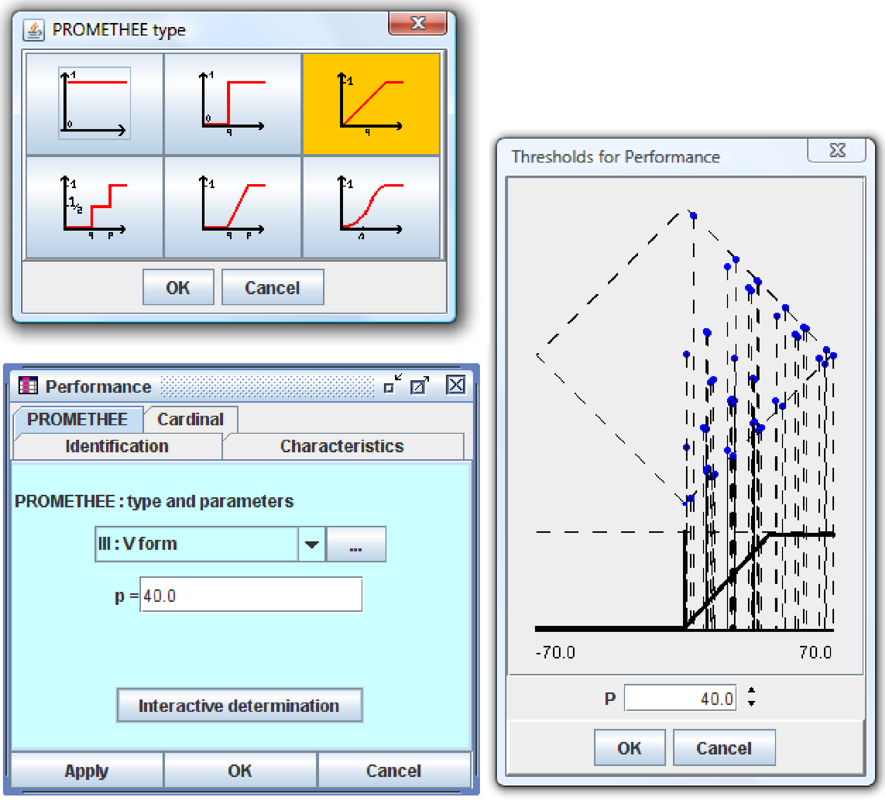


Figure 2: Performance transformation function

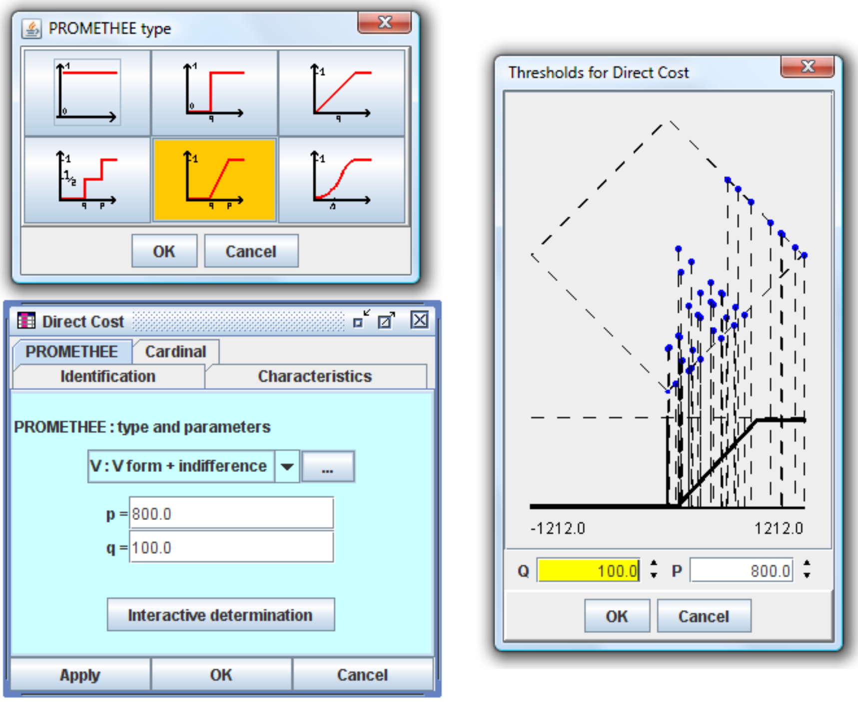


Figure 3: Direct Cost transformation function

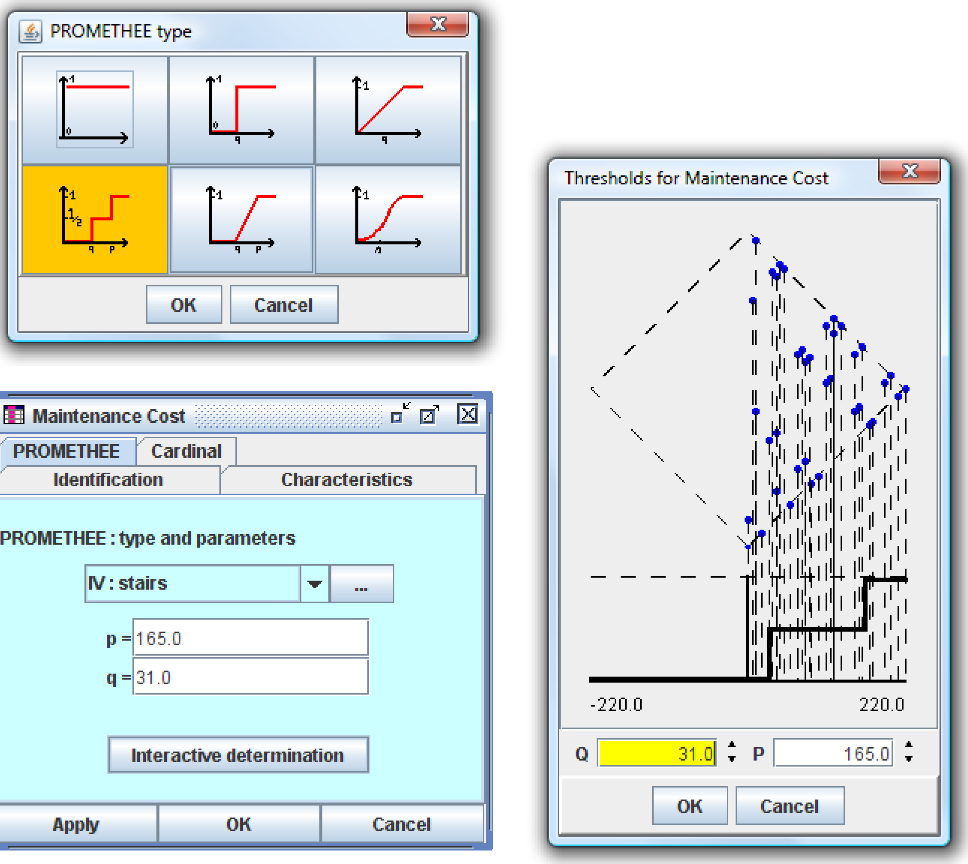


Figure 4: Maintenance Cost transformation function

WEIGHTS

After transformation of the deviation between the evaluations of couples of alternatives *a* and *b* on an interval (0,1) we obtain a preference indicator $P_j(a,b)$ for the criterion *j*. Then the aggregation of these preference indicators is computed by $\sum_j \omega_j P(a,b) = \pi(a,b)$ with $\omega_j = w_j / W$ and $W = \sum_j w_j$, w_j being the weight of criterion j. This is a very transparent linear additive aggregation scheme.

This is illustrated by the following figures from MCDMTool.

Military Equipment Acquisition : ranks & weights

Name	Rank	Weight
Operationality	1	20.0
Acquistion Cost	1	20.0
Ownership	1	20.0
Economic Compens...	1	10.0
Disposability	1	5.0
Human Resources	0	20.0
Bid Proposal Quality	1	1.0

Weights -> ranks | Ranks -> weights | Close

Operationality : ranks & weights

Name	Rank	Weight
Performance	1	10.0
Portability-Mobility	1	10.0
Standardization	1	10.0
Accessibility	1	5.0
Handling	1	5.0
Reliability	1	10.0
Software	1	5.0

Weights -> ra... | Ranks -> wei... | Close

Acquistion Cost : ranks & weights

Name	Rank	Weight
Direct Cost	1	20.0
Quantity Reductions	1	10.0
Payment scheme	1	1.0

Weights -> ra... | Ranks -> wei... | Close

Ownership : ranks & weights

Name	Rank	Weight
Maintenance Cost	1	20.0
Servicing	1	15.0
Subcontracts	1	10.0
Storage	1	10.0
Supply Support	1	1.0

Weights -> ra... | Ranks -> wei... | Close

Human Resources : ranks & weights

Name	Rank	Weight
Training	1	1.0
Conversion	3	1.0
Manpower planning	2	1.0
Safety	1	1.0

Weights -> ra... | Ranks -> wei... | Close

Figure 5: Weights

PROMETHEE II RESULTS

A complete ranking is obtained for each PROMETHEE sub-problem in the criteria hierarchy and for the acquisition project as a whole by computing for each alternative *a*

$$\phi(a) = \phi^+(a) - \phi^-(a) \text{ with } \phi^+(a) = \frac{1}{n-1}\sum_{x \in A-a} \pi(a,x) \text{ and } \phi^-(a) = \frac{1}{n-1}\sum_{x \in A-a} \pi(x,a)$$

where *A* is the set of all alternatives an *n* its cardinality.

The alternatives are then ranked in decreasing order of $\phi(a)$.

This is illustrated in Figure 7 with MCDMTool.

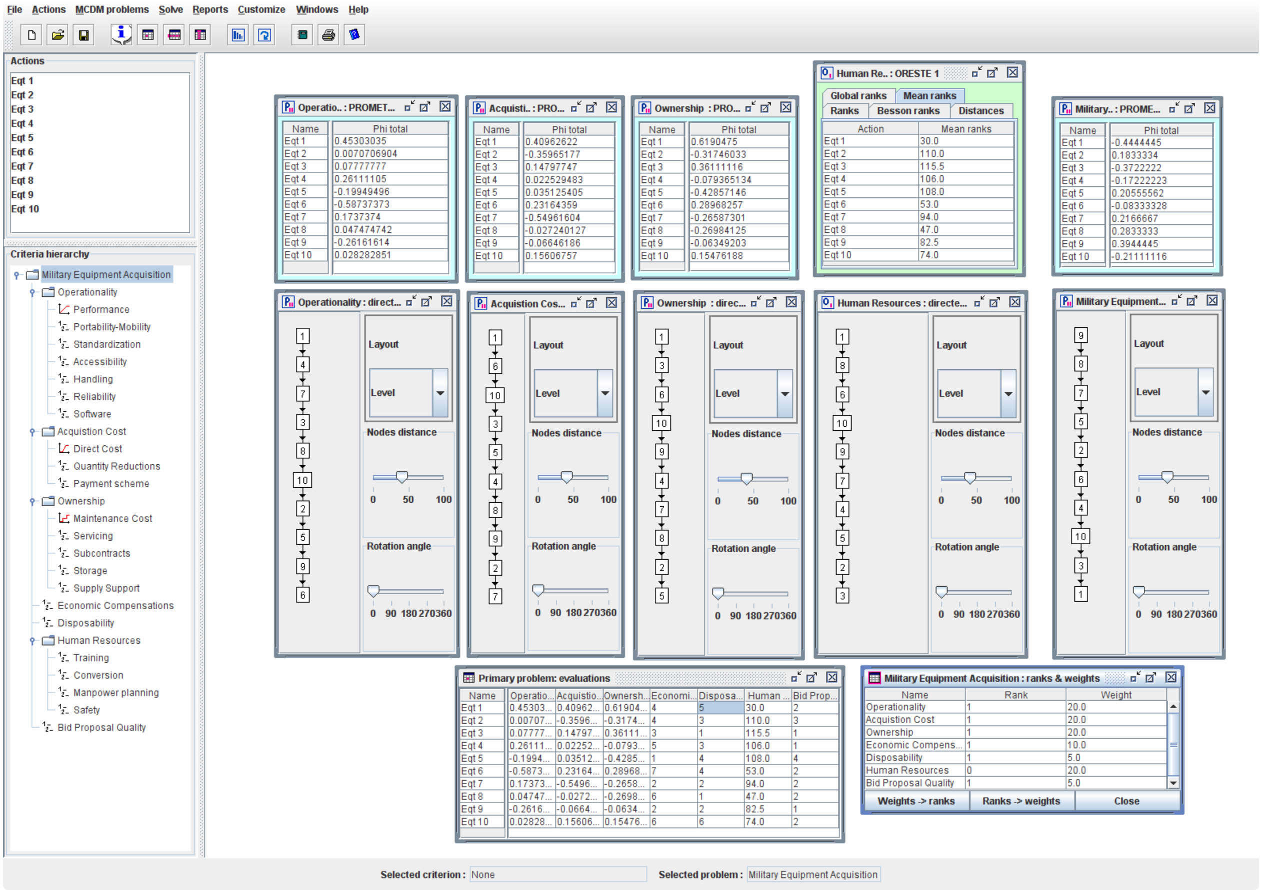


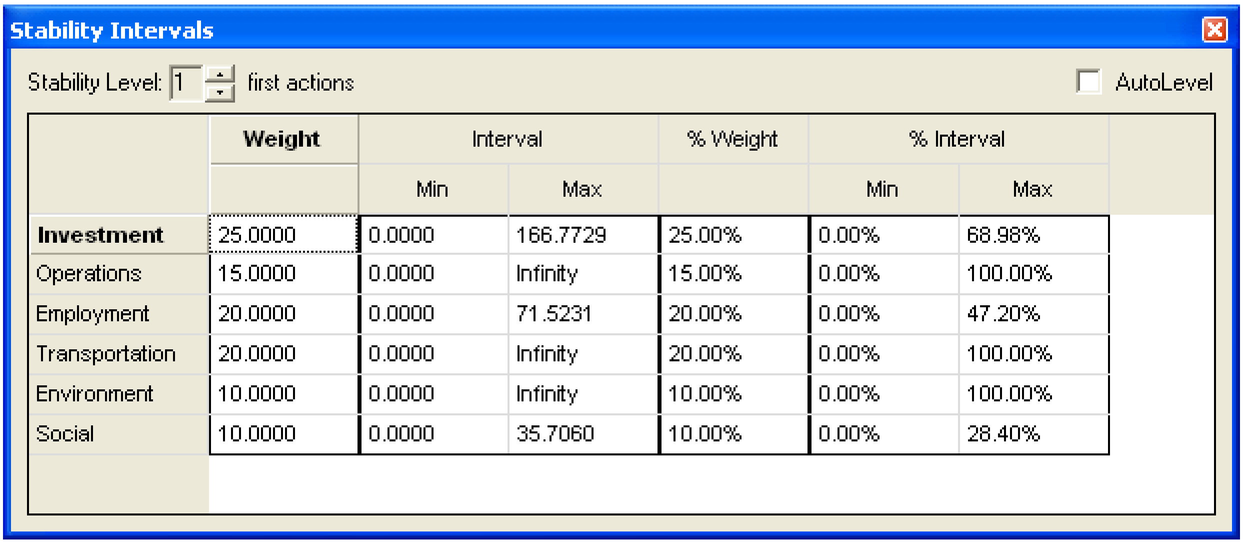
Figure 6: PROMETHEE II ranking

WEIGHT STABILITY ANALYSIS

Due to the linearity of the aggregation scheme with respect to the weights, the stability analysis vis-à-vis the weights is highly facilitated. We refer to the fundamental discussion of this aspect of the outranking methods in general and of PROMETHEE in particular in [8]. This has been implemented in the software Decision Lab 2000 [20] in which there are also some additional graphical representations based on [9] which can be helpful to understand the sensitivity of the final results depending on the weights. This is an important issue in the final discussion of the results of the MCDM analysis before taking a decision in the ranking or selection of some military equipment. The stability of the results as a function of the weights is of course measuring also the credibility of the decision which will be based on these results. This is very important in an organisation where all members on various levels will live with the solution which is chosen.

It should also be noticed that instead of the a posteriori weight stability analysis in PROMETHEE, we implemented in MCDMTool a fully interactive module which serves to determine a priori weights of criteria by pairwise comparison of the importance of the criteria, and to compute the weights compatible with these pairwise assessments, through an eigenvalue method similar to the computations which are performed in the background of the AHP method of Saaty [17]. Both the a priori and the a posteriori module for the discussion of the weights might be interesting to be integrated in the same software.

This stability analysis is illustrated by Figure 8 with the use of Decision Lab 2000.



Stability Intervals

Stability Level: 1 first actions AutoLevel

	Weight	Interval		% Weight	% Interval	
		Min	Max		Min	Max
Investment	25.0000	0.0000	166.7729	25.00%	0.00%	68.98%
Operations	15.0000	0.0000	Infinity	15.00%	0.00%	100.00%
Employment	20.0000	0.0000	71.5231	20.00%	0.00%	47.20%
Transportation	20.0000	0.0000	Infinity	20.00%	0.00%	100.00%
Environment	10.0000	0.0000	Infinity	10.00%	0.00%	100.00%
Social	10.0000	0.0000	35.7060	10.00%	0.00%	28.40%

Figure 8 : Weight stability intervals

CONCLUSION

The PROMETHEE II method is featuring all the desired qualities of an MCDM outranking method. As a consequence it is appropriate to use it in the context of acquisition of military equipment.

For the discussion of the conflict analysis and the incomparability analysis we refer to the SAS-080 contribution on “Assessing and visualizing incomparabilities by using an outranking method supporting the acquisition of military equipment”.

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