A note on the use of PROMETHEE multicriteria methods

Article *in* European Journal of Operational Research · March 1996

Impact Factor: 2.36 · DOI: 10.1016/0377-2217(94)00307-6 · Source: RePEc

2 authors, including:

Wim De Keyser
Sia - Belgium
14 PUBLICATIONS **119** CITATIONS

ELSEVIER

European Journal of Operational Research 89 (1996) 457–461

EUROPEAN JOURNAL OF OPERATIONAL RESEARCH

Theory and Methodology

A note on the use of PROMETHEE multicriteria methods

Wim De Keyser, Peter Peeters *

Vrije Universiteit Brussel, BEIF, Pleinlaan 2, B-1050 Brussels, Belgium

Received October 1993; revised March 1994

Abstract

The PROMETHEE methods are rather popular in the world of outranking methods. One of the reasons for this popularity is the existence of the very userfriendly software, called PROMCALC–PROMethee CALCulation. More and more practitioners are using PROMCALC to handle their multiple criteria problems. However, not all users are aware of the consequences of the model assumptions made in PROMETHEE methods. A short overview of some drawbacks of PROMETHEE methods that users must know and avoid are described in this paper.

Keywords: Multiple criteria; Outranking method

1. Introduction

PROMETHEE methods have taken an important place among the existing outranking multiple criteria methods. The number of practitioners which are applying these methods to practical multiple criteria decision problems, and researchers who are further developing and/or are interested in sensitivity aspects of these methods, increases year by year as can be illustrated by the increasing number of papers (see references) and conference presentations using one or more of the PROMETHEE methods.

The more a method is used, the more credit and the less doubts it gets. Nevertheless every method has its restrictions, mostly due to model assumptions, which should always be considered when the method is used.

The observation that most practitioners and students do not hesitate to apply PROMETHEE methods on almost any multiple criteria problem, encouraged the authors to formulate some of the drawbacks of these methods, even though most academic researchers in the field of multiple criteria methods are well aware of these drawbacks.

Several consequences of the model assumptions of the PROMETHEE methods are formulated in Section 2. In Section 3, the behaviour of the PROMETHEE methods is discussed when an action is added or deleted. The last section contains the conclusions of this paper.

2. Consequences of model assumptions of PROMETHEE methods

2.1. PROMETHEE methods may only be applied if the decision maker can express his preference between two actions on a given criterion on a ratio scale

The preference function f_j for a criterion j returns, for a difference d between two evalua-

* Corresponding author.

SSDI 0377-2217(94)00307-6

tions on that criterion, a value $f_j(d) \in [0,1]$. This value is a real value on a ratio scale. As a consequence of this, the decision maker must be able to express the magnitude of his preference between actions on a criterion accurately, by according *real* values – in the interval [0,1] – to the differences between evaluations on that criterion.

2.2. PROMETHEE methods may only be applied if the decision maker can express the importance he attaches to the criteria on a ratio scale

PROMETHEE methods need quantifiable criterion importances – weights – on a ratio scale. Therefore a decision maker must be able to supply such quantitative criterion importances with the necessary accurateness. The decision maker must furthermore be aware that a criterion with, e.g. weight 1.8 is twice as important as a criterion with weight 0.9, in order to calculate a value which expresses the outranking relation.

2.3. The weights of the criteria express trade-offs between the criteria

The weights, as defined and used in PROMETHEE methods, indicate trade-offs between the criteria. Let criterion i and criterion j have respectively a weight of λ_i and of λ_j. This means the decision maker is prepared to exchange a decrease of Δ_i on the value of the preference function of criterion i for an increase of $(\Delta_i \cdot \lambda_i)/\lambda_j$ on the value of the preference function of criterion j. The decision maker must agree with this model of his preference structure.

2.4. PROMETHEE methods may only be used with criteria where the differences between evaluations are meaningful

A preference function, as defined in PROMETHEE methods, is turning a difference between two evaluations on a criterion into a real value – between 0 and 1. This forms no problem for criteria with interval or ratio scale. For criteria with an ordinal (or nominal) scale, the difference has mathematically speaking no meaning. Such criteria cannot be used in PROMETHEE methods, except for the special case of a criterion with an ordinal scale where the preference of the decision maker is such that he prefers the best of two different evaluations with a preference function value of 1. This must be done by a cardinalisation of the evaluations in combination with the use of the type I preference function.

If one does not pay attention to this aspect of the PROMETHEE methods, one can fall into the trap of transforming values on an ordinal scale into values on a ratio scale.

2.5. It is not possible to take discordance into account when constructing the outrank relations of PROMETHEE methods

Discordance is however considered as a realistic concept in multiple criteria decision aid and is considered as one of the reasons for developing outranking methods (see Vincke, 1992).

The partial PROMETHEE I preorder (P^I, I^I, R) is transitive, which is a consequence of the absence of discordance. Since the partial preorder should model/reflect the preference of the decision maker towards the different actions, transitivity cannot always be taken for granted.

3. Adding or deleting an action

The partial PROMETHEE I preorder and the complete PROMETHEE II preorder are based on an all-to-all comparison between the actions; adding or deleting an action can put these preorders upside down: The outrank relation between two actions can switch (see 3.1) and/or the result of exploring the outranking relations between the actions can be affected (see 3.2).

3.1. The relative position in the preorder between two actions can change by adding or deleting an action

Action A_i comes before action A_j in the preorder means that the decision maker prefers action A_i above action A_j. The *preference of a decision maker between two actions* must in the authors' opinion only be based on those two

Table 1
Data for example 1

Criterion	C1: Criterion 1	C2: Criterion 2	C3: Criterion 3
Min/Max	Max	Max	Max
Type	2 ($q = 10$)	2 ($q = 100$)	3 ($p = 50$)
Weight	1	1	1
A1: Action 1	90	800	401
A2: Action 2	88	905	399
A3: Action 3	99	855	400

actions and may not depend on the presence or absence of other actions. One can agree on the fact that the preference of a decision maker between two actions can change when an other action is added or deleted but *only* if this addition/deletion implies a change in the data of the problem (such as additional criteria, chanced evaluations on one or more criteria, changed weights, etc.). The authors cannot agree on the fact that the decision maker's preference between two actions is changed, as will be shown in an example, when only an other action is deleted – or added.

3.2. Adding or deleting an action which is, e.g. dominated by all other actions or which is, e.g. equal to another action does not only change the PROMETHEE preorders but can also influence the final decision

Adding or deleting an action can change the final preorder. This seems reasonable when 'the best action' is deleted or 'a better action' is added. But it is unreasonable when the added or deleted action is dominated by all other actions or when the action is equal to an other action.

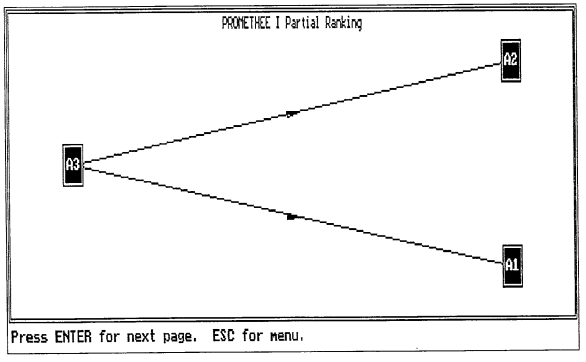

Fig. 1. PROMETHEE I graph for actions A1, A2 and A3.

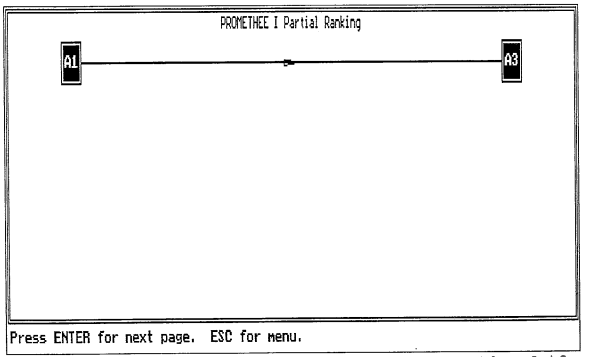

Fig. 2. PROMETHEE I graph for actions A1 and A3.

3.3. Example

It is easy to construct an example to illustrate both remarks; see Table 1. The PROMETHEE I graph is shown in Fig. 1. After deleting action A2, the PROMETHEE I graph becomes as shown in Fig. 2.

The example shows that if three actions are considered, the decision maker prefers A3 above A1, but if he only considers the actions A1 and A3, his preference between these two actions changes completely.

Consider the above example (three actions A1, A2 and A3; three criteria C1, C2 and C3). When an action A4, with the following values for the three criteria: (77, 800, 399), is added, the final PROMETHEE I decision, which was taking action A3, changes into the final PROMETHEE I decision of taking either action A3 or action A2!

We also like to remark that when a multiple criteria problem contains only two actions, there can never be an incomparability between these two actions in the PROMETHEE I ranking. So incomparability between two actions depends also on the presence/absence of other actions.

4. Conclusions

PROMETHEE methods may be applied when the following considerations are taken into account:

– The decision maker can express his preferences between two actions on all the criteria on ratio scales.

– The decision maker can express the importance he attaches to the criteria on a ratio scale.

– The decision maker wants to take all criteria into account and is aware of the fact that the weights are representing trade-offs.

– For all criteria the difference between evaluations must be meaningful.

– None of the possible differences on any of the criteria can give rise to discordance.

– The decision maker knows exactly what can happen if one or more actions are added or deleted and is fully aware of the influences on the final decision.

We hope, by underlining the above remarks on PROMETHEE methods, to stimulate the users to applying PROMETHEE methods on problems of which data and preference structure of the involved decision maker comply with the requirements and model assumptions of PROMETHEE methods.

References

Bana e Costa, C. (1990), *Readings in Multiple Criteria Decision Aid*, Springer-Verlag, Berlin.

Bouyssou, D. (1992), "Ranking methods for valued preference relations: A characterization of the net flow method," *European Journal of Operational Research* 60, 61–67.

Bouyssou, D., and Perny, P. (1992), "Ranking methods for valued preference relations: A characterization of a method based on leaving and entering flows", *European Journal of Operational Research* 61, 186–194.

Brans, J.P. (1982), "L'Ingéniérie de la décision. Elaboration d'instrument d'aide à la décision. Méthode PROMETHEE", Colloque d'Aide à la Décision, Université Laval Québec, Canada, 183–213.

Brans, J.P. (1990), "PROMETHEE V: MCDM problems with segmentation constraints", Internal Report CSOOTW/250, Vrije Universiteit Brussel.

Brans, J.P., and Mareschal, B. (1989a), "The PROMETHEE methods for MCDM, PROMCALC, GAIA and BANKADVISER software", Internal Report CSOOTW/224, Vrije Universiteit Brussel.

Brans, J.P., and Mareschal, B. (1989b), "BANK ADVISER: An industrial evaluation system", Internal Report CSOOTW/239, Vrije Universiteit Brussel.

Brans, J.P., and Mareschal, B. (1989c), "PROMETHEE-GAIA: Visual interactive modelling for multicriteria location problems", Internal Report CSOOTW/244, Vrije Universiteit Brussel.

Brans, J.P., and Mareschal, B. (1992), "How to discriminate hard and soft multicriteria problems in the discrete case (the PROMETHEE VI procedure)", Internal Report CSOOTW/257, Vrije Universiteit Brussel.

Brans, J.P., and Vincke, Ph. (1985), "A preference ranking organization method. The PROMETHEE method for MCDM," *Management Science* 31/6, 647–656.

Brans, J.P., Mareschal, B., and Vincke, Ph. (1984), "PROMETHEE: A new family of outranking methods in multicriteria analysis", in: J.P. Brans (ed.), *Operational Research '84*, North-Holland, Amsterdam, 477–490.

Brans, J.P., Mareschal, B., and Vincke, Ph. (1986), "How to select and how to rank projects: The PROMETHEE method", *European Journal of Operational Research* 24, 228–238.

Briggs, Th., Kunsch, P.L., and Mareschal, B. (1990), "Nuclear waste management: An application of the multicriteria PROMETHEE methods", *European Journal of Operational Research* 44, 1–10.

D'Avignon, G.R., and Mareschal, B. (1989), "Specialisation of hospital services in Québec: An application of the PROMETHEE and GAIA methods", Mathematical and Computer Modelling 12, 1393–1400.

Du Bois, Ph., Brans, J.P., Cantraine, F., and Mareschal, B. (1989), "MEDICIS: An expert system for computer-aided diagnosis using the PROMETHEE method", *European Journal of Operational Research* 39, 284–292.

Hens, L., Pastijn, H., and Struys, W. (1992), "Multicriteria analysis of the burden sharing in the European Community", *European Journal of Operational Research* 59, 248–261.

Karkazis, J. (1989), "Facilities location in a competitive environment: A Promethee based multiple criteria analysis", *European Journal of Operational Research* 42, 294–304.

Mareschal, B. (1988), "Weight stability intervals in multicriteria decision aid", *European Journal of Operational Research* 33, 54–64.

Mareschal, B. (1989), "Aide à la décision multicritère: Développement théoriques et applications", *Cahiers du Centre d'Études de Recherche Opérationelle* 31, 13–120.

Mareschal, B., and Brans, J.P. (1988), "Geometrical representation for MCDA", *European Journal of Operational Research* 34, 69–77.

Mareschal, B., and Brans, J.P. (1991), "BANKADVISER: An industrial evaluation system", *European Journal of Operational Research* 54, 318–324.

Mareschal, B., and Mertens, D. (1990), "Evaluation financiére par la méthode GAIA: Application au secteur bancaire belge", Revue de la Banque 6/90, 317–329.

Mladineo, N., Margeta, J., Brans, J.P., and Mareschal, B. (1987), "Multicriteria ranking of alternative locations for small scale hydro plants", *European Journal of Operational Research* 31, 215–222.

Mladineo, N., Lozić, I., Stošić, S., Mlinarić, D., and Radica, T. (1992), "An evaluation of multicriteria analysis for DSS in

public policy decision", *European Journal of Operational Research* 61, 219–229.

Petrovic, R., Senborn, A., and Vujosević, M. (1988), "Multicriteria ranking of spares allocations", *Naval Research Logistics Quarterly* 35, 697–705.

Ribarović, Z., and Mladineo, N. (1987), "Application of multicriterional analysis to the ranking and evaluation of the investment programmes in the ready mixed concrete industry", *Engineering Costs and Production Economics* 12, 367–374.

Roy, B., and Bouyssou, D. (1993), *Aide Multicritère à la Décision: Méthodes et Cas*, Economica, Paris.

Schärlig, A. (1985), Décider sur Plusieurs Critères. Panorama de l'Aide à la Decision Multicritère, Presses Polytechniques Romandes, Lausanne.

Stevens, S. (1946), "On the theory of scales of measurements", *Science* 103, 677–680.

Struys, W., and Pastijn, H. (1988), "The recourse to several criteria in determining a fair burden sharing within an alliance: The case of NATO", in: G.K. Rand (ed.), *Operational Research '87*, North-Holland, Amsterdam, 566–581.

Vincke, Ph. (1986), "Analysis of multicriteria decision aid in Europe. Invited Review", *European Journal of Operational Research* 25, 160–168.

Vincke, Ph. (1992), *Multicriteria Decision – Aid*, Wiley, New York.

Vuk, D., Koželj, B., and Mladineo, N. (1991), "Application of multicriterional analysis on the selection of the location for disposal of communal waste", *European Journal of Operational Research* 55, 211–217.