

Multi-attribute value theory (MAVT)

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Multiple–attribute value theory (MAVT)

Marjan van Herwijnen (marjan.van.herwijnen@ivm.falw.vu.nl)

1 Introduction

Multiple–attribute value theory (MAVT) can be used to address problems that involve a finite and discrete set of alternative policies that have to be evaluated on the basis of conflicting objectives[1]. For any given objective, one or more different attributes or criteria are used to measure the performance in relation to that objective. These aspects, the impacts of all alternative options for all attributes, are presented in a so–called evaluation table. These attributes are usually measured on different measurement scales.

A closely related theory to MAVT is multiple–attribute utility theory (MAUT). MAUT is based upon expected utility theory (von Winterfeldt and Edwards, 1986; French, 1988) and requires stronger assumptions to ensure additivity. The advantage of MAUT is that it can take uncertainty into account and represent it directly into its decision support model. MAUT is also called the strong form of decision making and MAVT the weak form. However, MAUT is very difficult to apply and no real applications are known. Therefore we only focuss here on MAVT.

Multiple–attribute value theory (MAVT) is a compensatory technique. This means that the method does allow compensation of weak performance of one criterion by a good performance of another criterion. MAVT aggregates the options' performance across all the criteria to form an overall assessment.

2 Methodology

The intention of MAVT is to construct a means of associating a real number with each alternative, in order to produce a preference order on the alternatives consistent with decision maker value judgements. To do this, MAVT assumes that in every decision problem a real value function U exists that represents the preferences of the decision maker. This function U is used to transform the attributes of each alternative policy into one single value. The alternative with the best value is pointed out as the best.

3 Process

The process to be followed to carry out MAVT consists of the following four steps:

1. Definition of alternatives: identify the policy alternatives which are to be compared with each other.
2. Selection and definition of criteria: identify the effects or indicators relevant for the decision.
3. Assessment of scores for each alternative in terms of each criterion: assign values to each effect or indicator for all alternatives.
4. Ranking of the alternative: a total score is calculated for each alternative by applying a value function U to all criteria's scores.

The first three steps are the same as in most MCA methods. Step 4 is specific for MAVT. MAVT is based on the assumption that in every decision problem a real value function U exists that represents the preferences of the decision maker. This function aggregates for each alternative a_j ($j=1..M$) the criteria c_i ($i=1..N$) that are under consideration by the decision maker. The problem using the general form of the function U can be formulated as:

The best alternative is alternative a for which (1)

$$U(c_1(a), c_2(a), \dots, c_n(a)) = \max_{j=1..M} U(c_1(a_j), c_2(a_j), \dots, c_n(a_j))$$

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The function U has to be determined in order to get the best alternative, which is a rather difficult and time-consuming procedure. The decision rule within MAVT is a complete compensatory rule, i.e. the good criteria can balance out the bad ones completely. Note that if environmental and economic criteria are taken into consideration, complete compensation could implicitly mean complete substitution between man-made capital and natural capital (Munda, 1995).

The theoretical concepts of MAVT were described by Fishburn (1967) and Keeney and Raiffa (1976). Different techniques to assess a general value function U can also be found in Winterfeldt and Edwards (1986) and French (1988). The simplest form of the value function U is the additive form. In the additive form, the function U can be split up into different functions U_i , which are strictly increasing real functions. The function U can then be retrieved by adding the sub-functions U_i . In this way, every criterion has its own value function, which simplifies the assessment procedure for the function U . The problem using the additive form can be formulated as:

The best alternative is alternative n for which
$$\sum_{i=1}^m U_i(x_{in}) > \sum_{i=1}^m U_i(x_{jn}) \quad (2)$$

$$\sum_{i=1}^m U_i(x_{in}) > \sum_{i=1}^m U_i(x_{jn})$$

The functions U_i in the *additive form* of the MAVT can be used to transform the different measurement scales of the criteria to an identical scale and are also called partial value functions. This form, however, will only be appropriate if the decision-maker's preference structure satisfies the mutual preference independence condition. A pair of attributes is said to be preference independent of all the other attributes if preferences between different combinations of levels of these two attributes, with all other attributes being held at constant values, do not depend on what those constant values are. The whole set of attributes is said to show mutual preference independence if all pairs of attributes are preference independent of all the others.

MAVT tries to deal with the real world complexity by allowing attributes to interact with each other in other than a simple, additive fashion. Unlike the simplified additive form it does not assume mutual independence of preferences. Interaction can be built in the value function model.

Well known and often used MAVT methods are Weighted Summation and Analytic hierarchy process (AHP).

4 Review

4.1 Evaluation of results

MAVT is theoretically well established and the simple additive form can be easily explained, and is easy to use. The more complex forms of MAVT however are difficult to carry out and experts are needed to apply the methods. MAVT is suitable to be applied in participatory processes.

The simple additive form of MAVT has been used to support the evaluation of a large number of problems all over the world (see Weighted Summation). Applications of the more complex form of MAVT are rare, probably due to the complexity of composing a value function that matches the problem at hand.

Policy processes

MAVT is a useful tool to support the selection of a policy option. In its easier versions it may be used in a relatively cheap and quick way. Its main advantage is that it is well axiomatized and it can use the expertise accumulated in Cost-benefit Analysis, whose evaluation are also based in the utility functions and welfare economics.

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Sustainable development aspects

MAVT can be used to assess the sustainability of a policy because it allows to simultaneously take into account indicators that refers to the three dimensions of sustainability: the economic, the social and the economic one. In other words, it can be used to combine information in such a way that it can clarify sustainable development aspects. However, as it is a compensatory method, MAVT entails the evaluation process under weak sustainability assumptions.

MAVT can incorporate the following SD aspects as separate criteria to compare alternative policies: (de-)coupling aspects, adaptability and (ir-)reversibility. MAVT is suitable to compare impacts independently of the gauge year. MAVT can incorporate the impacts on different groups/sectors/regions as separate categories and give a clear overview of the differences for these sectors. MAVT is suitable to compare impacts independently of the spatial dimension, as long as the spatial dimensions of the separate criteria are comparable. And finally, the simplified additive MAVT can be applied to spatial data (Sharifi and Herwijnen 2002, Herwijnen 1999).

Operational aspects

It is very difficult, if not impossible, to provide an accurate estimate on the costs for applying MAVT. However, as a very rough approximation these can be expected now to mount about 15000 euro. This is measured without gathering data. The costs for gathering data totally depend on the type of problem and cannot be estimated here. About 2 months is needed to apply MAVT on the data gathered. One week to structure the problem and the remaining time to compose a value function that can be used to transform the data. Because ideally gathering data can only be done after the problem is structured, the time needed for an assessment is much longer and totally depends on the time needed to gather the data (estimation: between 1 and 12 months).

Furthermore, a large amount of data is needed to estimate the impacts. If quantitative data are not available, expert judgement can be used to estimate the impacts on a qualitative scale. MAVT can handle quantitative as well as qualitative data.

The main results of MAVT are a rank order of policy options and a better understanding of the problem at hand. The complex format of MAVT is not easy to grasp and therefore the transparency of the tool is limited. Experts are needed to support the process of structuring the problem and to compose the value function. Several computer programs for MAVT intend to increase the user-friendliness of the tools as well as its reliability. Most of these software programs can also support the analysis of uncertainty of the scores, weights and/or value function(s).

The marginality of effects of different policy options can be identified because MAVT compares each policy alternative with other alternatives and/or the current situation and assesses to which extent such effects are significant.

Because the criteria are defined by the user and depend on the problem, MAVT can be used on different countries, geographic levels and levels of aggregation. One condition however is that the criteria should be defined on comparable countries, geographic levels and levels of aggregation.

MAVT has no mandatory use.

The time the results become outdated depends totally on the input data and the context of application, so this cannot be established. MAVT looks at impacts of one selected year, which year is up to the user.

Because the criteria are defined by the user and depend on the problem, MAVT is independent of country, geographic level and level of aggregation. One condition however is that the criteria should be defined on comparable countries, geographic levels and levels of aggregation.

4.2 Experiences

The Keeney and Raiffa approach of the multiple attribute value theory (MAVT) to decision support has been applied to many real decisions, in both the private and public sectors (Munda, 2005). Although well-regarded and effective, the non-additive form it is relatively complex and best implemented by specialists on major projects where time and expertise are both necessary and available.

What makes the Keeney and Raiffa model potentially demanding to apply is firstly that it takes uncertainty formally into account, building it directly into the decision support models and secondly that it allows attributes to interact with each other in other than a simple, additive fashion. It does not assume mutual independence of preferences. In this way, the analysis becomes more realistic (it represents better the way the human decision-making works), but also more complicated, so that in most cases MAVT is used in its additive form, in order to allow a simpler and more transparent decision support, which can be implemented more quickly, by a wider range of users and for a larger set of problem types (Keeney & Raiffa 1976). The simplified additive form of MAVT has been applied many times (ODPM 2004, Beinart and Nijkamp 1998).

4.3 Combinations

MAVT in general can be included in the same packages of tools as Weighted Summation and the simplified additive form of MAVT. Experiences on this can be found there. But experiences with the more complex form of MAVT as part of a package of tools are rare.

MAVT can be used to support the evaluation of alternative policies/plans/-projects in SIA and Strategic Environmental Assessment.

4.4 Strengths and weaknesses

Strengths

- MAVT helps in structuring a problem. By classifying the problem in various objectives, criteria to measure the objectives and alternative options to solve the problem MAVT provides a structured approach for dealing with the problem. MAVT also accommodates various types of information: quantitative as well as qualitative.
- MAVT enhances the understanding of the policy problem by forcing the decision maker and/or decision analyst to compose a value function that represents their preferences. This means that MAVT reduces the amount of information in order to improve its comprehensibility.
- Furthermore, MAVT provides a means of communication for reasoning and negotiations by clarifying the strengths and weaknesses of the alternative policies and by the possibility to clearly visualize and communicate the intermediate and final results.
- Moreover, MAVT can incorporate the diverse views of stakeholder groups to construct the criteria tree, to develop alternative options/solutions for the problem and to compose the value function.
- To apply an effective MAVT good supporting software is essential (Belton and Stewart 2002). Much software is available to apply the additive form of MAVT, weighted summation (see for example Janssen et al. 2001). An advantage of using software is the ease to test the robustness of the results using sensitivity analyses.

Weaknesses

- The main weakness of MAVT is that it assumes full compensability of criteria, that is, the criteria are all reduced and expressed in the same unit (in this case through value functions). This implies that a bad performance on a criterion (for example a high environmental impact) can be compensated a good performance on another (for example a high income). This feature makes MAVT an adequate instrument to operationalize the concept of weak sustainability, but not the idea of strong sustainability.

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- The composition of non-additive value function in MAVT is a very difficult task, especially if the number of criteria involved is large and they are very different in character. A decision analyst is needed to support the decision-makers to carry out this task.
- The mutual independence preference condition is often difficult to met and in many cases simply ignored when applying the additive form of MAVT.

4.5 Further work

Applications of the non-additive form of MAVT are not found. Examples within the EU context are also not found yet. These are necessary to demonstrate the use for the EU. As holds for every MCA, MAVT compares different alternative options. Therefore different alternative policy options are needed in a EU context and that is often not the case. This aspect has to be worked out further. A first step has been made in the impact assessment guidelines developed by the EU (SEC, 2005) who advice to consider alternative policy options instead of only one.

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