Analytic hierarchy process (AHP)

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The Analytic Hierarchy Process (AHP)

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1 Introduction

The Analytic Hierarchy Process (AHP) has been developed by T. Saaty (1977, 1980, 1988, 1995) and is one of the best known and most widely used MCA approaches. It allows users to assess the relative weight of multiple criteria or multiple options against given criteria in an intuitive manner. In case quantitative ratings are not available, policy makers or assessors can still recognize whether one criterion is more important than another. Therefore, pairwise comparisons are appealing to users. Saaty established a consistent way of converting such pairwise comparisons (X is more important than Y) into a set of numbers representing the relative priority of each of the criteria.

2 Methodology

The AHP, as a compensatory method, assumes complete aggregation among criteria and develops a linear additive model. The weights and scores are achieved basically by pairwise comparisons between all options with each other (ODPM, 2004).

Note that AHP, as all MAVT methods, can only be applied when the mutual preferential independence axiom applies.[2]

3 Process

The basic procedure to carry out the AHP consists of the following steps:

1. Structuring a decision problem and selection of criteria

The first step is to decompose a decision problem into its constituent parts. In its simplest form, this structure comprises a goal or focus at the topmost level, criteria (and subcriteria) at the intermediate levels, while the lowest level contains the options.

Arranging all the components in a hierarchy provides an overall view of the complex relationships and helps the decision maker to assess whether the elements in each level are of the same magnitude so that they can be compared accurately. An element in a given level does not have to function as a criterion for all the elements in the level below. Each level may represent a different cut at the problem so the hierarchy does not need to be complete (Saaty, 1990).

When constructing hierarchies it is essential to consider the environment surrounding the problem and to identify the issues or attributes that contribute to the solution as well as to identify all participants associated with the problem.

2. Priority setting of the criteria by pairwise comparison (weighing)

For each pair of criteria, the decision maker is required to respond to a question such as “How important is criterion A relative to criterion B?” Rating the relative “priority”of the criteria is done by assigning a weight between 1 (equal importance) and 9 (extreme importance) to the more important criterion, whereas the reciprocal of this value is assigned to the other criterion in the pair. The weighings are then normalized and averaged in order to obtain an average weight for each criterion.

3. Pairwise comparison of options on each criterion (scoring)

For each pairing within each criterion the better option is awarded a score, again, on a scale between 1 (equally good) and 9 (absolutely better), whilst the other option in the pairing is assigned a rating equal to the reciprocal of this value. Each score records how well option “x” meets criterion “Y”. Afterwards, the ratings are normalized and averaged.

Comparisons of elements in pairs require that they are homogeneous or close with respect to the common attribute; otherwise significant errors may be introduced into the process of measurement (Saaty, 1990).

4. Obtaining an overall relative score for each option

In a final step the option scores are combined with the criterion weights to produce an overall score for each option. The extent to which the options satisfy the criteria is weighed according to the relative importance of the criteria. This is done by simple weighted summation (see the previous chapter).

Finally, after judgements have been made on the impact of all the elements and priorities have been computed for the hierarchy as a whole, sometimes and with care, the less important elements can be dropped from further consideration because of their relatively small impact on the overall objective. The priorities can then be recomputed throughout, either with or without changing the judgements (Saaty, 1990).

Remark: Especially in the case of complex sustainability issues the compensability among criteria can be problematic. The idea of 'musts' and 'wants' initially developed by Kepner and Tregoe (1965) and referred to by De Brucker et al. (1995) is a possibility to 'weaken' the compensatory nature of AHP (or other MCA methods), if necessary. An option that does not satisfy one or more 'musts' is considered infeasible and is eliminated from further consideration. The remaining options are then evaluated based on how well they meet the 'wants' (objectives to be maximised).

4 Review

4.1 Evaluation of results

Policy processes:

AHP can effectively support decision making with regard to complex sustainability issues and can help to recognize and define a problem in detail. It is widely used to decompose a decision problem into its constituent parts, which are then structured hierarchically. Multiple and even conflicting goals can be taken into consideration. Furthermore, the paired comparison approach forces decision makers to consider each individual trade−off in the decision problem, which can be a lengthy task. As a result, AHP delivers a ranking of options which facilitates the selection of a policy option. AHP is less suitable for the implementation and the evaluation of implemented policy options.

Sustainability aspects:

AHP is capable to compare long−term impacts, independently of the gauge year. Further sustainability aspects such as (de−)coupling, adaptability, (ir−)reversibility can be incorporated as criteria to compare alternative policies. Also the impacts on distributional effects over different groups/sectors/regions can be included in AHP as separate categories. AHP can compare impacts independently of the global dimension and can be applied to spatial data. Environmental, economic and social impacts can be simultaneously covered by AHP.

Operational aspects:

Manpower and time needs as well as the costs for applying the tool are difficult to estimate and depend highly on the subject. The same goes for data needs and data availability. In general, much data is needed to estimate the impacts, whereas the required amount of expert judgement to explain the results is medium. Qualitative and quantitative data can be incorporated.

The methodology for AHP is clear, straightforward and well documented. Since the approach requires complex calculations, corresponding software supports the users.

Under some circumstances, ranking irregularities can occur when AHP or some of its variants are used. But sensitivity analysis allows the decision maker to assess how alternative ratings would change if criteria weights were changed.

AHP can support the modelling of risk in a variety of ways. Particularly, the modelling of relative rather than absolute probabilities and the use of risk adjusted values can provide new opportunities for decision support. No specific time scale is associated with AHP and there are no limitations regarding the geographical coverage.

4.2 Experiences

AHP has been very successful in gaining the acceptance of practitioners, possibly owing to the helpfulness of the hierarchical problem presentation and the appeal of pairwise comparisons in preference elicitation (Salo and Hämäläinen, 1997). The range of reported practical applications is extensive (Vargas, 1990) and includes Resource Allocation, Strategic Planning and Project/Risk Management. Ramanthan et al. (2001) proposes namely the AHP to address the need for considering multiple criteria and multiple stakeholders in Environmental Impact Assessment (EIA).

Gomez−Limon & Atance (2004) used the AHP technique in order to reveal the preferences that citizens assign to the different possible objectives of the European Common Agricultural Policy (CAP). This methodological approach has been implemented among citizens of Castilla y León (Spain).

AHP as one of the presented MCA methods was not applied during the case study of Sustainability−A−Test. With regard to the topic of the case study, the Biofuels Directive and the Energy Crop Premium, AHP could have been used to decompose and present the policy problem in a multicriteria fashion, and later on to support the stages of policy options description and evaluation.

4.3 Combinations

Although AHP is a decision−making methodology in itself, its ability to elicit accurate ratio scale measurements and combine them across multiple criteria has led to AHP applications in conjunction with many other decision support tool and methodologies. AHP has been used in combination with, linear programming, integer programming, goal programming, data envelope analysis, balanced score cards, genetic algorithms, and neurol networks (reported in Millet and Wedley, 2003).

A'WOT (Kurttila et al., 2000) is an example of a combination specially developed for the purposes of practical strategic planning. The approach in which the SWOT (Strengths, Weaknesses, Opportunities and Threats; Wheelen and Hunger, 1995; Hill and Westbrook, 1997) forms the general framework, and the AHP is applied within this framework in order to bring quantitative analysis capacity into the planning process, has been given the name A'WOT. It has also been tested in strategic natural resource planning in state forestry in Finland (Pesonen et al., 2001). As only preliminary tests have been made so far, the method is bound to evolve further, and new versions will be developed (Kangas et al., 2001).

AHP can also be used to compare the impacts of alternative policies generated by other tools like physical assessment tools, modelling tools and environmental appraisal tools. It can be applied in conjunction with stakeholder analysis and, finally, AHP is capable to support the evaluation of alternative policies/plans/projects in SIA and SEA.

4.4 Strengths and weaknesses

The strengths and weaknesses of the AHP have been subject of substantial debate among specialists in MCA.

Strengths:

- The advantages of AHP over other multi criteria methods are its flexibility, intuitive appeal to the decision makers and its ability to check inconsistencies (Ramanathan 2001). Generally, users find the pairwise comparison form of data input straightforward and convenient.
- Additionally, the AHP method has the distinct advantage that it decomposes a decision problem into its constituent parts and builds hierarchies of criteria. Here, the importance of each element (criterion) becomes clear (Macharis et al. 2004).
- AHP helps to capture both subjective and objective evaluation measures. While providing a useful mechanism for checking the consistency of the evaluation measures and alternatives, AHP reduces bias in decision making.
- The AHP method supports group decision−making through consensus by calculating the geometric mean of the individual pairwise comparisons (Zahir 1999).
- AHP is uniquely positioned to help model situations of uncertainty and risk since it is capable of deriving scales where measures ordinarily do not exist (Millet & Wedley 2002).

Weaknesses:

Despite the popularity of the AHP, many authors have expressed concern over certain issues in the AHP methodology.

- Many researchers have long observed some cases in which ranking irregularities can occur when the AHP or some of its variants are used. This rank reversal is likely to occur e.g. when a copy or a near copy of an existing option is added to the set of alternatives that are being evaluated. Triantaphyllou (2001) proved that rank reversal is not possible when a multiplicative variant of the AHP is used. According to Belton (1986) and Belton and Gear (1997) a key issue for the AHP ranking reversals is the interpretation of the criteria weights. However, the AHP and some of its variants are considered by many as the most reliable MCDM method.
- The AHP−method can be considered as a complete aggregation method of the additive type. The problem with such aggregation is that compensation between good scores on some criteria and bad scores on other criteria can occur. Detailed, and often important, information can be lost by such aggregation.
- With AHP the decision problem is decomposed into a number of subsystems, within which and between which a substantial number of pairwise comparisons need to be completed. This approach has the disadvantage that the number of pairwise comparisons to be made, may become very large (n (n−1)/2), and thus become a lengthy task (Macharis et al. 2004).
- Another important disadvantage of the AHP method is the artificial limitation of the use of the 9−point scale. Sometimes, the decision− maker might find difficult to distinguish among them and tell for example whether one alternative is 6 or 7 times more important than another. Also, the AHP method cannot cope with the fact that alternative A is 25 times more important than alternative C (see also Murphy, 1993; Belton and Gear, 1983; Belton, 1986). Due to the discussion on the scale's restrictions, Hajkowicz et al. (2000) modified the procedure in their study by using a 2−point−scale, due to time constraints placed on decision makers. So the decision makers only indicated whether a criterion was more or less important or equally important to its partner.

4.5 Further work

Though the range of reported AHP−applications is extensive, examples within a EU context are still rare. With this respect further work should be done to find more real EU−examples for its application and how AHP can be combined with other tools being currently assessed within the Sustainability A−Test project.

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