UNIUNEA EUROPEANĂ

GUVERNUL ROMÂNIEI

Instrumente Structurale
2007 - 2013

# MULTI-CRITERIA ANALYSIS

## HANDBOOK

January 2012

UNIUNEA EUROPEANĂ

GUVERNUL ROMÂNIEI

Instrumente Structurale 2007 - 2013

The Handbook was prepared by experts who supported the implementation of the contract „Development of the capacity for the Cost-Benefit Analysis", project co-financed by ERDF through TAOP.

Monica Roman / professor, the Bucharest Academy of Economic Studies, Faculty of Cibernetics, Statistics and Computerised Economics, Department of Statistics and Econometrics

Project implemented by:

*AAM Management Information Consulting Private Company Limited by Shares*

*AAM Management Information Consulting SRL*

*Leader A.T.E.C. SRL*

*Intrarom SA*

*Infogroup Consulting SA*

# CONTENT

# 1. INTRODUCTION

## 1.1 OBJECTIVES OF THE MCA HANDBOOK

The general objective of this Manual is to provide institutions/interested organisations and general public with a guideline on when to use and on how to conduct and present a Multi-criteria Analysis (MCA) of investment projects according to the principles and rules established by international donor organisations, such as the European Commission. This will offer a more solid ground for the investment decision-making process in elaborating a project proposal. It will also help interested parties to access internationally available financial funds for their field of activity.

The manual is about techniques which do not necessarily rely on monetary valuations. It therefore complements guidance on those techniques which primarily use monetary valuations, namely financial analysis, cost effectiveness analysis (CEA), and cost-benefit analysis (CBA). These monetary techniques have been extensively used by applicants for funds, both at Romanian and European level being the subject of a large number of guides and manuals[1].

There are also a large number of elaborated and detailed textbooks on Multi-criteria Analysis available in international academic literature, focused on general methodological principles. At the same time, there are published some methodologies and manuals for decision making process[2], which are domain-specific[3] or country specific.

Most Romanian consultants and experts are familiar with monetary techniques, but less so with the MCA techniques described in this manual. Nonetheless investments in road infrastructure such as highway investments have been appraised using procedures that take account both of impacts measured in monetary units, such as construction costs, time savings and reductions in accident costs, and of social and environmental impacts that may be quantified but not valued (such as the number of houses suffering specified increases in noise) or assessed only in qualitative terms (such as impacts on landscape).

One of the premises that fundaments the initiation of this manual is the fact that there is no practical experience in the using of MCA in the project appraisal at Romanian level; therefore the first specific objectives is the explanation of methodological specific issues of MCA in order to make this method more comprehensive to the various parties involved (project applicants, project evaluators etc.)

**Thus, the present handbook, on Multi-Criteria Analysis (MCA) has the following objectives**:

- explaining ***why MCA should be used***, ***in which typical situations can be used and how can it be used*** (presenting the principles, concepts and terminology of the method, the forms/techniques of the MCA etc.).

  This Manual provides an overview of the main types of MCA methods and the general steps of MCA. At the same time, this document offers numerical EXAMPLEs of how these methods should be

[1] See the *Assessment report on the efficiency and effectiveness of the CBA related practice* elaborated during the first component of the Present project.
[2] In the Guide to cost-benefit analysis of investment projects (European Commission, 2008) there is a detailed list of references on this specific issue.
[3] On environment, education, water, solid waste, transport etc.

applied on a project proposal framework. This way, it fills the gap between the existing theoretical guidelines and Romanian sector reality.

- ***identification of the investment types in which case the MCA can be used***.
- clarifying the use of ***MCA as alternative to CBA or in conjunction with CBA***.
- offering ***practical exemplification*** on when and how MCA should be used per investment types, considering the uses of MCA.

## 1.2 TARGET AUDIENCE OF THE MCA HANDBOOK

A large category of entities could benefits from the MCA Manual. The MCA Manual should be used by applicants and consultants as a guide on how to carry out MCA on various investments projects. At the same time, MCA Manual can be used both by the authorities responsible of the management and implementation of the Operational Programmes or financial institutions for monitoring of the quality of different project proposals. Therefore, the handbook was written in an accessible, comprehensive style, with a large number of **examples** and numerical exercises. The manual should provide the user the basic knowledge on when and how to conduct MCA, without requiring a strong quantitative background. At the same time, for a more demanding audience, a list of references that could be used for further reading is provided.

## 1.3 CONTENTS OF THE MCA HANDBOOK

The MCA Manual consists of three main chapters, as well as an introductory section and a set of Conclusions that summarizes our work and provides several recommendations.

Chapter 2 introduces MCA by explaining the main concepts involved in this method and by presenting an overview of the main process steps.

Chapter 3 describe the main techniques that are usually applied in the practice of MCA in the context of project appraisal and recommend several better known software products used in MCA.

Chapter 4 situates the MCA in the project appraisal and present the advantages and disadvantages of the method. At the same time, in this chapter there are described the circumstances in which this method is applied.

Conclusions are presented in the final section.

# 2. KEY CONCEPTS OF MULTICRITERIA ANALYSIS

***Definition***

- *MCA describes any structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives.*

In MCA, multiple desirable objectives are specified and corresponding attributes or indicators are identified. Therefore MCA is proved to be useful in a large variety of applications. For instance, it could be applied by an individual for selecting a car to buy, in selecting a real estate property, in deciding for a specific investment or in evaluating social policies.

Multi-criteria analysis appeared in the 1960s as a decision-making tool[4]. Recently, it is becoming more and more popular in project management, both in ex-ante and in ex-post evaluation of projects, as Beria et al, (2010) state in their paper[5].

***Purpose and application***

- *The purpose of the method is to make a comparative assessment of alternative projects or other heterogeneous measures.*

Therefore, the actual measurement of indicators need not be in monetary terms, but are often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative impact categories and criteria. Different environmental and social indicators may be developed side by side with economic costs and benefits. Explicit recognition is given to the fact that a variety of both monetary and nonmonetary objectives may influence policy decisions. MCA provides techniques for comparing and ranking different outcomes, even though a variety of indicators are used. As consequence, Multi-criteria analysis is particularly applicable to cases where a single-criterion approach (such as cost-benefit analysis) falls short, especially where significant environmental and social impacts cannot be assigned monetary values. The purpose of the tool is to structure and combine the different assessments to be taken into account in decision-making, whereby decision-making is made up of multiple choices and the treatment given to each of the choices condition the final decision to a large extent.

Importantly, multi-criteria analysis is used to highlight the reasoning and subjective convictions of the *different stakeholders* on each particular question. It is usually used to syntheses the opinions expressed, in order to determine the priority structures, to analyse conflictual situations or to formulate recommendations or operational advice.

## 2.1 MAIN CONCEPTS USED IN MCA

With MCA, several criteria can be taken into account simultaneously in a complex situation. The method is designed to help decision-makers to integrate the different options, reflecting the opinions of the actors concerned, into a prospective or retrospective framework. Participation of the decision-makers in the

[4] For a history, see Köksalan, M., Wallenius, J., and Zionts, S. (2011). *Multiple Criteria Decision Making: From Early History to the 21st Century*. Singapore: World Scientific.

[5] Beria, Paolo, Maltese, Ila, Mariotti, Ilaria - Comparing cost benefit and multi-criteria analysis: the evaluation of neighbourhoods' sustainable mobility, Società Italiana degli Economisti dei Trasporti - XIII Riunione Scientifica –Messina 2011

process is a central part of the approach. Having these in minds, the following key concepts are detailed bellow: options, criteria, performance matrix, scoring, weighting and standardisation.

### 2.1.1 OPTIONS

The investment project proposals have various *objectives*, which are the purposes which an organisation wishes to achieve or finance. In some cases, broad overall objectives, or ultimate objectives, are broken into lower-level or intermediate objectives which are more concrete, and these may be further detailed as sub-objectives, immediate objectives, or criteria which are more operational.

**Options (or alternatives) are the** ways of achieving objectives. The best option will be the one that most nearly achieves the objectives. Options might be projects alternatives, programmes, schemes, or anything else about which a project is needed. Both denomination of "alternative" and "option" will be used in this manual.

In the following ***EXAMPLE,*** a possible set of *objectives* in the case of sustainable development project is presented:

- Sustainability,
- Economic efficiency,
- Liveable streets,
- Environmental protection,
- Equity, social inclusion and accessibility ,
- Safety,
- Economic growth.

### 2.1.2 CRITERIA

***Criterion is*** *one of a number of measures against which options are assessed and compared for the degree to which they achieve objectives. Each criterion should measure something relevant and not depend on another criterion.*

Attribute is also sometimes used to refer to a measurable criterion. In this manual we use the word "criterion" rather than "attribute".

According to Baker et al. (2001)[6], criteria should be:

- able to discriminate among the alternatives „in a meaningful way" and to support the comparison of the performance of the alternatives,
- complete to include all goals,
- operational,

[6] Baker, D., Bridges, D., Hunter, R., Johnson, G., Krupa, J., Murphy, J. and Sorenson, K. (2002) *Guidebook to Decision-Making Methods*, WSRC-IM-2002-00002, Department of Energy, USA. http://emi-web.inel.gov/Nissmg/Guidebook_2002.pdf

- non-redundant,
- few in number.

In some methods, as stated by Keeney and Raiffa (1976)[7], non-redundancy is required in the form of independency.

Criteria are generally of **two types**:

- Quantitative – For EXAMPLE employability (number of new jobs created), level of carbon dioxide emissions, number of km. of highway or net present value (euro, RON). These criteria measure through ***economic indicators*** the degree to which the economic efficiency objective is achieved. It is obvious that among quantitative criteria, there are the monetary ones. Where monetary values can be derived, they are used. These values are based on CBA principles.
- Qualitative – An EXAMPLE of qualitative criteria is the impact of an investment on local environment. It could have no impact, minimal (positive or negative) impact, limited impact, moderate impact, or significant impact. This criteria measure the achievement of environmental protection objective.

In some countries there are established criteria that should be considered in project applications. As an EXAMPLE, in the UK NATA[8] enables decision makers to consider the economic, environmental and social impacts of transport projects or policies in light of the UK Government's five main objectives (i.e. *criteria*) for transport:

- To protect and enhance the natural and built environment;
- To improve safety for all travellers;
- To contribute to an efficient economy, and to support sustainable economic growth in appropriate locations;
- To promote accessibility to everyday facilities for all, especially those without a car;
- To promote the integration of all forms of transport and land use planning, leading to a better, more efficient transport system.

In turn, some of the objectives are divided into sub-objectives. Following the EXAMPLE above, in the roads application of NATA, the following three objectives are divided into *sub-criteria*:

- Environment is divided into noise, local air quality, landscape, biodiversity, heritage, and water, while the impact on carbon dioxide emissions is also distinguished separately.
- Economy is divided into journey times plus vehicle operating costs, highway construction and maintenance cost, reliability, and regeneration;
- Accessibility is divided into public transport, severance, and pedestrians and others.

Considering the nature of the criteria, these should be **maximized or minimized**. In the first case, the highest value of the score in wanted, such is, for EXAMPLE, the performance of a car, expressed in horsepower, the

---

[7] Keeney, R.L., Raiffa, H.: *Decisions with multiple objectives*, John Wiley & Sons, 1976.
[8] DfT (2007), *The NATA Refresh: Reviewing the New Approach to Appraisal*. Department for Transport

profitability of an investment, the number of jobs created, the number of people trained in a programme. In the second case, the lowest values for the criteria are desirable; such are the price of a car, the labour cost or the consumption of energy.

In the EXAMPLE below, we consider the acquisition of 20 school buses for a municipality. The selection of one bus model from three possible models is a subject of Multi-criteria analysis. The information in Table 1 gives the description of 5 criteria, providing: the symbol and the name of the criteria, the indicator used for quantifying the criteria, ranges of values of the criteria and the wanted effect of each criterion.

**Table 1. Criteria and their ranges**

| **Criteria** | | **Indicator** | **Ranges** | **Effect**<br><br>**Maximum (+)/mimum (-)** |
|---|---|---|---|---|
| $C_1$ | Price | Price (cash or financed price in Euros ) | 15000 to 20000 | - |
| $C_2$ | Performance | Engine power, (horsepower) | 100 to 150 | + |
| $C_3$ | Economy | Petrol consumption (l per 100 km) | 7 to 12 | - |
| $C_4$ | Maintenance Cost | Cost (Euros per year) | 1500 to 2200 | - |
| $C_5$ | Design | 1 is ugly and 5 is beautiful | 1 to 5 | + |

### 2.1.3 THE PERFORMANCE MATRIX

A standard instrument of multi-criteria analysis is a **performance matrix (also known as decision matrix or** consequence table). Each row of this matrix describes an option and each column describes the performance of the options against each criterion. The individual performance assessments are often numerical, but may also be expressed as 'bullet point' scores or colour coding.

Table below is presenting the general form of the performance matrix in the case of *m options and n criteria*. The scores from the matrix cells are $a_{ij}$.

**Table 2. The performance matrix**

| *Criteria*<br><br>*Alternatives* | $C_1$ | $C_2$ | $...C_j...$ | $C_n$ |
|---|---|---|---|---|
| $A_1$ | $a_{11}$ | $a_{12}$ | ... | $a_{1n}$ |
| $A_2$ | $a_{21}$ | $a_{11}$ | ... | $a_{11}$ |
| $...A_i...$ | ... | ... | $a_{ij}$ | ... |

| | | | | |
|---|---|---|---|---|
| $A_m$ | $a_{m1}$ | $a_{m2}$ | ... | $a_{mn}$ |

**Numerical example**

Table 3 continues the simple EXAMPLE described before and shows the performance of a number of 3 different bus types in regard to a set of criteria thought to be relevant. As can be seen, all these criteria are measured in cardinal numbers, though the fifth criterion is qualitative.

**Table 3. Estimated values of alternatives for criteria**

| Alternatives | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | 17000 | 120 | 9 | 1600 | 3 |
| $A_2$ | 19000 | 140 | 10 | 2000 | 4 |
| $A_3$ | 20000 | 130 | 8 | 1800 | 5 |

In a basic form of MCA this performance matrix may be the ***final product*** of the analysis. The decision makers are then left with the task of assessing the extent to which their objectives are met by the entries in the matrix. Such intuitive processing of the data can be speedy and effective, but it may also lead to the use of unjustified assumptions, causing incorrect ranking of options.

### 2.1.4 SCORING AND WEIGHTING

In MCA techniques the information in the basic matrix is usually converted into consistent numerical values.

- By Scoring, the expected consequences of each option for each criterion are assigned a numerical score on a strength of preference scale.. More preferred options score higher on the scale, and less preferred options score lower. In practice, scales extending from 0 to 100 are often used, where 0 represents a real or hypothetical least preferred option, and 100 is associated with a real or hypothetical most preferred option. All options considered in the MCA would then fall between 0 and 100[9].

Weighting is the numerical weights assigning in order to define, for each criterion, the relative valuations of a shift between the top and bottom of the chosen scale.

The Weighting of decision criteria is the step when a 'value' or 'weight' is allocated to each of the decision criteria - that is, the decision criteria are weighted relative to one another – the weighting of decision factors is necessary if ultimately we wish to combine them.

The method of **swing weighting** to elicit weights for the criteria is one of the most used. This method is based on comparisons of differences: how does the swing from 0 to 100 on one preference scale compare to the 0 to 100 swing on another scale? To make these comparisons, annalists are encouraged to take into account both the difference between the least and most preferred options, and how much they care about that difference. Thus, the weight on a criterion reflects both the range of difference of the options, and how much that difference matters.

[9] Multi-criteria analysis: a manual, January 2009, Department for Communities and Local Government: London

Another way to assess weights is ***direct estimation*** of their relative importance by assigning a value to each criterion. This method assigns weights to criteria using a scale such as 0 to 10 or 0 to 100. If used carefully, i.e. taking into account the ranges of each criterion, direct estimation can be an effective methodology. Typically experts, decision-makers or stakeholders set these 'weight' in accordance with their interpretation of society's preferences. For EXAMPLE, if experts assume that society places more importance on economic value than equity, then they will assign a higher weight to economic value. This step in the MCA process is the most complex; not only must the analyst know the preferences of society for the various decision factors, but must also be able to translate these preferences into *relative* weights.

On the numerical example used so far, we shall consider that a group of experts analysed the criteria and consulted the main stakeholders: the municipality, the schools directors, the parents' exponents. They have decided that bus price is the most important criterion and its weight should be 40%, the engine performance and the design of the bus are the less important criteria with 10% weights, while economy and maintenance costs have a medium relevance and 20% weights. These results are presented in table 4.

**Table 4. Weights directly estimated**

| Criterion | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| Weight | 0,40 | 0,10 | 0,20 | 0,20 | 0,10 |

Other EXAMPLEs of techniques usually employed to establish importance weights include:

- Delphi Method,
- Rating from predefined scales,
- Analytical Hierarchy Process (AHP), which will be treated in Chapter 3.

Mathematical routines, which may be written into computer programmes, then combine these two components to give an overall assessment of each option being appraised. This approach therefore requires individuals to provide those inputs that they are best suited to provide, and leaves computers the task of handling detailed information in a way that is consistent with the preferences that have been revealed by these human inputs.

### 2.1.5 STANDARDIZATION THE PERFORMANCE MATRIX

*Standardisation is the process through which the criterion values expressed in different measurement units are transformed into a common scale, which allows their comparison.*

Given the variety of scales on which attributes can be measured, Multi-criteria decision analysis requires that the scores of the various criteria are transformed to comparable units. Only if the scales of the criteria are the same, the scores of these criteria can be compared or combined. Making the scores of the criteria comparable is often called *standardization* or *normalization*. Through a value function or standardization procedure the measurement units are made uniform, and the scores lose their dimension along with their measurement unit.

Various methods to standardize scores are available[10]: linear scale transformation methods like maximum standardization, interval standardization and goal standardization and also non-linear value function approach. The formula behind this method is presented in Annex 1.

The method doesn't maintain the relative order of magnitude, but scales the raw options' scores precisely in the interval [0,1]

There are several software packages available that can be used to help with the computations in MCA and they are described in the Annex 2 of present manual.

Following the example above, we applied two normalization procedures on the performance matrix described in table 2. Firstly, vector normalization was applied, by using the formula 2.1, in which $r_{ij}$ *are* the standardized scores and $a_{ij}$ are the scores resulted from the scoring process.

- $r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}}$ ( 2.1)

This method is characterized by the fact that it does not take into account the type of criteria (minimum or maximum). The results are presented in table 5.

Secondly, normalization through linear transformation was used; this method is considering the formula 2.2 for criteria, $C_2$, and $C_5$, that are maximized and formula 2.3 for the criteria $C_1$ $C_3$, $C_4$, , that are minimized.

$$r_{ij} - \frac{a_{ij}}{a_j^{max}}, \quad a_j^{max} = \max_i\{a_{ij}\} \qquad (2.2)$$

$$r_{ij} = 1 - \frac{a_{ij}}{a_j^{max}} = \frac{a_j^{max} - a_{ij}}{a_j^{max}} \qquad (2.3)$$

The results are values in the range [0,1] and are presented in table 6.

**Table 5. Normalized performance matrix (vector normalizing method)**

| Alternatives | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | 0,52 | 0,53 | 0,64 | 0,51 | 0,42 |
| $A_2$ | 0,59 | 0,62 | 0,57 | 0,64 | 0,57 |
| $A_3$ | 0,62 | 0,58 | 0,51 | 0,57 | 0,71 |

**Table 6. Normalized performance matrix (linear transformation method)**

| Alternatives | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | 0,15 | 0,86 | 0,10 | 0,20 | 0,60 |

[10] See Dobre, I. , Bădescu, A. , Păuna, L., Teorie Deciziei, Editura ASE, Bucureşti, 2007.

| | | | | | |
|---|---|---|---|---|---|
| $A_2$ | 0,05 | 1,00 | 0,00 | 0,00 | 0,80 |
| $A_3$ | 0,00 | 0,93 | 0,20 | 0,10 | 1,00 |

## 2.2 MAIN STEPS OF MCA

The main steps involved in Multi-criteria analysis can be broken down into several phases described sequentially below. It is possible to repeat the phases and thus to make corrections.

These steps are described in detail below[11]:

1. **Establish the decision context**, such as goals of the project that is submitted or evaluated, its feasibility. In this sense, the analyst should have some clear answers at questions such as: What are the aims of the MCA, and who are the decision makers and other key players?

   It is crucial to have a clear understanding of objectives, since MCA is all about multiple conflicting objectives. There are ultimately trade-offs to be made. Nonetheless, in applying MCA it is important to identify a single high level objective, for which there will usually be sub-objectives.

2. **Define options**.

   This step[12] has the purpose to identify the alternative options to be considered. The options under consideration will generally be specific to the particular problem and context, but may include investments, projects, policies, development plans etc. It is important to have a clear and detailed description of what each option is.

3. **Define criteria**.

   **In this stage, the analyst** identifies and defines all criteria that are relevant to the decision problem. These will include all important categories of costs and benefits resulting from the options under consideration. It is often useful to group criteria into economic, social and environmental categories. In a MCA it is possible to include criteria that are difficult to quantify and can perhaps only be assessed in qualitative terms such as political sensitivity, equity, and irreversibility.

4. **Create performance matrix** which describes the expected performance of each option against the criteria. Information on the magnitude of each impact (criteria) can be expressed in monetary units, physical units, or simply on a qualitative scale. Data on impacts can be collected from surveys, existing data, experts, or stakeholders.

5. **Standardisation of scores** for each criterion to a common interval scale (usually to values between 0-1 or 0-100. In this respect the methods described in previous section could be applied.

[11] Adapter from *Multi-criteria analysis: a manual,* January 2009, Department for Communities and Local Government: London

[12] Within the framework of the same project in which the present handbook was prepared, also an Working Paper (No 8) "Identifying and defining technical-economic scenarios and options in CBA" was drafted. For more details on these aspects please refer to the mentioned working paper

6. **Weighting of criteria** to quantify the relative importance of each criterion in the decision process. Weights should be derived from existing information or from stakeholders by asking them to state their preferences for the various criteria, as presented in section 2.1. Specific MCA methods could be applied, as it is Analytical Hierarchic Process (AHP) described in chapter 3.

7. **Ranking of options**.

   Combine the weights and scores for each of the options to derive an overall value. In this stage the decision maker should select the most appropriate method for ranking the alternatives. Some frequently used techniques are presented in Chapter 3, though at present the alternative options are ranked usually through a weighted summation of criteria scores for each alternative.

8. **Examine the results**

   In this phase, the expert is analysing the results obtained and presents them in a comprehensive manner.

9. **Sensitivity analysis**.

   Sensitivity analyses can be useful to the decision makers to help them evaluate their values to make sure they select the alternative that best meets their objectives. The purpose of a sensitivity analysis is to validate the alternative evaluation and alternative rankings that result from the decision process by demonstrating that small changes in the alternative scores against the decision criteria or decision criteria weights do not change the alternative ranking.

   First the decision criteria weights are checked for sensitivity. The analyst changes each of the decision criteria weights by a certain percentage (for instance 10%) while maintaining the 100% sum of the weight factors. If these changes do not result in a change in the alternative rankings, the decision analysis is considered robust otherwise the MCA should be revised and restarted.

# 3. MULTI-CRITERIA EVALUATION METHODS

This section briefly summarises the main features of some of the better-known multi-criteria evaluation methods explaining also our decision to pursue the three multi-criteria methods used next in the decision support framework for the financing of investment projects.

## 3.1 DIRECT ANALYSIS OF THE ALTERNATIVES PERFORMANCE

In some cases, the MCA is limited to a direct and qualitative analysis of performance matrix. In such cases, only a limited amount of information about options' relative qualities can be obtained. Dominance of some criteria against others is checked. Dominance occurs when one option performs at least as well as another on all criteria and strictly better than the other on at least one criterion. In principle, one option might dominate all others, but in practice this is unlikely.

We recommend the use of this method only in the very early stages of the project development, for instance for clarifying the criteria or for providing information on possible alternatives. Otherwise, when appling for financing a project, more elaborated methods should be applied.

## 3.2 WEIGHTED SUMMATION

Weighted summation- also known as ***linear additive models***- is a widely spread method applied in Multi-criteria decision problems. The method is applicable under the assumption that the criteria are preferentially independent of each other and if uncertainty is not formally built into the MCA model. The linear model shows how an option's values on the many criteria can be combined into one overall value. This is done by multiplying the standardized scores $r_{ij}$ on each criterion with the appropriate weight of that criterion $w_j$, followed by summing the weighted scores of all criteria. The calculation of the total score for each alternative $A_i$, namely $AS_i$ , can be calculated using the following equation:

$$AS_i = \sum_{j=1}^{n} W_j * r_{i,j} \tag{3.1}$$

Models of this type have a well-established record of providing robust and effective support to decision-makers working on a range of problems and in various circumstances[13]. For instance, in the Netherlands, the commission of Environmental Impact Assessment (EIA) advised to apply weighted summation to evaluate alternative solutions. Weighted summation has been applied in other countries too, according to Beinat and Nijkamp (1998)[14].

It is important to mention that the standardization process and the weights applied entail a high degree of subjectivity. Therefore, explaining the strengths and weaknesses of the alternative project and explaining the final ranking are important steps in presenting the results.

[13] *** Multi-criteria analysis: a manual, January 2009, Department for Communities and Local Government: London
[14] Beinat, E. and Nijkamp, P., (editors) 1998. *Multi-criteria analysis for land-use management*. Kluwer, Dordrecht.

**Numerical Example**

In the example of selecting the school bus model for a municipality, the scores for each of the three alternatives are computed based on the normalized performance matrix (see table 7) and on the weights directly inputted by the experts (see table 4).

The results are presented below:

**Table 7. Results for weighted summation method**

| Alternatives | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $AS_i$ |
|---|---|---|---|---|---|---|
| $A_1$ | **0,15** | **0,86** | **0,10** | **0,20** | **0,60** | **0,27** |
| $A_2$ | **0,05** | **1,00** | **0,00** | **0,00** | **0,80** | **0,20** |
| $A_3$ | **0,00** | **0,93** | **0,20** | **0,10** | **1,00** | **0,25** |
| Weight | **0,40** | **0,10** | **0,20** | **0,20** | **0,10** | |

The conclusion that arises is that the best alternative is A1, which scores maximum for the criteria with the highest impact: it ensures the lowest price. The alternative score for A1 is 0,27 while the other two criteria have lower scores: 0,25 for A3 and 0,20 for A2.

## 3.3 THE ANALYTIC HIERARCHY PROCESS

Analytic Hierarchy Process (AHP) was developed by Saaty[15] (1980) as a method of analyzing decisions based upon a hierarchy of components of the decision. As noticed by Gissel and Leleur[16] (2004), it has proved to be one of the more widely applied MCA methods and is mentioned in most of the manuals and guides on MCA.[17] This method is essentially an interactive one where a decision-maker or group of decision-makers relay their preferences to the analyst and can debate or discuss opinions and outcomes. The method largely stems from the theories of human behaviour including thought process, logic, intuition, experience and learning theories.

The AHP also develops a linear additive model, but, in its standard format, uses procedures for deriving the weights and the scores achieved by alternatives which are based, respectively, on pairwise comparisons

[15] Saaty, T. 1980, *The Analytic Hierarchy Process*, McGraw-Hill, New York.

[16] Gissel Goldbach, Stine and Leleur, Steen (2004)- Cost-Benefit Analysis and alternative approaches from the Centre for Logistics and Goodds. Study of evaluation techniques, 2004

[17] See for instance, Multi-criteria analysis: a manual, 2009, Department for Communities and Local Government: London; Methodology for multi-criteria Analysis of Agri Environmental Schemes; or Evaluating Socio Economic Development, Sourcebook 2: Methods & Techniques. Multi-criteria analysis.

between criteria and between options. Therefore, the AHP is based upon the construction of a series of ‘pair-wise comparison’ matrices which compare criteria to one another. This is done to estimate a ranking or weighting of each of the criteria that describes the importance of each of these criteria in contributing to the overall objective. If the criteria are broken down into a number of sub-criteria, the pair wise comparisons are repeated for each level of the hierarchy. A pair wise comparison of n criteria ($C_1$ … $C_n$) to reflect the importance or weighting of each criteria in influencing the overall objective, involves constructing a n by n matrix (C) which shows the dominance of the criteria in the left hand side column with respect to each criteria in the top row.

$$C = \begin{array}{c|ccc} & C_1 & \cdots & C_n \\ \hline C_1 & c_1/c_1 & \cdots & c_1/c_n \\ \vdots & \vdots & \ddots & \vdots \\ Cn & c_n/c_1 & \cdots & c_n/c_n \end{array}$$

Each cell entry of C, reflects a ratio scale of the underlying priority weights assigned to each of the criteria. A nine point *Intensity of Importance scale* was developed by Saaty to determine these. It is claimed that the scale is based on psychological experiments and is designed to allow for and accurate reflection of priorities in comparisons between two items whilst minimising the difficulties involved in doing so.

**Table 8. The AHP Intensity of Importance Scale**

| Intensity of Importance | Definition |
|---|---|
| 1 | Equal importance of both elements |
| 3 | Weak importance of one element over another |
| 5 | Essential or strong importance of one element over another |
| 7 | Demonstrated importance of one element over another |
| 9 | Absolute importance of one element over another |

Source: Saaty, 1982

The values 2, 4, 6 and 8 are intermediate values that can be used to represent shades of judgement between the five basic assessments.

In matrix C, each cell entry is positive and the diagonal elements ($c_{jj}$) are all equal to 1. If it is assumed that transitivity of preferences prevails. For example, if C1 is preferred by a scale of 5 to C2, then C2 is preferred by a scale of 1/5 to C1) then the reciprocal property cjj’ = 1/ cjj’ is satisfied and estimates need only be provided for those cells which lie above the diagonal.

The calculations required are quite complex. In practice they would be undertaken by a special AHP computer package.

A more straightforward alternative described in a recent manual[18], which also has some theoretical attractions is to follow the next steps:

- calculate the geometric mean of each row in the matrix
- total the geometric means, and
- normalise each of the geometric means by dividing by the total just computed.

The results are the computed weight assign to each of the criteria, $w_j$,

The alternative score (ASi) of each of the option with respect to all of the criteria can be estimated with linear additive model, as follows:

$$AS_1 = a_{11}(w_1) + a_{21}(w_2) + \ldots + a_{N1}(w_N)$$

$$AS_2 = a_{12}(w_1) + a_{22}(w_2) + \ldots + a_{N2}(w_N)$$

.

.

.

$$AS_m = a_{1m}(w_1) + a_{2m}(w_2) + \ldots + a_{Nm}(w_N)$$

**Numerical Example**

As numerical EXAMPLE, we will consider the decision matrix used for selecting the school bus model for a municipality. We will apply the method in order to develop the weights for the five criteria and based on these weights the alternative score will be computed.

The computations are presented in table 9.

**Table 9. Criteria weights derived with AHP**

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | Geometric mean | Weight |
|---|---|---|---|---|---|---|---|
| $C_1$ | 1,00 | 3,00 | 5,00 | 3,00 | 7,00 | 3,16 | 0,46 |

[18] Multi-criteria analysis: a manual, January 2009, Department for Communities and Local Government: London.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **$C_2$** | 0,33 | 1,00 | 0,33 | 0,20 | 5,00 | 0,64 | 0,09 |
| **$C_3$** | 0,20 | 3,00 | 1,00 | 3,00 | 5,00 | 1,55 | 0,23 |
| **$C_4$** | 0,33 | 5,00 | 0,33 | 1,00 | 5,00 | 1,23 | 0,18 |
| **$C_5$** | 0,14 | 0,20 | 0,20 | 0,20 | 1,00 | 0,26 | 0,04 |
| **Sum of the geometric means** | | | | | | **6,84** | |

The computed weights are presented in the last column of table above. If we compare the result with the weights assigned by experts, we notice that the results are in the same line. For the first 4 criteria the weights are reasonable close to direct weights. The differences are “reported” to the fifth criteria, which in AHP was a weight of 4 %, compared to 10 % in the previous method.

The next step is to compute the Alternative Score (AS_AHP) and to select the option which provides the highest score. The results provided in table 10 are in the line with previous results obtained. The best option is, again, A1 and its score is very close to the previous one. A3 is the next option and the worse option Is A2.

**Table 10. Results from AHP**

| *Alternatives* | *$C_1$* | *$C_2$* | *$C_3$* | *$C_4$* | *$C_5$* | *AS_AHP* |
|---|---|---|---|---|---|---|
| $A_1$ | 0,15 | 0,86 | 0,10 | 0,20 | 0,60 | 0,23 |
| $A_2$ | 0,05 | 1,00 | 0,00 | 0,00 | 0,80 | 0,15 |
| $A_3$ | 0,00 | 0,93 | 0,20 | 0,10 | 1,00 | 0,19 |
| **Weight** | 0,46 | 0,09 | 0,23 | 0,18 | 0,04 | |

Though the method was criticized due to the the link between the verbal descriptions and the corresponding numerical scale, it certainly provides some advantages:

- The pairwise comparisons are perceived by users as straightforward and convenient.
- It is very useful when criteria are of a qualitative nature.
- Inconsistencies in relative judgments can be handled.

## 3.4 OUTRANKING METHODS: ELECTRE I

The methods that have evolved all use outranking to seek to eliminate alternatives that are, in a particular sense, ‘dominated’. However, unlike the straightforward dominance idea outlined in before, dominance within the outranking frame of reference uses weights to give more influence to some criteria than others. One option is said to outrank another if it outperforms the other on enough criteria of sufficient importance (as reflected by the sum of the criteria weights) and is not outperformed by the other option in the sense of recording a significantly inferior performance on any one criterion. All options are then assessed in terms of the extent to which they exhibit sufficient outranking with respect to the full set of options being considered as measured against a pair of threshold parameters.

The outranking variant is used where the criteria are not all considered commensurable, and therefore no global score can be produced. The analysis is based on multiple comparisons of the type: "does Measure A outrank Measure B from the point of view of the environment criterion?", "does Measure A outrank Measure B from the point of view of the employability criterion?", etc. These questions can be answered yes or no or be qualified, in which case the notions of a weak preference and a threshold criterion are introduced. The analysis makes all possible comparisons and presents a synthesis of the type: "Measure A is at least as good as Measure B, in relation to a majority of criteria (case of agreement), without being altogether too bad in relation to the other criteria (case of disagreement)".

The analysis could include protection against a favourable judgment for a measure that would be disastrous from the point of view of the given criterion, by setting a 'veto threshold' for each criterion. The introduction of a veto threshold strongly differentiates the logic of outranking from the logic of compensation. If there were a veto threshold, a very bad impact on the environment would make it impossible to consider the measure good, even if its impact on employability were considered excellent.

The main variants of Multi-criteria analysis which use outranking are[19]:

- ELECTRE I. This variant functions with an concordance index and a discordance index, presented in the form of scores. A disagreement threshold (a veto) is introduced for all the criteria. The solution is found by using software that processes a situation in which the best measure(s) must choose, for EXAMPLE a situation in which the aim is to identify best practice.
- ELECTRE TRI. This variant serves to sort measures into different categories; for EXAMPLE, the most successful measures, measures which have no significant impact and intermediate measures.
- ELECTRE II produces a ranking of measures, from the most successful to the least successful. Outranking and veto thresholds are of the franc type.
- ELECTRE III also performs a classification, but introduces vague outranking relationships.
- PROMETHEE uses only an index of agreement and introduces progressive outranking.

ELECTRE[20] method developed by Roy[21] (1974) is a procedure that sequentially reduces the number of alternatives the decision-maker is faced with in a set of non-dominated alternatives. Following the practice

[19] For more information, see, Vincke, P. (1992) *Multi-criteria Decision-Aid,* John Wiley, Chichester
[20] ELECTRE derives from *Elimination et Choix Traduisant la Réalité*.
[21] Roy, Bernard (1968). "Classement et choix en présence de points de vue multiples (la méthode ELECTRE)". *la Revue d'Informatique et de Recherche Opérationelle (RIRO)* (8): 57–75.

in MCA applied in project submission and evaluation[22], we consider that ELECTRE I is the method that adequately responds to the needs of experts and applicant of projects. In this respect, we describe the basics of the method and we present a numerical example.

***Outranking*** is a concept originally due to Roy and may be defined as follows:

The concept of an outranking relation $S$ is introduced as a binary relation defined on the set of alternatives $A$. Given two alternatives $A_i$ and $A_j$, $A_i$ outranks $A_j$, or $A_i S A_j$, if given all that is known about the two alternatives, there are enough arguments to decide that $A_i$ is at least as good as $A_j$. The goal of outranking methods is to find all alternatives that dominate other alternatives while they cannot be dominated by any other alternative. Thus outranking is defined fundamentally at the level of pairwise comparison between every pair of options being considered.

To find the best alternative, outranking also requires knowledge of the weights of the criteria. Each criterion $C_j \in C$ is assigned a weight $w_j$.

The starting point is to define what are termed ***the concordance and discordance indices***.

Using the same notation as in the main body of the manual, the ***concordance index, c(Ai,Aj),*** can be calculated for every ordered pair of options *(A**i, Aj)*** simply as the sum of all the weights for those criteria where option i scores at least as highly as option j. Therefore, every pair of alternatives $A_i$ and $A_j$ is assigned a concordance index $c(A_i, A_j)$ given by:

$$c(A_i, A_j) = \frac{1}{\sum_{k=1}^{n} w_k} \sum_{\{k: r_k(A_i) \geq r_k(A_j)\}} w_k \qquad (3.2)$$

where the sum of the criteria weights in the numerator is taken only for those criteria where the values of $A_i$ dominate the values of $A_j$.

The discordance index, ***d(Ai,Aj)***, is a little more complex. If option **i** performs better than option **j** on all criteria, the discordance index is zero. If not, then for each criterion where **j** outperforms **i**, the ratio is calculated between the difference in performance level between **j** and **i** and the maximum observed difference in score on the criterion concerned between any pair of options in the set being considered. This ratio (which must lie between zero and one) is the discordance index:

$$d(A_i, A_j) = \begin{cases} 0 \;\; if \; r_k(A_i) \geq r_k(A_j) \;\; for \; all \; k, \\ \frac{1}{\delta} \max\{r_k(A_i) - r_k(A_j)\}, \;\; otherwise. \end{cases} \qquad (3.3)$$

[22] See for instance, Multi-criteria analysis: a manual, 2009, Department for Communities and Local Government: London; Methodology for multi-criteria Analysis of Agri Environmental Schemes; or Evaluating Socio Economic Development, Sourcebook 2: Methods & Techniques. Multi-criteria analysis.

where,

$$\delta = \max\{r_k(A_i) - r_k(A_j)\}. \quad (3.4)$$

Defined in this way, the discordance index is only of real value in later stages of the analysis if criteria are of roughly equal importance. However, it is possible to refine the discordance definition to avoid this difficulty, albeit at the cost of inducing some element of subjective judgement. It is the discordance index that captures the notion of an option's unacceptability if it records an outstandingly poor performance, even on just one dimension.

To bring the two sets of **n**(**n** - 1) indices together for all n options being considered, the next phase is to define a (relatively large) concordance threshold, **c***, and a (relatively low) discordance threshold, **d***, for which

$$C^*+d^*=1 \quad (3.5)$$

An option then outranks another option overall if its concordance index lies above the chosen threshold value and its discordance index lies below the threshold value.

These are the $g_k(A_i)$. Once the two indices are known, an outranking relation $S$ is defined by:

$$A_iSA_j \text{ if and only if } \begin{cases} c(A_i, A_j) \geq c^*, \\ d(A_i, A_j) \leq d^*, \end{cases} \quad (3.6)$$

where $c^*$ and $d^*$ are thresholds set by the decision maker.

The set of all options that outrank at least one other option and are themselves not outranked contains the promising options for this problem. If the set is too small, perhaps even an empty set, it can be expanded by appropriate changes to the concordance and/or discordance thresholds. Similarly, if the set is too big, it can be made smaller.

Summarizing, the steps followed in the outranking method are as follows:

Step 1. Obtain the values of the criteria, the weight for each criterion and standardized the performance matrix.

Step 2. Construct the outranking relations by following the concordance and discordance definitions.

Step 3. Obtain a minimum dominating subset by using the minimum concordance and maximum discordance indices.

Step 4. If the subset has a single element or is small enough to apply value judgment, select the final decision. Otherwise, Steps 2 through 4 are repeated until a single element or small subset exists.

**Numerical example**

As numerical EXAMPLE, we will consider the decision matrix used for selecting the school bus model for a municipality.

**Step 1.** The performance matrix in a standardized form, as well as the weight for each criterion is presented in the table below. We use the weights derived by using AHP in numerical example from section 3.3.

**Table 11. The normalized performance matrix**

| Alternatives | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| $A_1$ | 0,15 | 0,86 | 0,10 | 0,20 | 0,60 |
| $A_2$ | 0,05 | 1,00 | 0,00 | 0,00 | 0,80 |
| $A_3$ | 0,00 | 0,93 | 0,20 | 0,10 | 1,00 |
| **Weight** | 0,46 | 0,09 | 0,23 | 0,18 | 0,04 |

**Step 2.** Concordance index are computed first.

$C_{11}$, $C_{22}$ and $C_{33}$ are not subject of the computation of concordance indices.

$C_{12}$=($w_1$ +w3 +w4)/(w1 + w2 + w3+ w4 + w5)=(0,46+0,23+0,18)/1=0,87

$C_{13}$= (w1 +w4)/(w1 + w2 + w3+ w4 + w5)=(0,46+0,18)/1=0,64

$C_{23}$=(w1 +w2)/(w1 + w2 + w3+ w4 + w5)=(0,46+0,09)/1=0,55

$C_{21}$=(w2 +w5)/(w1 + w2 + w3+ w4 + w5)=(0,09+0,04)/1=0,13

In the same manner there are computed concordance indices for $C_{31}$ and $C_{32}$.

The resulted concordance matrix is presented in the table below.

**Table 12. The concordance matrix**

| Alternatives | $A_1$ | $A_2$ | $A_3$ |
|---|---|---|---|
| $A_1$ | - | 0,87 | 0,64 |
| $A_2$ | 0,13 | - | 0,55 |
| $A_3$ | 0,36 | 0,45 | - |

The discordance indices, are computed using formula 3.3.

Again, $d_{11}$, $d_{22}$ and $d_{33}$ are not subject of the computation of disconcordance indices.

$d_{12}$= max {1-0,85; 0,8-0,6}=0,2

$d_{13}$= max {0,92-0,85; 0,2-0,1;1-0,6}=0,4

$d_{21}$= max {0,15-0,05; 0,1-0;0,2-0}=0,2

$d_{23}$= max {0,2-0; 0,1-0;1-0,8}=0,2

$d_{31}$= max {0,15-0; 0,2-0,1}=0,15

$d_{32}$= max {0,05-0;1-0,92}=0,08

Having all the indices computed, the discordance matrix is presented in the table below.

**Table 13. The discordance matrix**

| *Alternatives* | *$A_1$* | *$A_2$* | *$A_3$* |
|---|---|---|---|
| $A_1$ | - | 0,2 | 0,4 |
| $A_2$ | 0,2 | - | 0,2 |
| $A_3$ | 0,15 | 0,08 | - |

**Step 3. We choose** threshold, **c***, and a (relatively low) discordance threshold, **d*** as:

C*=0,6 and D*=0,4;

Therefore,

$c(A_i, A_j) > 0.60$ and $d(A_i, A_j) < 0.40$.

Controlling for these inequalities in concordance and discordance matrixes, we find that $A_1$ outranks alternatives $A_2$ and $A_3$, and hence, it is the best car to choose.

Sometimes, this is represented as a graph, as in the next figure:

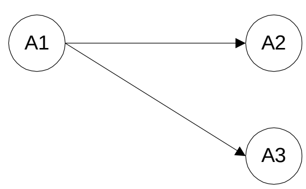


Figure 2. The graph of options outrankig

By this method, we cannot say that alternative $A_2$ outranks or is more preferred to alternative $A_3$.

As conclusions to this chapter, in the following table the results of applying the three quantitative methods are presented.

**Tale 14. Comparison between the three methods**

| *Alternatives* | *AHP* | *WEIGHTED SUM* | *ELECTRE I* |
|---|---|---|---|

| | | | |
|---|---|---|---|
| $A_1$ | 0,23 | 0,27 | $A_1$ outranks $A_2$ AND $A_1$ outranks $A_3$ |
| $A_2$ | 0,15 | 0,20 | |
| $A_3$ | 0,19 | 0,25 | |

The three methods are converging to the same results; the conclusion is that option A1 in the best alternative and therefore it should be preferred by the decision maker.

# 4. MCA IN THE CONTEXT OF STRUCTURAL INSTRUMENTS IMPLEMENTATION

## 4.1 DIFFERENCES BETWEEN MCA AND CBA

As it is mentioned in the introductive chapter, one of the objectives of the Handbook is to set the use of MCA in the context of CBA. In this sense, in this section it is carried out a comparative analysis of the two methods.

Based on the knowledge on MCA provided in previous chapters, several conceptual differences between MCA and CBA seem obvious and they are worth to be mentioned. These are briefly synthesized in Table 15.

**Table 15.** ***Differences between MCA and CBA***

| MCA | CBA |
|---|---|
| **MCA incorporates other types of criteria such as distributional, equity, ecological, social and others.** | **CBA is based on economic efficiency criteria.** |
| **Alternatives are not being based exclusively on money valuations.** | **Alternatives are evaluated by performance criteria (e.g., NPV) that are measured in monetary terms.** |
| **It evaluates both quantitative or qualitative data and a combination of the two.** | **It requires only quantitative data.** |
| **It facilitates a participatory approach to decision-making, involving the stakeholders.** | **It relies only on the experience and perceptions of the applicant.** |

The main types of data required for an MCA include scientific, social and economic information about the problem to be addressed, as well as information obtained from identified stakeholders.

The MCA advantages, as well as the disadvantages of the method, are described below.

*Advantages of MCA*

- Compared to CBA, it enables a more realistic representation of the decision problem to be made, and in particular for the trade-offs to be made explicit.
- The interactive nature of the approach enables both the analyst and the decision maker to learn more about the problem.
- Although MCA is a structured approach, it is flexible enough to allow the use of value judgment.
- It is suitable for problems where monetary estimates of the effects are not readily available. Allows qualitative measures.
- Participation and legitimacy.

*Weak points of MCA*

- Although MCA does not necessarily require quantitative or monetary data, the information requirements to compile the effects table and derive the weights can, nevertheless, be considerable.
- Although the weights used in the process are explicit weights, the analyst may unintentionally introduce implicit weights during the evaluation process. If not properly used MCA has the potential to become a 'black box', producing results that cannot be explained.
- Potential ambiguity, subjectivity.
- Some components of arbitrariness, especially in the perception of public costs vs. private benefits, as noticed by Maltese et al. (2010)[23].
- Lack of clarity, consistency, accountability.

## 4.2 CIRCUMSTANCES IN WHICH MCA MAY BE APPLIED

The question on when to use CBA, when to use MCA – and when, possibly, a combination of the two – is quite difficult to answer. We have identified several specific aspects on which the possible answers depend on: the life cycle of investment projects; the specific field in which the project is submitted; the complexity of the problems to be solved through project' objectives, the nature of the relevant effects as well as the extent to which these effects can be quantified and assigned a monetary value; the size of the project.

Of course, all these must be considered together when opting for MCA, given the fact they are inter-related.

### 4.2.1 MCA RELATED TO THE LIFE CYCLE OF THE INVESTMENT

It must be first underlined that MCA means comparison between projects with various objectives or implies comparison between options of the same project.

Taking into account this primary utility of MCA and applying it to the life cycle of investment projects funded by ERDF and CF, this Handbook comes to the following uses of the MCA:

- The ***programming phase*** of Structural Instruments

  In this context, MCA has to be connected with the objectives of the operational programmes. Once the objectives of an Operational Programme are decided upon, MCA can be used as a method, by the responsible programming authority, in order to determine which ones of a series of alternative investment options are more likely to lead to meeting the objectives that were set for the programme. Thus, the key areas of intervention and the operations of the programme can be decided upon by applying MCA to a range of possible investment alternatives.

- The ***preparation of projects***

[23] Beria, Paolo, Maltese, Ila, Mariotti, Ilaria - Comparing cost benefit and multi-criteria analysis: the evaluation of neighbourhoods' sustainable mobility, Società Italiana degli Economisti dei Trasporti - XIII Riunione Scientifica –Messina 2011

In general, MCA is mainly used in *ex ante* evaluations of public investment projects and their variations (the layout of a highway, the construction of a new infrastructure, etc.).

When preparing a project, the applicant for funding by ERDF and CF is first selecting among different project alternatives. In this context, MCA is used for selecting from among a series of project alternatives the best one, the one for which co-financing will be requested. In this case, MCA serves the applicant as a decision making tool.

Provided that the Managing Authority has requested the applicant to use MCA (see below the next bullet point – "the evaluation and selection of projects"), this will have to document the application of the method to his/her project and attach the resulting material to the financing request which is submitted to the Managing Authority/Intermediate Body.

We underline here, that if a CBA is being prepared for a given project, then MCA can be used in the second step of the CBA: the identification of the project's scenarios and options (for a detailed analysis of this issue, please consult the Working Paper No 8 "Identifying and defining technical-economic scenarios and options in CBA"). The scenarios and options can be identified by using MCA.

- The ***evaluation and selection of projects***

MCA may be also used in the **projects' appraisal process**, but with the following limitations:

- MCA means comparison between projects with the same objectives or it means comparison between options of the same project. MCA is a tool for the selection of alternative projects with the same objectives (quantified in physical terms). In this sense, the method cannot be used for appraising a project based on certain output values like in the case of CBA (financial or economic performance indicators).
- MCA alone is not sufficient in itself to justify a project; even it provides information in order to select an option, it does not provide anything about financial sustainability of the selected project / alternative. An additional tool to MCA (CBA or others) should be used in the project appraisal process in order to evaluate the financial sustainability of a proposed project.

Bearing in mind these limitations, the Managing Authority may decide to ask the applicants to prepare for their project a MCA, then the MCA of a given project should be assessed:

- as part of *the eligibility check* phase of the evaluation and selection process. As such, the aim of the responsible officer in charge with the eligibility check will be to verify correctness of the application of the MCA method[24];
- as part of the *technical and financial evaluation*, as a sub-criteria criteria for scoring the quality and the maturity of the proposed project. As such, the aim of the evaluator will be to score the soundness of MCA application.

[24] see the Check list provided in Annex 3 of the present Handbook.

Maybe the best use of MCA is in the **selection phase** of the process. In this context, the Managing Authority will use MCA for selecting among different projects, which passed the evaluation phase, in order to decide which one will be co-financed (given the limited budget at disposal).

But, in the actual programming period, in most of the cases (ROP and SOP IEC), the process of project appraisal is a continuous one, and this approach do not allow MCA usage, because the appraisers evaluate the projects one by one, without any comparison between them. In order to use MCA in a continuous process, the managing authorities should develop benchmarks for recommended MCA categories. MCA categories should be in line with program objectives and indicators and reflect the contribution of the projects to these objectives. Benchmarks MCA categories could be developed during programming stage, in line with the operational programmes, based on statistical data from previous programming periods. They will be up-dated based on data from the new implemented projects.

It is relatively easy to transfer criteria, scoring scales and weightings to the project selection system if this system is also organised on the basis of scoring-weighting. By basing the selection of projects on the same logic as the evaluation of measures, the chances of stimulating and funding projects which contribute effectively to the programme priorities are increased. Therefore, applying the MCA in elaborating the project is creating the premises for applying the same method in order to select between projects.

- The ***ongoing*** and ***ex-post evaluation of programmes***

Multi-criteria analysis is also applied to *the ongoing or ex post evaluations* of programmes, supporting the decision making on the reallocation of budgets, either while the project/programme is underway or during the preparation of the following project/programme. The main decisions in this respect are taken at the measures level. These are evaluated while the programme is ongoing, in order to establish which of the measures are the most effective. MCA is involved in ranking the measures by applying specific methods. Measures judged to be the least successful must be re-examined with a view to either reducing their budgets or re-organising them to enhance their effectiveness. Where relevant, recommendations can also be made to increase the budgets of those measures ranked as being the best.

MCA has often been adopted for *ex post* evaluating the level of general sustainability at lower scales, as in Nijkamp, (1993)[25]. However, it probably has potential for wider use as a tool in intermediate and ex post evaluations as an aid for making a judgment. Therefore, the method could be successfully applied by project applicants when selecting options for a specific project[26], connected with the multiple objectives of that project.

---

[25] Nijkamp P., Blaas E. (1993), *Impact assessment and evaluation in transportation planning*, Kluwier Academic, Dordrecht, The Netherlands

[26] Within the framework of the same project in which the present handbook was prepared, also an Working Paper (No 8) "Identifying and defining technical-economic scenarios and options in CBA" was drafted. For more details on these aspects please refer to the mentioned working paper.

### 4.2.2 MCA RELATED TO THE SECTOR OF THE PROJECT

If we focus on the ***sector of the project*** (transport, agriculture, environment, sustainable development etc.), we should notice that after the popularity of CBA and other financial-economic evaluation methods we have seen an increasing popularity in Multi-criteria methods. Such methods can be used for various purposes. Because they are applicable to every situation, they can be used in project management in many different ways. Therefore, ***we do not consider that MCA should be recommended only for some specific sectors, since it has been proved to be useful in various types of investment projects, under different programmes. The method could be generally applied no matter the project sector.***

Beria, Paolo, Maltese, Ila, Mariotti, Ilaria (2011) are providing a useful review of the circumstances in which MCA has been applied, considering the field of the project. Following their work, we briefly present several EXAMPLEs of sectors in which MCA was applied, alone or integrated with CBA.

- **Transport:** in the EU Member States different evaluation techniques are adopted with a great prevalence of CBA. In most of the cases, CBA is supplemented by a specific appraisal for impacts that are difficult to be monetized (Sweden, Netherlands, UK); in some others (i.e. Belgium, Austria and Greece), MCA is used, but it includes CBA as one of the criteria. In France, CBA has recently been considered weak in stimulate stakeholders' interactions, thus, in order to create a larger public debate, MCA tools have also been adopted (Damart and Roy, 2009)[27].
- **Sustainable development**: for instance, in the ExternE-Pol project it was possibile to integrate Multi-criteria methodology into the wider structure of CBA (Diakoulaki and Grafakos, 2004) by using a specific framework. Doing so, all the stakeholders' preferences could be exploited, thus deriving indirect monetary values for environmental goods and impacts.
- **Environmental impacts assessment from transportation projects**: either for small-scale (local) or large-scale (regional/national), a combination of CBA and MCA has been developed, titled EFECT[28] (Tsamboulas, D., Mikroudis, G., 2009).
- **Sustainable mobility at neighbourhood level:** MCA has been adopted (Maltese et al., 2011), while no specific evidence has been provided for the application of CBA. This is due to the fact that CBA well fits in the assessment of specific infrastructures or policies where monetary or monetizable costs and benefits prevail (investment, time, environmental benefits, etc.) therefore when it is applied to assess soft policies at the urban scale, it can be well supplemented by a broader evaluation approach like MCA. The MCA, indeed, effectively evaluate effects like social inclusion, change in behaviour of citizens, change in the use of city, quality of life, etc.

The following table seeks to illustrate the possibilities of using the Multi-criteria analysis per different investment sector, in the process of management and implementation of Structural Instruments. Eight different investment sectors are considered here, corresponding to the investments types that are currently

[27] Damart, Sebastien, Roy, Bernard. (2009). The uses of cost-benefit analysis in public transportation decision-making in France. Transport Policy, Volume 16, Issue 4, pp 200-212.

[28] EFECT (Evaluation Framework of Environmental impacts and Costs of Transport) is a methodological framework which aims to cover all kinds of transport environmental initiatives, namely policies, plans and projects, by using an additive function.

supported by ERDF and CF through the Regional Operational Programme, the Sectoral Operational Programme Increase of Economic Competitiveness and the European Territorial Cooperation Programmes. For when to use MCA for these investment sectors please refer also to chapter 4.2.0 "MCA related to the life-cycle of the investment".

The investments at national level, supported through SOP Transport and SOP Environment were intentionally omitted, given the fact that these are mainly major projects and the main (compulsory) method used is the Cost-Benefit Analysis (CBA).

It should be stressed although that MCA can be used in conjunction with CBA (in case of those projects for which CBA is required[29]), as a method subscribed to the CBA step of alternatives/options analysis[30].

In this context, for the investments types mentioned in the table below, the purpose is to identify the possibility of using MCA, in case of them, ***as an alternative method to CBA***. Practically, this implies applying for such projects only the CBA step of alternatives/options analysis but in a different way, by using the MCA method.

Again, we stress that MCA alone is not sufficient in itself to justify a project; even it provides information in order to select an option, it does not provide anything about financial sustainability of the selected project / alternative. An additional tool (we are not considering here CBA) should be used in the project appraisal process in order to evaluate the financial sustainability of a proposed project.

Thus, the table below identifies the investment types and then indicates for which purpose to use MCA. Additionally, the stakeholders that should apply MCA /should be consulted in a MCA are identified.

**Table 17. Applicability of MCA and CBA related to the sector of the project**

| Investment sector | Use of MCA | Involved stakeholders |
|---|---|---|
| ▪ Local and regional ***transport*** infrastructure | Determining the best option available for making the investment. Answering to the following question: why should a certain transport infrastructure be supported and not another similar one. | The applicant and the direct beneficiaries of the investment. |
| ▪ ***Environment*** | Determining the best option available for making the investment. Answering to the following question: why should a certain environment investment be supported and not another one. | The applicant and the direct beneficiaries of the investment. |
| ▪ Social infrastructure (***social services, health, public safety, education***) | All of these types of investments are made out of necessity. So, the main question, in a context of limited resources is how to distribute these resources to the best effect.<br>In case of health and public safety investments, | The Managing Authority, the Intermediate Bodies, the members of the Coordination Committees at |

[29] Under the same the same framework as the present Handbook, respectively the project "Development of the capacity for the Cost-Benefit Analysis", financed by ERDF through TAOP, the Working Paper No 2 "Role of performance indicators in selection/approval of projects" recommended the use of CBA for projects with a value over 5 million Euro, while Working Paper No 1 "Cost Benefit Analysis and other methods for evaluating projects financed by ERDF and CF" recommended not use CBA for projects that have a social role (schools, churches, hospitals etc.) and for projects in which is difficult to determine the economic costs and benefits.

[30] For scenarios and options analysis in a CBA, please refer to the Working Paper No 8 "Identifying and defining technical-economic scenarios and options in CBA", document prepared under the same framework as the present Handbook, respectively the project "Development of the capacity for the Cost-Benefit Analysis", financed by ERDF through TAOP.

| | | |
|---|---|---|
| | whose number is also limited at regional and local level, through the use of MCA it could be determined ex-ante (in the programming phase) which such infrastructure should be supported against others.<br>In case of social services and education types of investments, given the fact that a numerous number of these facilities exist in each region, county, MCA could be used for determining the best option available for making the investment. Respectively for answering to the following question: why should a certain social service/education infrastructure be supported and not another similar one. | programme level for health and public safety investments.<br>The applicant and the direct beneficiaries of the investment, in case of social services and education investments. |
| ▪ Regional and local development of ***business environment*** (business support structures, rehabilitation of unused industrial facilities, micro-entreprises, investments in innovative production systems by entreprises) | Determining the best option available for making the investment. Answering to the following question: why should a certain business investment should be made and not another similar one. | The applicant and the direct beneficiaries of the investment. |
| ▪ ***Tourism*** (tourism infrastructure, restauration of the cultural and historical heritage) | For investments regarding the restoration of the cultural and historical heritage, such as museums and cultural sites, churches, monasteries, are made out of necessity. So, the main question, in a context of limited resources is how to distribute these resources to the best effect.<br>In their case, through the use of MCA it could be determined ex-ante (in the programming phase) which such infrastructure should be supported against others.<br>In case of tourism infrastructure investments, MCA could be used for determining the best option available for making the investment. Answering to the following question: why should a certain tourism investment should be made and not another similar one. | The Managing Authority, the Intermediate Bodies, the members of the Coordination Committees at programme level for investments regarding the restoration of the cultural and historical heritage.<br>The applicant and the direct beneficiaries of the investment, in case of tourism infrastructure investments. |
| ▪ ***Research*** and technical development | Determining the best option available for making the investment. Answering to the following question: why should a certain research investment should be made and not another similar one. | The applicant and the direct beneficiaries of the investment. |
| ▪ ***Information technology*** for both public and private sectors | Determining the best option available for making the investment. Answering to the following question: why should a certain IT investment should be made and not another similar one. | The applicant and the direct beneficiaries of the investment. |
| ▪ ***Energy efficiency*** (renewable resources, diversification and interconnection of energy networks) | Determining the best option available for making the investment. Answering to the following question: why should a certain energy efficiency investment should be made and not another similar one. | The applicant and the direct beneficiaries of the investment. |

### 4.2.3 MCA RELATED TO THE SIZE OF THE PROJECT

When taking into account the ***size of the project***[31], especially in transport infrastructure projects, the existence of multiple effects depends to a large degree on the size of the project. Gissel and Leleur (2004) connect the role of the size project with the stage of planning the project, in the case of transport infrastructure projects. They recommend the use of MCA in early stage of planning the project, both for large and for small project. In more advanced stages of planning the projects, they recommend CBA for small projects and a joint use of CBA and MCA for large projects.

In the case of considering the stage of project submission, when not all the effects are quantifiable, MCA should be applied for selecting among various options of the project, both for the major and for the non-major projects.

In the case of ***non-major projects***, with multiple effects, CBA could be a part of MCA. At the same time, in proposal stage of the project, when only a limited amount of data exists, it is possible that MCA is the only method applied. In such cases, therefore in early planning phases, the method is useful by itself in selecting among projects alternatives. The specific cases are focused on projects with a limited number of objectives, and with less economic effects, but with strong social, environmental or even political effects. If these effects are not quantifiable, MCA is the method that is successfully applied in selecting between project's alternatives. In such cases, MCA is not so expensive, due to the small area of analysis and the consequent number of the stakeholders to be consulted. It is important to emphasize the fact that when MCA is conducted as alternative to CBA, the economic objectives are evaluated through economic criteria, such are, for instance, financial rates; these are introduces in the MCA framework alongside with other types of criteria.

In the case of ***major projects*****,** with multiple objectives and quantifiable economic effects, CBA and MCA should both be applied in the proposal stage of the project.

**For example**, when selecting the alternatives for constructing a bypass for a city, the objectives are:

- Economic: to ensure the optimum costs of investment;
- Environmental: to preserve the landscape,
- Accessibility: to promote the network accessibility and the urban development.

The criteria that might evaluate these objectives are:

- **Benefits/Costs** rate is the rate between Total benefits and construction costs. Total benefit is the sum of CBA benefit elements over a 30-year period – discounted to the base year. Construction costs are obvious.
- **Landscape;**
- **The network accessibility;**

[31] Working paper no. 2 from the present project is reviewing the project definitions according to their size. We briefly remind that in the present framework are considered as well as major projects and non-major projects. In the programming period 2007-2013, in the General Regulation for the Structural and Cohesion Funds, major projects are defined as those with a total cost exceeding €25 million in the case of the environment and €50 million in the case of all the other sectors (Article 39 Regulation 1083/2006). This financial threshold is €10 million for IPA projects (Article 157(2) Regulation 718/2007).

- **Urban planning;**

The last three are measuring strategic effects, being qualitative criteria. For their case, the stakeholders and experts are consulted in order to assign scores. Weights could be also assign by experts or computed, for more transparency and objectivity, through one of the methods mentioned in previous chapter.

**Table 17. Applicability of MCA and CBA related to the size of the project**

| Size of the project | Methods applied in selecting among projects alternatives |
|---|---|
| Small projects | MCA |
| Large projects | MCA and CBA |

### 4.2.4 MCA RELATED TO THE COMPLEXITY OF THE PROJECT

When considering the complexity of the projects, MCA is most appropriate in case where complex problems should be solved, with **multiple objectives** and important effects. The projects could also raise difficult political questions of a principle nature. For CBA to be "enough", there should be no important effects, which cannot be given an economic value. When this is not the case, CBA should be supplemented with qualitative and possibly quantitative analyses, such as MCA. With the widely accepted CBA as a solid base for project assessment, a clear step towards more comprehensive analyses would be extending the assessment with MCA data. For instance, in such cases, CBA could be integrated as a part of MCA[32], as an economic criteria in the analysis, in the manner descried in the example above.

In case of the projects that are currently supported by ERDF and CF through the Regional Operational Programme, the Sectoral Operational Programme Increase of Economic Competitiveness and the European Territorial Cooperation Programmes, the objectives are complex in most of the cases and the nature of these objectives could be social, economical, environmental, political. **At the same time, MCA could be applied in the cases in which the project has simple objectives and these objectives are rather qualitative in their nature, being less quantifiable. As mentioned above, these kind of projects are less probable to be financed by ERDF and CF.**

**Table 18. Applicability of MCA and CBA related to the complexity of the project**

| **Types of the objectives \ Type of project** | **Many objectives quantifiable** | **Few objectives quantifiable** |
|---|---|---|
| **Complex project:** | **CBA+MCA** | **MCA** |

[32] A comprehensive example on Danish transport projects is also detailed in Gissel Goldbach, Stine and Leleur, Steen (2004)- Cost-Benefit Analysis and alternative approaches from the Centre for Logistics and Goodds. Study of evaluation techniques, 2004

| | | |
|---|---|---|
| **Many objectives and many effects** | | |
| **Simple projects:**<br>**Few objectives, few effects** | **CBA** | **MCA** |

This chapter is emphasizing the complexity of deciding what method is the most appropriate in investment project appraisal: MCA, CBA or a combination of the two. We have tried to provide guidance in selecting the method, considering the characteristics of the methods, the advantages or disadvantages, and, most important, having in mind the various characteristics of the project. A large literature was consulted in this respect, but at the same time the lack of practical experience in Romania in applying MCA in project appraisals is considerably limiting the analysis, by not providing a significant collection of case studies. In these circumstances, the manual should be completed in time with case studies based on Romanian context, in ordered to provide better fundaments in decision process.

# 5. CONCLUSIONS

The aim of this manual is to offer decision-makers a methodological framework in order to analyse the alternatives in the case of investment project submission under the EU funded programmes. In this respect, MCA could be employed. Multi-criteria analysis is proposed as an alternative to CBA because it addresses a broader range of project impacts, speaks more directly to decision-makers' concerns and is open to alternative assessments of the weights that various impacts receive.

Being addressed to a large public, ranging from various applicants, experts, analysts to governmental evaluators, the manual aimed to be written in a comprehensive and simple style.

We conclude that there is considerable synergy between the methods and the opposition of MCA and CBA, seems largely artificial. MCA could be successfully applied in few specific cases without the support of CBA, in selecting among projects alternatives. At the same time, as noticed, a joined used of the MCA and CBA is also recommended. Among others, Tudela[33] (2006) suggests a combination of the two methods.

MCA usually includes CBA for a project's impacts on economic efficiency and then monetises less tangible impacts to derive an overall quantitative indicator of the broader net value of the project. At the same time, MCA remains restrictive in that for some impacts, satisfactorily objective monetization techniques have so far proved elusive (e.g. for landscape impacts). One other important feature of MCA is that it enables different weights to be attached to different aspects of the evaluation. In CBA, the weights (that is, the monetary valuation of physical effects) are determined on the basis of the best available evidence. In MCA, weights can reflect evidence, expert opinion, or maybe even policy preferences, but also can introduce subjectivity into the analysis.

[33] Tudela A., Akiki N., Cisternas R. (2006). Comparing the output of cost benefit and multi-criteria analysis. An application to urban transport investments, *Transportation Research Part A*, 40 (2006), 414–423.

# 6. REFERENCES


1. Baker, D., Bridges, D., Hunter, R., Johnson, G., Krupa, J., Murphy, J. and Sorenson, K. (2002) *Guidebook to Decision-Making Methods*, WSRC-IM-2002-00002, Department of Energy, USA. http://emi-web.inel.gov/Nissmg/Guidebook_2002.pdf
2. Beria, Paolo, Maltese, Ila, Mariotti, Ilaria - Comparing cost benefit and multi-criteria analysis: the evaluation of neighbourhoods' sustainable mobility, Società Italiana degli Economisti dei Trasporti - XIII Riunione Scientifica –Messina 2011
3. Damart, Sebastien and Roy, Bernard. (2009). The uses of cost-benefit analysis in public transportation decision-making in France. Transport Policy, Volume 16, Issue 4, pp 200-212.
4. DfT (2007), The NATA Refresh: Reviewing the New Approach to Appraisal. Department for Transport.
5. DG REGIO (2008), Guide to Cost-Benefit Analysis of investment projects. Structural Funds, Cohesion Fund and Instrument for Pre-Accession, European Commission, Directorate General Regional Policy.
6. Diakoulaki, D., S. Grafakos (2004), Externalities of Energy: Extension of Accounting Framework and Policy Applications. Final Report on Work Package 4.
7. Dias, L., V. Mousseau, J. Figueira, J. Clímaco (2002), "An Aggregation/Disaggregation Approach to Obtain Robust Conclusions with ELECTRE TRI", European Journal of Operational Research, vol 138, 332-348.
8. Dobre, I. , Bădescu, A. , Păuna, L. ( 2007), Teorie Deciziei, Editura ASE, Bucureşti.
9. Dobre, I. Bădescu, A., Irimiea, N. C. (2000), Teoria deciziei – Studii de caz, Editura SCRIPTA, Bucureşti.
10. European Commission, 2008, Guide to cost-benefit analysis of investment projects, http://europa.eu.int/comm/regional_policy/sources/docgener/guides/cost/guide08_en.pdf
11. Figueira, J., Greco, S., Ehrgott, M., Multiplecriteria decision analysis: state of the art of surveys, Kluwer Academic Publishers, Boston/Dordrecht/London, 2008.
12. Gissel Goldbach, Stine and Leleur, Steen (2004)- Cost-Benefit Analysis and alternative approaches from the Centre for Logistics and Goodds. Study of evaluation techniques, 2004
13. ITF - Improving the Practice of Cost Benefit Analysis in Transport, Discussion Paper No. 2011-1, International transport forum, OECD Publication, Paris. www.internationaltransportforum.org/jtrc/DiscussionPapers/jtrcpapers.html
14. Keeney, R.L., Raiffa, H.: *Decisions with multiple objectives*, John Wiley & Sons, 1976.
15. Nijkamp P., Blaas E. (1993), *Impact assessment and evaluation in transportation planning*, Kluwier Academic, Dordrecht, The Netherlands.

16. Proctor, W. 2000 'Towards Sustainable Forest Management, An application of Multi-criteria, Analysis to Australian Forest Policy', Paper presented to the Third International Conference of the European Society for Ecological Economics, May 3 - 6, Vienna, Austria.
17. Roy, Bernard (1968). "Classement et choix en présence de points de vue multiples (la méthode ELECTRE)", *la Revue d'Informatique et de Recherche Opérationelle (RIRO)* (8): 57–75.
18. Roy (1974) "Critères multiples et modélisation des préférences: l'apport des relations de surclassement", *Revue d'Economie Politique,* 1.
19. Roy B. and Buyssou D. (1993), Aide Multicritère la décision: Méthodes et Cas, Paris: Economica,
20. Saaty, T. 1980, *The Analytic Hierarchy Process*, McGraw-Hill, New York.
21. Saaty, T. 1982, *Decision-making for Leaders*, Wadsworth, California.
22. Tsamboulas, D., Mikroudis, G. (2000) "EFECT - evaluation framework of environmental impacts and costs of transport initiatives", *Transportation Research Part D,* **5**, pp. 283-303
23. Tudela A., Akiki N., Cisternas R. (2006). Comparing the output of cost benefit and multi-criteria analysis. An application to urban transport investments, *Transportation Research Part A*, 40 (2006), 414–423.
24. Vincke, P. (1992) *Multi-criteria Decision-Aid,* John Wiley, Chichester.
25. Vreeker, R., Nijkamp, P., Ter Weller, C. (2002) "A Multi-criteria decision support methodology for evaluating airport expansion plans", *Transportation Research Part D*, **7**, pp. 27-4
26. ***- Evaluating Socio Economic Development, SOURCEBOOK 2: Methods & Techniques. Multi-criteria analysis, http://ec.europa.eu/regional_policy/sources/docgener/evaluation/evalsed/sourcebooks/method_techniques/evaluating_alternatives/multi_criteria/index_en.htm
27. ***- Guidebook to decision-making methods, WSRC-IM-2002-00002, the U.S. Department of Energy, 2001, http://www.dss.dpem.tuc.gr/pdf/Decision%20Making%20Guidebook_2002.pdf
28. ***Methodology for Multi-criteria Analysis of Agri Environmental Schemes
29. *** Multi-criteria analysis: a manual, January 2009, Department for Communities and Local Government: London.

# 7. ANNEX 1

## 7.1 METHODS FOR STANDARDIZING THE PERFORMANCE MATRIX

Various methods to standardize scores are available[34]: linear scale transformation methods like maximum standardization, interval standardization and goal standardization and also non-linear value function approach.

**Notations used:**

i-The index for alternatives

j- the index for criteria

$A_{ij}$- the score for alternative I against criterion j

$R_{ij}$- the normalized scored after applying a standardizing method

**a. Vector Normalizing Method**

- $r_{ij} = \frac{a_{ij}}{\sum_{i=1}^{m} a_{ij}^{2}}$ (1)
- $r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^{2}}}$ (2)

**b. Normalization through linear transformation**

- *for a criterion to be maximized:*

$$r_{ij} = \frac{a_{ij}}{a_j^{max}}, \quad a_j^{max} = \max_i\{a_{ij}\} \qquad (3)$$

- *for a criterion to be minimized:*

$$r_{ij} = 1 - \frac{a_{ij}}{a_j^{max}} = \frac{a_j^{max} - a_{ij}}{a_j^{max}} \qquad (4)$$

**c. The *score range* method.**

- *for a criterion to be maximized*

$$r_{ij} = \frac{a_{ij} - a_j^{min}}{a_j^{max} - a_j^{min}}, \quad a_j^{min} = \min_i\{a_{ij}\} \qquad (5)$$

- *for a criterion to be minimized*

[34] See Dobre, I. , Bădescu, A. , Păuna, L., Teorie Deciziei, Editura ASE, Bucureşti, 2007.

$$r_{ij} = \frac{a_j^{max} - a_{ij}}{a_j^{max} - a_j^{min}} \qquad (6)$$

The values of normalized scores $r_{ij}$ are in the range of [0;1].

# 8. ANNEX 2

## 8.1 SOFTWARE PRODUCTS

Though the MCA methods described in this manual do not demand more than simple pencil and paper, there situation in which complicated calculus procedures might be involved. In this respect, there are several widely applied software products, both by academics and practitioners; The advantages[35] to using some computer support, such are:

- easy amendment to input data (including sensitivity testing).
- attractive and informative presentation of outputs.

Very brief description is presented here for several better known packages used for MCA,

❖ HIVIEW package was originally created over twenty years ago at Decisions and Designs, Inc. With support from ICL, the London School of Economics continued the development in the 1980s, producing a DOS version that could be used easily in a group setting.

It is available at www.LSE.ac.uk/Enterprise

❖ The next six products created at Lamsade: ELECTRE IS, ELECTRE III-IV and ELECTRE TRI, IRIS, UTA+ and SFA. The Lamsade is a French laboratory located in the Paris Dauphine University, it was created by Bernard Roy in 1976. Lamsade stands for Laboratoire d'Analyse et de Modélisation des Systèmes pour l'Aide à la Décision.

IRIS[36] is a Decision Support Software designed to address the problem of sorting a set of actions (alternatives, projects, candidates) into predefined ordered categories, according to their evaluations (performances) at multiple criteria. IRIS implements the methodology presented in Dias et al. (2002).The main characteristics or IRIS (version 2.0) are:

- IRIS implements a variant of the pessimistic ELECTRE TRI, where the outranking relation is defined as proposed by Mousseau and Dias (2002)[37].
- Allow decision makers to build sorting models in a progressive and interactive manner, where the output at a given iteration is used to guide the revision of the input for the following iteration.

The software is available at www.lamsade.fr .

❖ VISA is a Windows-based implementation of the basic MCDA model. It is marketed by Visual Thinking and has been developed at Strathclyde University. It could be found at www.visualt.com

❖ Desysion Desktop supports application of the MCDA model in a Windows environment. Developed by the company DecideWise International BV in Amsterdam, it implements MCDA in a way that places

[35] Multi-criteria analysis: a manual, January 2009, Department for Communities and Local Government: London
[36] IRIS stands for Interactive Robustness analysis and parameters' Inference for multi-criteria Sorting problems
[37] Dias, L., V. Mousseau, J. Figueira, J. Clímaco (2002), "An Aggregation/Disaggregation Approach to Obtain Robust Conclusions with ELECTRE TRI", European Journal of Operational Research, vol 138, 332-348.

special emphasis on guiding decision makers through the whole of the overall process of decision making.

The software is available at www.decidewise.com

# 9. ANNEX 3

## 9.1 CHECK-LIST FOR MCA EVALUATORS

The purpose of this Annex is to provide a checklist through which the quality of a MCA applied in order to select the best alternative of a project, can be assessed. It is meant to be an instrument to provide a quick reference to. This Checklist is based on the MCA steps as described in the Section 2 of the present manual.

The checklist can be used by the project evaluators, in the case of the project that have applied MCA in order to discriminate between alternatives. In the same time, it could be a useful instrument for applicants when developing a MCA.

1. **Establish the decision context**.
    - Was the field of the analysis clearly delimited?
    - Is the use of the multicriteria analysis justified by an evaluation question?
    - Are the objectives of the project clearly defined and understood?
2. **Define options**.
    - Has the list of options to be compared in the multi-criteria analysis been elaborated or approved by the beneficiaries and experts of the sector?
    - Are the options clearly defined?
    - Are the options clearly explained and described?
3. **Define criteria**.
    - Was the group representative of all the stakeholders concerned by the project?
    - Are the criteria independent?
    - Are the criteria defined through appropriate indicators?
    - Has the coherence of the criteria been checked?
    - Are the usual types of criteria (economic, environmental, social and political) all represented?
4. **Create performance matrix and standardize the scores.**
    - Has a performance table been established?
    - Are the standardization procedure applied?
5. **Weighting of criteria**
    - How was selected the weighting procedure?
    - Is the weighting procedure clearly explained?
    - Are the weights developed through direct estimation of experts?

- Have the rules for the setting up of the list of evaluation criteria been clearly explained to the group of experts?

6. **Ranking of options**

- How were selected the MCA methods involved in ranking the options?
- Was selected the most appropriate method?
- Was the method correctly applied?

7. **Examine the results**.

- Has result of the analysis be obtained in a sufficiently reliable way to be useful for the evaluation?
- Are the results presented in a synthetic and comprehensive manner?

# 10.GLOSSARY

| | |
|---|---|
| ***Alternatives or Options*** | The specific ways of achieving objectives. |
| ***Analitical Hierarhy Process (AHP)*** | Multicriteria analysis method based upon the construction of a series of 'pair-wise comparison' matrices which compare criteria to one another. |
| ***Criterion*** | one of a number of measures against which options are assessed and compared for the degree to which they achieve objectives. Each criterion should measure something relevant and not depend on another criterion. |
| ***ELECTRE method*** | A procedure that sequentially reduces the number of alternatives the decision-maker is faced with in a set of non-dominated alternatives. |
| ***Multicriteria Analysis (MCA)*** | A structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives. |
| ***Objectives*** | The purposes which an organisation wishes to achieve or finance |
| ***Performance matrix or decision matrix or*** *consequence table* | Matrix in which each describes an option and each column describes the performance of the options against each criterion. |
| ***Scoring,*** | The expected consequences of each option for each criterion are assigned a numerical score on a strength of preference scale |
| ***Standardisation*** | The process through which the criterion values expressed in different measurement units are transformed into a common scale, which allows their comparison. |
| ***Weighting*** | The numerical weights assigning to define, for each criterion, the relative valuations of a shift between the top and bottom of the chosen scale |

Any comments or suggestions regarding this document may be submitted on:
*http://www.evaluare-structurale.ro/index.php/en/cost-benefit-analysis/forum*

Additional information are available on internet:
http://www.evaluare-structurale.ro

Contract No 46/ 8.12.2010

„Development of the Capacity for the Cost-Benefit Analyisis"

Project co-financed by the European Regional Development Fund through the Technical Assistance Operational Programme 2007-2013