Annex 7.2.5.
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**Report on the use of MCDA in EIA and SEA**

# A literature review
# –
# The use of multi-criteria decision analysis in Environmental Impact Assessment

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NOTE. This paper is not a scientific paper. The paper is compiled mainly for the internal use of the IMPERIA project (LIFE11 ENV/FI/905) in order to get a better overall understanding about the issue of using multi-criteria decision analysis in the environmental impact assessment. Lot of the texts is copied from the referred articles.

# 1. Introduction

A literature review, "The use of multi-criteria in Environmental Impact Assessment and Strategic Environmental Assessment", was carried out by the Thule Institute, University of Oulu in 2012 (research was updated and widened in spring 2013). The literature review introduced in this report was conducted as a part of the tasks in the IMPERIA project (LIFE11 ENV/FI/905). The aim of the review was to find out international articles and experiences on the use of MCDA in Environmental Impact assessment (EIA) in order to survey good practices and benefits of supporting EIA process with MCDA methodologies.

Environmental impact assessment is herein called assessments that are based on EIA directive (as stated by European Commission, Environment). *The EIA Directive (85/337/EEC) is in force since 1985 and applies to a wide range of defined public and private projects, which are defined in Annexes I and II:*

- *Mandatory EIA: all projects listed in Annex I are considered as having significant effects on the environment and require an EIA.*
- *Discretion of Member States (screening): for projects listed in Annex II, the national authorities have to decide whether an EIA is needed. This is done by the "screening procedure", which determines the effects of projects on the basis of thresholds/criteria or a case by case examination. However, the national authorities must take into account the criteria laid down in Annex III. The projects listed in Annex II are in general those not included in Annex I (railways, roads waste disposal installations, waste water treatment plants), but also other types such as urban development projects, flood-relief works, changes of Annex I and II existing projects…).*

*The EIA Directive of 1985 has been amended three times, in 1997, in 2003 and in 2009:*

- *Directive 97/11/EC brought the Directive in line with the UN ECE Espoo Convention on EIA in a Transboundary Context. The Directive of 1997 widened the scope of the EIA Directive by increasing the types of projects covered, and the number of projects requiring mandatory environmental impact assessment (Annex I). It also provided for new screening arrangements, including new screening criteria (at Annex III) for Annex II projects, and established minimum information requirements.*
- *Directive 2003/35/EC was seeking to align the provisions on public participation with the Aarhus Convention on public participation in decision-making and access to justice in environmental matters.*
- *Directive 2009/31/EC amended the Annexes I and II of the EIA Directive, by adding projects related to the transport, capture and storage of carbon dioxide (CO2).*

*The initial Directive of 1985 and its three amendments have been codified by DIRECTIVE 2011/92/EU of 13 December 2011.*

*The EIA procedure can be summarized as follows: the developer may request the competent authority to say what should be covered by the EIA information to be provided by the developer* *(scoping stage); the developer must provide information on the environmental impact (EIA report – Annex IV); the environmental authorities and the public (and affected Member States) must be informed and consulted; the competent authority decides, taken into consideration the results of consultations. The public is informed of the decision afterwards and can challenge the decision before the courts.*

*Environmental impact assessment* is an intrinsically complex multi-dimensional process (Ramanathan, 2001), which regulation and implementation varies in different national legislations. It involves the identification, prediction and evaluation of impacts arising as a consequence of decisions, and these impacts may be multidimensional in nature (Balasubramaniam & Voulvoulis, 2005).

Multi-criteria decision analysis (MCDA) is a formal methodology to face available technical information and stakeholder values to support decision in many fields and can be especially valuable in environmental decision making (Huang et.al., 2011). MCDA can provide an ideal framework for EIA which involves trade-offs among various environmental problems and development. It also ensures accuracy in the sense that it has an inbuilt method to check the inconsistency of judgements (Ramanathan, 2001). Several terms concerning multi-criteria decision analysis can be found in the articles (e.g. Multi-Criteria Assessment - MCA), but in this review abbreviation MCDA is comprised of all similar terms.

# 2. Methods and material

## 2.1 Literature search

The literature search was executed by using the *Web of Knowledge*, the *ProQuest*, *Elsevier Science Direct* and *Google Scholar* databases with command lines. The used headwords included in the literature search were ***multi-criteria***, ***MCA***, ***MCDA***, **EIA, environmental impact assessment, EIS, environmental impact statement, strategic impact assessment, SEA, structured decision making, SDM**. At first, the search gave hundreds of results, but narrowing down the headwords the results became more accurate.

In total hundreds of articles were found with the final command lines. First, abstracts from the most interesting articles based on the title and keywords were reviewed. Second, 26 articles, which abstracts and keywords fitted the aim of the literature review the best, were chosen to more detailed analysis. Huang et.al. (2011) has found in their literature review MCDA methods to be used in 42 EIA related papers. Many of these articles were same as found by the literature search for this paper, but 6 new added to the literature list.

Third, a summary table was made about all the chosen articles. The subjects that were collected from the articles to the summaries were title, authors, journal, the year of publication, country, paper type (e.g. review, research), the branch/industry, field in EIA, the applied MCDA method, objectives of the paper, the role of participation (stakeholders' role), applied models, main conclusions and further evaluations and feasibility of the results.

Altogether 32 articles (Appendix 1.) out of hundreds of papers matched the aims of the analysis. The fields of industry in EIAs in the articles found were following:

- Energy
- Transport/Construction
- Waste / wastewater
- Mining
- Other industry field / N.A.

Classification of paper types presenting MCDA methods in EIA are shown in the following table (Table 1). Paper types are classified to *review, case-study, method-study* (presenting or developing tool when applying the method) or *comparative study* (comparing two or more MCDA-methods in EIA context*).*

**Table 1. Types of articles presenting MCDA methods in different EIA applications.**

| Application | Review | Case | Method | Comparative | Total |
|---|---|---|---|---|---|
| Energy | | 1 | 2 | | 3 |
| Transport/Construction | | 5 | 4 | | 9 |
| Waste | 1 | 4 | 5 | | 10 |
| Mining | | | 1 | | 1 |
| Other / N.A. | 1 | | 6 | 2 | 9 |
| EIA total | 2 | 10 | 18 | 2 | 32 |

## 2.2 *MCDA methods introduced in articles*

Classification of MCDA papers by methods and application field of EIA are shown in the following table (Table 2). These numbers are based on the results of article by Huang et.al. (2011) and this literature review (conducted by the authors). In some EIA related articles also spatial multi-criteria evaluation (SMCE) is presented.

**Table 2. Methods and EIA application field of the reviewed articles.**

| Application Method | EIA Total | Energy | Transport/ Construction | Waste | Mining | Other / N.A. |
|---|---|---|---|---|---|---|
| AHP/ANP | 8 | 1 | 3 | 1 | | 3 |
| MAUT/MAVT | 3 | | 1 | | | 2 |
| Outranking | 7 | 1 | | 5 | | 1 |
| Topsis | 1 | 1 | | | | |
| SMCE | 3 | | | 2 | | 1 |
| Multiple | 5 | | 3 | | 1 | 1 |
| Review/ Other | 5 | | 2 | 2 | | 1 |
| Total | 32 | 3 | 9 | 10 | 1 | 9 |

Below is shortly presented three basic categories of MCDA models: Multi-Attribute Value Theory (MAVT), Outranking (e.g. PROMETHEE and ELECTRE) and Analytical Hierarchy Process (AHP).

Many multi-criteria methods such as **multi-attribute value theory** can be applied in situations where different decision alternatives are evaluated on the basis of conflicting objectives. In a simple case with no hierarchical structure and no interactions between attributes, an alternative would have an overall value $V=\sum_i w_i v_i (x_i)$, where $x_i$ is the consequence of alternative x in criterion i, $v_i$ is its value normalized to the 0–1 range and $w_i$ is the importance weight assigned to criterion i. The weight $w_i$ describes how important the decision maker considers the range of values (from the worst to the best possible level) in this criterion compared to the corresponding ranges in the other criteria (Huang et.al., 2011). MAVT models are typically structured hierarchically into the form of a “value tree”. This modelling usually follows three step process: 1) problem structuring (value tree, criteria, alternatives), 2) creating the preference model (making value functions and giving weights for the criteria) and 3) analysing results (reliability and sensitivity analyses) (SYKE, Marttunen et.al., 2008).

**Outranking** approaches are methods that essentially involve holding various “votes” across dimensions (Huang et.al., 2011). Alternative dimensions of action are compared pairwise, to derive alternatives that can be combined across dimensions. These models seeks e.g. to find out overall order of the alternatives.

**AHP** is a compensatory MCDA (Multi-criteria decision analysis) technique in the sense that it admits trade-offs among the various elements of the model (Ramanathan, 2001). AHP helps to elicit the complex judgements of different experts in a common platform (Ramanathan, 2001). The advantages of AHP over other multi-criteria methods, as often cited by its proponents, are its flexibility, intuitive appeal to the decision-makers (experts and stakeholders here), and its ability to check the inconsistencies in judgements (Saaty, 2000). On the other hand, serious doubts have been raised about the theoretical foundations of the AHP and about some of its properties. In particular, the rank reversal phenomenon has caused concern (Communities and Local Government, 2009). This is the possibility that, simply by adding another option to the list of options being evaluated, the ranking of two other options, not related in any way to the new one, can be reversed. This is seen by many as inconsistent with rational evaluation of options and thus questions the underlying theoretical basis of the AHP. (Communities and Local Government, 2009)

# 3. Results

## *3.1 Trends in MCDA applications in EIA*

Huang et.al. (2011) has conducted a state-of-the-application review of MCDA in the environmental field. They examined the growth of MCDA applications over the last two decades, while detailed analysis of applications based on a developed taxonomy describing MCDA approaches practiced in the field was conducted for papers published in 2000-2009 (Huang et.al. 2011). They founded MCDA methods in 42 EIA related papers.

Six of the listed articles, search for this paper, are published after year 2009. These articles present different MCDA methods and perspective to EIA. Probably the number of EIA cases where MCDA applications are used, is growing rapidly because of the rising need for systematic and multi-criteria evaluation of environmental impacts.

### *3.2 Arguments for using MCDA methods in EIA*

The results of the literature review reveal that MCDA methods can support EIA processes especially in the following tasks: stakeholder participation, consensus seeking, criteria setting and assessment of alternatives.

The geographical scale of environmental problems can range from the local and regional (e.g. noise pollution) to global scales (e.g. greenhouse effect). According to Balasubramaniam & Voulvoulis (2005) this has important implications for the decision environments of environmental problems, as with increasing spatial scale of impacts greater numbers of participants are required. Transboundary impacts not only cross physical boundaries, but sectoral, administrative and political boundaries as well, thereby diversifying the range of actors in the decision problems (Balasubramaniam & Voulvoulis, 2005). Thus, complexity is further increased in decision environments. Typically there are a large number of decision-makers, and the points of view of different interest groups are increasingly incorporated in the decision-making process. Balasubramaniam & Voulvoulis (2005) states that participants to a decision making process have different preferences with respect to the decision consequences and the prioritization of criteria. In natural resource utilization, for example, interest groups such as developers, environmental groups and political organizations may interpret a project from different viewpoints according to their own often conflicting objectives. Consequently, conflict arises from the diversity of the perceptions and preferences of multiple participants, which adds to the complexity of decision environments. Whichever decision-aid is employed, appraisals inform but are not necessarily the final decision. In theory, other considerations, such as political and cultural, are weighed in before the final decision is made. (Balasubramaniam & Voulvoulis, 2005)

Balasubramaniam & Voulvoulis (2005) emphasises also other decision-aids such as CBA can equally provide a structured approach for the decision-maker to choose an alternative. However, EIAs measure impacts in non-monetary terms, and evaluate impacts against non-commensurable criteria, making MCDA a more appropriate choice. MCDA assumes that criteria are independent. In real-life EIAs this assumption may be incorrect (Bose & Chakrabarti, 2003).

When using SMAA-O -method Lahdelma et al. (2000) have found that utilising ordinal information instead of taking precise, cardinal measurements can require considerably less work. However, not all MCDA methods are appropriate when ease of use and simplicity are required of a decision-aid (Balasubramaniam & Voulvoulis, 2005). Overall, MCDA has had useful applications in environmental decision problems.

Experiences from real-life cases suggest that MCDA can support EIA processes in many ways (e.g., Marttunen and Hämäläinen, 1995). A clear definition of the problem and criteria improves communication and understanding. Information on the stakeholders' attitudes is gathered in a systematic way and can be presented in a graphic mode. One of the strengths of the MCDA method in EIA is that it explicitly acknowledges that impact significance assessment contains a strong subjective element.

In the Netherlands multi-criteria decision analysis is used to support EIAs scoping phase and the final evaluation phase. Opponents to the use of MCDA state that the method is prone to manipulation, is very technocratic, and provides a false sense of accuracy. Proponents claim that MCDA provides a systematic, transparent approach that increases objectivity and generates results that can be reproduced (Janssen, 2001). According to Dutch experiences MCDA methods suits when public participation is institutionalized and all relevant parties must be heard during the EIA process (Janssen, 2001).

### *3.2.1 Support to stakeholder participation*

According to Persson & Olander (2004) project stakeholders are defined as, individuals and organisations who are actively involved in the project, or whose interests may be affected by the execution of the project or by a successful project (PMI Standards Committee, 2000). An important part of the management of the project systems environment is an organised process to identify and manage the probable stakeholders in that environment, and determine how they will react to the project decisions (Persson & Olander, 2004).

Stakeholder analysis is recommended to be performed at the early phase of the EIA. According to Persson & Olander (2004) the stakeholder analysis should consider the following aspects:
1. Identify all potential stakeholders, external as well as internal.
2. Assess each stakeholders claim on the project, are they proponents or opponents in relation to the goals of the project.
3. Assess each stakeholder's interest and power to influence project decisions.
The power/interest matrix can be a useful tool to conduct the stakeholder analysis.

Persson & Olander (2004) states that to effectively manage stakeholder interests it is not enough to just identify their demands and needs. Project management must also identify the relative power that different stakeholders have on the implementation of the project. A method to do this is stakeholder mapping, an approach, which is adapted from the concept of environmental scanning. A tool in stakeholder mapping is the power / interest matrix, which analyses the following questions:

- How interested is each stakeholder group to impress its expectations on the projects decisions? Do they mean to do so? Do they have the power to do so? (Persson & Olander, 2004)

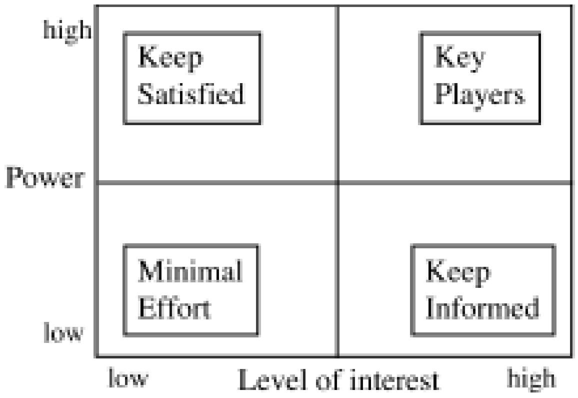


Figure 3-1. Stakeholder mapping, the power / interest matrix (Persson & Olander, 2004).

For example waste management and water resource planning problems involving public participation have been facilitated by MCDA, through the structuring and articulation of the public's values (Balasubramaniam & Voulvoulis, 2005). Also Marttunen & Hämäläinen (1995) points out that impact data is useful in political decision making only if it is put in a form which reflects its importance from the different perspectives of the stakeholders. Interactive multi-attribute decision analysis is a natural method for this purpose (Marttunen & Hämäläinen, 1995). Marttunen & Hämäläinen (2008) states, that previously the use of MCDA methods had often been limited to analysis of the desirability of various alternatives at the end of the project. They aim to improve communication and common understanding in the steering group of stakeholders and improve joint problem solving (Marttunen & Hämäläinen, 2008).

Bojorquez-Tapia et.al. (2005) presented workshops for different expert groups according to the area of specialization as a part of stakeholder participation. Noh & Lee (2003) presented weighting based on expert judgement. A participatory approach is an attempt to avoid conflicting and hostile reactions from the involved communities. A group of 455 decision-makers worked with a facilitator group for 16 months to identify the criteria (Noh & Lee, 2003).

Geneletti (2010) presents different stakeholder analysis which was conducted to identify the main concerns. Stakeholder analysis identified e.g. a set of criteria to be satisfied by new inert landfill sites. In the paper by Geneletti (2010) the purpose of the research was to propose and test an approach involving stakeholders' opinion that could be replicated by the local administration in landfill siting processes.

Social Development Needs Analysis (SDNA) is introduced as an enhancement to participatory Social Impact Assessment methods to give practical guidance to site managers in evaluating community investment alternatives (Esteves & Vancley, 2009).

Marttunen & Hämäläinen (1995) found in their case studies reactions that the improved understanding and common problem definition can decrease the contradictions between opposing stakeholders. This may help to find a new consensus alternative.

Macharis et.al. (2012) develops a methodology in which stakeholders are involved and in which their points of view are explicitly taken into account without their being asked to converge directly to a consensus. Ramanathan (2001) stated that the authorities responsible for the project would like to know not only the potential significant impacts, but also about their relative importance. While the experts in the SEIA team can reasonably estimate relative importance, it would be more desirable if the importance as perceived by the different stakeholders is also provided. Knowing the relative severity of different socio-economic impacts will help the authorities in prioritizing their environmental management plan.

According to Marttunen et.al. (2013) a crucial question is how to design and implement MCDA processes which are understandable, meaningful and effective from participants' points of views? Their experiences showed that in a highly interactive and integrated MCDA process the stakeholders involved gain a better understanding of different viewpoints as well as key uncertainties. While the process may not lead to a specific action plan, it can provide a basis for better co-operation. The viewpoints of the stakeholders may not have changed much during the process, but because of improved understanding of the reasoning behind different views, the co-operation might have become easier (Marttunen et.al, 2013).

### *3.2.2 Consensus seeking in EIA*

Research conducted by Petts (2001) for example, examined the effectiveness of, and barriers to, more extensive public participation at earlier stages in the process through novel community consensus building approaches (including the formation of Community Advisory Fora) using the example of a local waste strategy for a case study authority in the UK. (Petts, 2001).

Tamura et.al. (1994) proposes that, in addition to the physical/biological impacts, we should include an assessment of the preference of the regional inhabitants who live near the project and hence will be environmentally affected by the project. It is quite important to obtain a consensus of the regional inhabitants before realizing a big project in order to avoid serious trouble afterwards. (Tamura et.al., 1994)

The derivation of weights for each criterion through a participative framework opens up the decision-making process and can lead to a degree of consensus in the final part of the process permitting the incorporation of multiple views from different stakeholder groups. (Higgs, 2005)

According to Higgs (2005) the potential for AHP in participatory planning has been demonstrated in multi-criteria problems in other environmental contexts that combine both quantitative or objective information and qualitative criteria (using for example fuzzy set theory) or subjective preferences of local populations or decision makers/experts to evaluate trade-offs among multiple and conflicting decision criteria in order to find a consensus between participants (for example in the selection of forest wilderness sites.

Cloquell-Ballester et.al. (2007) presents that consensus building is a task which must be integrated and made explicit with sufficient entity throughout the process, and emphasis is drawn to the necessity of developing specific tools that facilitate its attainment (Bojórquez-Tapia et al., 2005).

According to Cloquell-Ballester et.al. (2007) every impact has to be submitted to expert " attribute-by-attribute " evaluation. Two conditions must be controlled to accept a judgement as well-founded: consistency and consensus. For the case of this proposal, consistency refers to the standard deviation of experts' individual judgements, whereas consensus refers to the degree of agreement between stakeholders. Consensus building has to be constructed and specific tools have to be applied within the evaluation context (Bojórquez-Tapia et al., 2005). Final judgements have to be translated into numerical values (expert judgement data) to facilitate impact significance assessment. (Cloquell-Ballester et.al., 2007)

### *3.2.3 Criteria setting*

Multi-criteria techniques could be particularly useful in situations where there are a large number of alternative sites for a development, where there a large number of potential criteria to be taken into consideration or where subjective judgements by different stakeholders of the different alternatives is needed to try to reach an objective consensus in the final decision-making process or to make these processes more open and accountable (Higgs G., 2005).

Lahdelma et.al. (2000) states that a discrete multiple criteria decision problem consists of a finite set of alternatives that are evaluated in terms of multiple criteria. The criteria provide numerical measures for all relevant impacts of different alternatives. The relevance of different impacts depends on stakeholders' points of view. It is necessary to define precisely how each criterion is measured. Usually criteria are aggregate values computed from a much larger amount of so-called primary factors, which form the lowest level of information, also known as the assessment level.

Karjalainen et.al. (2013) sees that value-focused MCDA can support the identification and valuation of ecosystem services in the EIA process. This is closely linked to stakeholder engagement and deliberation. For example, how the values (or objectives) and assessment criteria are obtained in the scoping stage — whether the process is more top-down and expert-driven or more bottom-up and collaborative. Based on this listing of objectives, the expert group developed the initial proposal for the value tree. A starting point was to take three dimensions of sustainability (ecological, economic and social, including cultural aspects) as the upper level of criteria. All other criteria were classified as subcriteria under these main criteria (Figure 3-2). Several iterative modifications within the expert and project group resulted in a value tree which was accepted by all stakeholder groups (Karjalainen et.al., 2013).

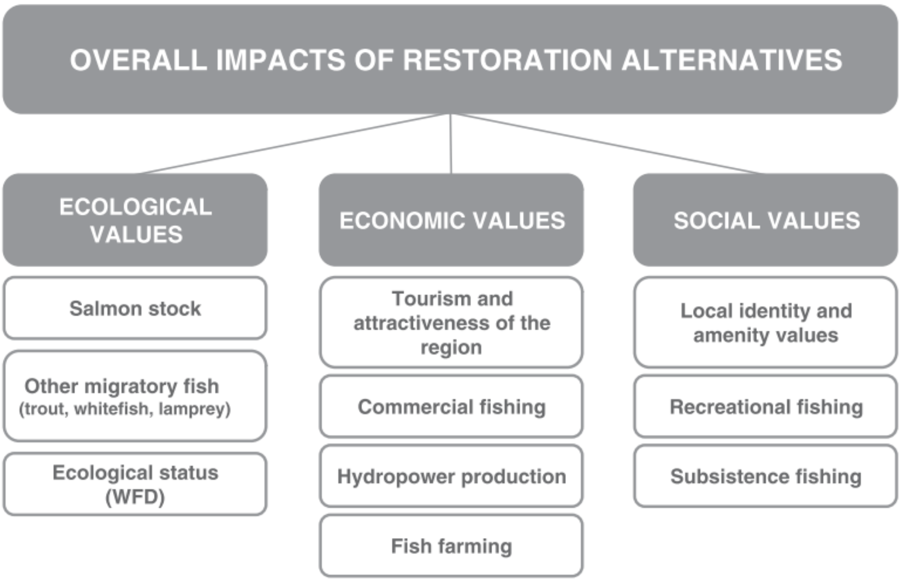


**Figure 3-2. Value tree in the River Iijoki project - value-focused approach (Karjalainen et.al., 2013).**

### 3.2.4 *Assessment of alternatives*

According to Lahdelma et.al. (2000) environmental planning and decision-making are essentially conflict analyses characterized by socio-political, environmental, and economic value judgements. Several alternatives have to be considered and evaluated in terms of many different criteria, resulting into a vast body of data that are often inaccurate or uncertain. To complicate the process further, there are typically a large number of decision-makers (DMs) with conflicting preferences. The different points of view of various interest groups also should be considered in the process.

In article by Marttunen & Hämäläinen (1995) the goal was to find the alternatives which would be environmentally and socially acceptable and yet technically and economically feasible. In the case studies we tried both bottom-up and top-down approaches and both worked well. The former approach helps to focus attention on the range of impact of the alternatives, whereas the latter emphasizes the overall setting of the problem. In general, it is essential to remember that the prioritization should reflect value differences related to the alternatives and not the stakeholders' general values in life. This seemed to be one of the most difficult things for the participants to keep in mind. (Marttunen & Hämäläinen, 1995)

Balasubramaniam & Voulvoulis (2005) states, that when choosing the best alternative, MCDA can also rank and sort alternatives. The transparency of MCDA can make it an appropriate decision-aid where conflict resolution may be required, since it facilitates trade-off analysis by providing information on trade-offs, displayed as the performance scores of alternatives on different criteria (Balasubramaniam & Voulvoulis, 2005).

Higgs (2005) presents framework by Carver (1999) where potential input from stakeholders are enabled, as well as waste management experts, in a MCE of potentially suitable areas using their choice of criteria (data layers) and user-defined weights in siting facilities that may be subject to public opposition (Carver 1999). This not only has the potential to reach a consensus on final sites for such facilities but also permits 'what-if' analyses to be conducted to assess the consequences of varying the values for the criteria (or their weightings) on the ranking of alternatives (Appendix 2.). (Higgs, 2005)

In MAVT, the alternatives are first evaluated with respect to each criterion and the criteria are then weighted according to their relative importance (Karjalainen et.al., 2013). As a result, one receives the overall values of the alternatives indicating their preference to the evaluator (Figure 3-3).

Janssen (2001) provides examples of how MCDA has been used in environmental impact assessment in a variety of application areas at different spatial scales in The Netherlands where public participation in environmental decision making is institutionalized. In these applications 'MCDA is used to bring forward the differences among alternatives' (Janssen, 2001) and GIS is playing an increasing role in environmental impact assessment applications where geo-referenced data are used as inputs to the MCDA (Higgs, 2005).

According to Cloquell-Ballester et.al. (2007) the use of multi-criteria techniques to aid decision-making should be inherent in studies undertaken within the framework of Environmental Impact Assessment. Intrinsic problems of EIA, such as the selection of alternatives and the evaluation of environmental impacts, possess an unquestionable multi-criteria character since both are undertaken in consideration of different factors, and for which it is impossible to reduce these problems into one single criterion. In this sense, it has been possible to confirm that determining the significance of environmental impacts is indeed a multi-criteria problem, and one of the most important problems to be resolved in an EIA, as both project approval and the necessity of correction measures are based on impact significance. (Cloquell-Ballaster et.al., 2007)

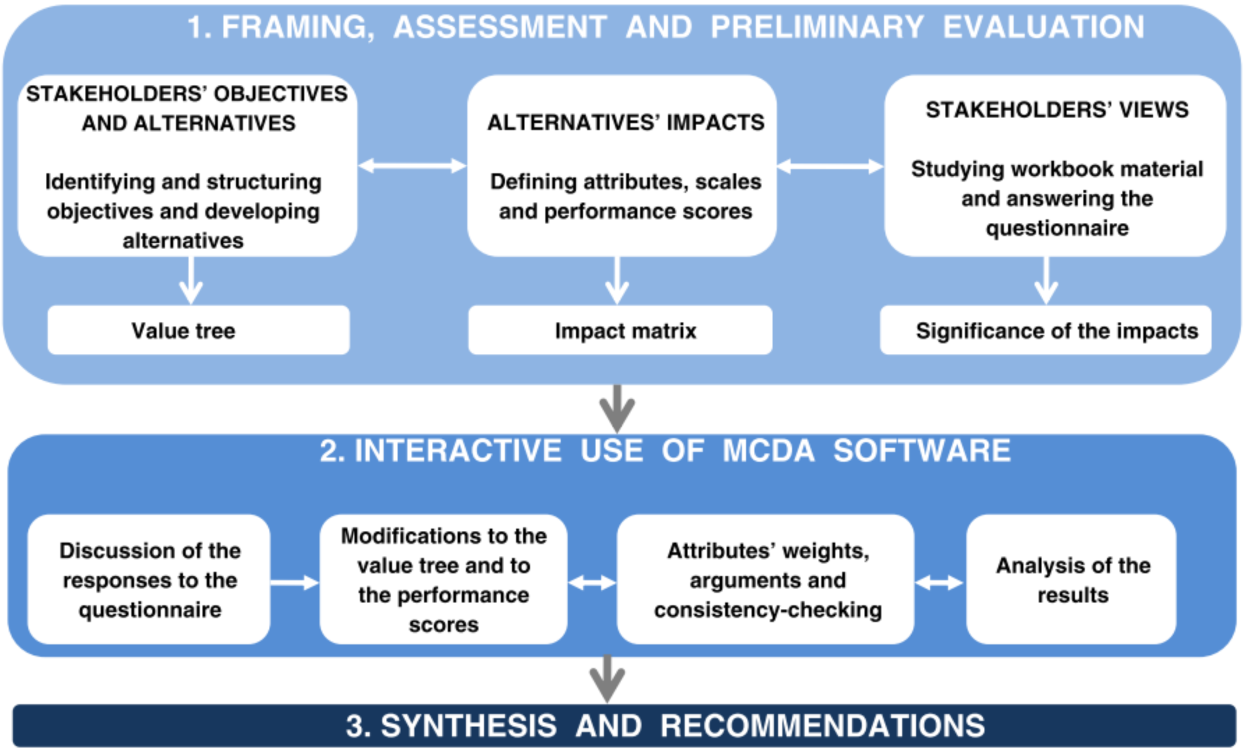


**Figure 3-3. The interactive MCDA process - the Decision Analysis Interview (DAI) approach (Karjalainen et.al., 2013).**

### *3.2.5 Spatial multi-criteria evaluation (potential of GIS)*

According to Higgs (2005) one area where new techniques are increasingly being used is in site selection using GIS-based decision making within a decision-support system (DSS) framework. There is a growing recognition that multi-criteria-based techniques can be used to incorporate stakeholder interest in environmental issues and thus have potential as public participation tools (Malczewski, 2004). Multi-criteria approaches have the potential to reduce the costs and time involved in siting facilities by narrowing down the potential choices based on pre-defined criteria and weights while also permitting sensitivity analysis of the results from these procedures. (Higgs, 2005)

Geneletti (2010) presents combining stakeholder analysis and spatial multi-criteria evaluation (SMCE) to select and rank inert landfill sites. SMCE techniques were applied to combine the criteria, obtain a suitability map of the study region. Through GIS modeling these sites were compared and ranked according to their visibility, accessibility and dust pollution. The two-stage approach allowed first to identify potential invert landfill sites within the study region, and then rank them according to their preferability. The two stages were conducted using different sets of criteria and inputs from different groups of people. (Geneletti, 2010)

Higgs (2006) has integrating multi-criteria techniques with geographical information systems in waste facility location to enhance public participation. His research focuses on the potential for GIS, particularly when integrated with multi-criteria evaluation (MCE) techniques, in involving the public at various stages of the decision-making process with a particular emphasis on the siting stages. GIS has the potential to speed up the process of finding suitable sites for waste facilities and to permit sensitivity analysis that will examine the impact of varying some of the criteria in a sieve-mapping exercise. Studies suggest that the potential integration with MCE as a public participation tool could improve the speed of the site selection process by incorporating public opinions at the outset of the decision-making process. (Higgs, 2006)

Roudgarmi et.al. (2008) have researched alternatives evaluation in EIA by spatial multi-criteria evaluation (SMCE) technique. GIS has several limitations in the domain of decision-aid. Therefore, it has limitation for application in alternatives evaluation and decision making in environmental assessment. The remedy suggested by some researchers is to integrate the GIS with different operations research/management science tools that have experienced very successful applications in different domains since the 1960s. The most suitable family of analytical methods is that of multi-criteria analysis (MCDA). The geographical information systems (GIS) support the solution of complex spatial problems, providing the decision-maker with a flexible environment in the process of the decision research and in the solution of the problem. The visualization of the context, structure of the problem and its alternative solutions is one of the most powerful components of a decision support system (Roudgarmi et.al., 2008). Thus, the integration GIS–MCDA has the objective of favoring decision-makers, providing them with ways to evaluate several alternatives, based on multiple, conflictive criteria. Roudgarmi et.al. (2008) states that the methodology and study results have some important capabilities for EIA such as (Figure 3-4): a) Weighing methods which are used for impacts and different environmental groups such as AHP and ranking methods; b) Standardizing methods that are very important in dimensionless of impacts scales; c) Aggregation of environmental impacts; d) Determination of magnitude and location of environmental impacts by GIS capabilities.

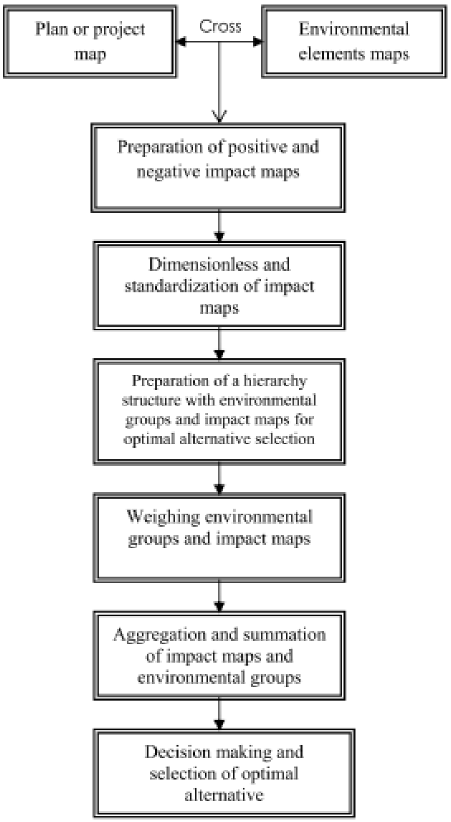


**Figure 3-4. Presentation of the concluded methodology for alternative evaluation in EIA by a spatial way (GIS) (Roudgarmi et.al., 2008).**

# 4. Conclusions

On the whole, a satisfactory amount of suitable articles were found for the literature review. Based on the reviewed articles major findings and conclusions are following:

- The local information from different stakeholders is crucial for environmental impact assessment and alternative evaluation (EIA).
- MCDA is used to bring forward the differences among the alternatives.
- MCDA suits a consensus seeking approach in environmental decision-making process and it is possible to have long list of different impacts. In EIA needs to be taken into account the consensus formation process between the local and regional inhabitants and the enterpriser of the project.
- MCDA supports to move from environmental judgements to decision-making.
- MCDA implementation in the EIA process can increase stakeholders' understanding of the projects' environmental impacts.
- GIS and spatial multi-criteria evaluation can be effective way to evaluate alternatives.
- In addition to the physical/biological impacts, it should be included an assessment of the preference of the local inhabitants who live near the project and hence will be environmentally affected by the project.

- Environmental assessment still largely proceeds in advance of discussion with the public rather than through discussion with them. MCDA methods can improve communication and common understanding in the steering group of stakeholders and improve joint problem-solving.

MCDA methods can be particularly appropriate when the decision-making context is characterized by multiple objectives and multiple criteria, incommensurable criteria, mixed data and the need for ease of use, and the analysis context is characterized by multiple participants (Balasubramaniam & Voulvoulis, 2005). Whilst MCDA is not appropriate for all environmental decision-making problems, in the right contexts it can be appropriate, and has had many useful characteristics. By presenting information in a reasoned and orderly way, amenable to interpretation by decision makers, MCDA can provide structure to EIA.

# 5. Further research needs

In spite of the wide research on the use of the MCDA methods in environmental decision making, there are still many open issues. The main future research needs include:

- Development of specific methods of improving participation during the entire EIA process and to facilitate consensus finding in the determination of the significance.
- MCDA is rarely used in the 'big choice' at the more strategic level. Thus there is a great need for innovative approaches and real-life examples how MCDA can be used to support SEA projects.
- Development of methods that could use the results of the alternatives' evaluation to support the design of new alternatives could make a major contribution to the EIA decision process.
- The use of MCDA to support joint fact-finding is nowadays rather limited. Many EIA cases would benefit from that because there are divergent opinions regarding the impacts and there are also uncertainties in the scientific and expert inputs.
- Interaction of the actors is essential in the EIA projects. MCDA has a great potential to support interaction and dialogue between stakeholders. The big question is how to do weight elicitation in an understandable and theoretically sound way with people who are not familiar with MCDA. More experiences from real-life cases are still needed to make general recommendations.
- AHP is most widely used multi-criteria method. It, like MCDA methods in general, has several unquestionable advantages but also some pitfalls which decision analyst should be aware before applying the method often a tiring exercise for the decision-maker. It is important to develop methods to reduce the number of judgements needed, but so that the theoretical soundness of method would not be compromised.

# Appendix 1.

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# Appendix 2.

Issues to be considered if the potential of multi-criteria evaluation-based techniques in location waste facilities are to be realized (Higgs, 2005).

**Stage 1.**

- Definition of the problem/objective.
- Choice of geographical area and locating facility and stage in development process.
- Choice of timescales.
- Review of hardware/software requirements.
- Choice of stakeholders / public groups/ those affected/interested by the site-selection decision.
- Contact with relevant agencies, stakeholders and developers.
- Selection of communities – comparison of approaches and area of study.
- Selection of community members to represent as wide as range of views/perspectives as possible and to reduce bias.
- Review of previous participative mechanisms (if any) and of the different methods of multi-criteria decision analysis techniques which may be relevant for waste facility location.

**Stage 2.**

- Clarifying the choice of criteria for the relevant application.
- Data availability and acquisition in relation to site-selection criteria.
- Choice of public/stakeholder/focus groups to reflect diverse range of opinions from those directly or indirectly involved and obtaining representative views (possibly from previous public participation exercise).
- Choice of consultation mode to elucidate views, formulate alternatives and obtain a consensus on values (e.g. through approaches such as questionnaires, workshops, e-mail, etc.).
- Issues of concern to such groups; traffic/air pollution, visual impacts, health concerns.
- Possibility of training in information and computer technology to enable familiarization with the technology.
- Design of the system and user involvement – choice of factors or criteria to be included to enable communication and data exploration.

**Stage 3.**

- Data preparation, assembly, conversion and analysis in GIS environment (vector and raster).
- Development of software interface and functionality.
- Choice of the multi-criteria decision analysis technique to be used in the case studies.
- Design of visualization-based multi-criteria model.
- Incorporation of local knowledge to technical stages of the project.
- Evaluation of different software options including the purchase of proprietary software (e.g. GeoChoice) which links multi-criteria evaluation with GIS (e.g. ArcView) or development of new software.
- Explore different multi-criteria evaluation options in the site selection process – weighted linear combination (WLC), ordered weighted average (OWA), etc.
- Calculation of resultant suitability map and where available, comparison with previous non-multi-criteria evaluation-based exercises.
- Mechanisms/dissemination of information/data to public groups – choice of forum of presentation (e.g. workshops, web-based dissemination).
- Final presentation of potential sites prior to decision-making process.
- Seeking feedback on the effectiveness of methodologies from relevant agencies, developers and the general public.
- Evaluation of the methodologies employed.