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Report

Multi-criteria analysis applied to environmental impacts of hydropower and water resources regulation projects

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ABSTRACT
This report discusses the potential of Multi-Criteria Decision Analysis (MCDA) in improving water management processes in Norway. MCDA is especially relevant in those steps and investigations that are related to the assessment of the environmental impacts and mitigating measures accompanying a hydropower project concession agreement.

The report discusses existing approaches in water management processes in Norway and shows that elements of MCDA are already present in the main guidance documents on conducting Environmental Impact Assessment (EIA) and Social Economic Analysis (samfunnsøkonomisk analyse). In this respect, the report provides recommendations for how MCDA can be further integrated with the existing management processes concerning hydropower and water resources regulation projects. The recommendations are also based on the lessons learned through relevant applications conducted in Finland, Norway and the Alps region. The cases, summarised in the Appendix, were discussed during a workshop sponsored by the Norwegian Environment Agency, 27-28 February 2013.

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1 Extensive summary

This report discusses the potential of Multi-Criteria Decision Analysis (MCDA) in improving water management processes in Norway. The study was a supplementary activity funded by the Norwegian Directorate for Nature Management (DN), under the CEDREN EcoManage project.

The scope of the study was to assess how MCDA can be used in support of different decision-settings in watershed management in Norway and in particular related to hydropower generation:

- Project level assessment, with a specific focus on
  - First time evaluation of water regulation concessions
  - Revisions of water regulation concessions
- Strategic screening of hydropower concessions that are coming up for revision
- Watershed management - composition of programs of measures under the Water Framework Directive (WFD).

In all these contexts we analyzed:

- To what extent MCDA can be used in the different steps of the decision-making processes in screening, watershed management and project evaluation as they are currently practiced in Norway
- When the increased effort of using MCDA is justified relative to the existing practices.

The main conclusions of the study can be summarized as in the following.

On Multi-Criteria Decision Analysis

There is a large potential for the application of MCDA in environmental impact evaluation and social economic analysis. This is illustrated by the large variety of case studies and real life applications presented in this report. Moreover, the recent emphasis in Norway on political quality control of large infrastructure projects through choice-of-concept studies has also lead to greater interest in the use of formal MCDA methods in social economic analysis.

MCDA as a framework to support the whole decision process

First, MCDA can be used as a framework to support a whole decision process. The principles and practices can be adapted to most environmental planning processes and MCDA can be useful even without any modeling phase. MCDA can be useful in the initial phase of problem identification structuring. This is often an iterative, deliberative process where particular attention should be paid to: defining the decision situation, identifying objectives and stakeholder's values and developing an evaluation framework and alternatives. Another important aspect where the use of MCDA is especially relevant is collaborative planning processes involving many decision makers, stakeholders and domain experts. Such decision processes require methods to support transparent and participatory decision making.

However, when designing the content and realization of the MCDA process it is important to take into account the purpose of the application and case specific characteristics. Decision and decision situations are unique (for the decision maker), although they may often seem similar (from a more institutional point of view).

In general, the achievement of the potential benefits of MCDA increases if it is integrated into the decision process from the beginning and carried out in close interaction with key stakeholders. The involvement of an analyst with MCDA competence is often recommended in process implementation of MCDA.

MCDA as a modeling tool

Second, MCDA provides various methods and models to support the evaluation of the alternatives: weighting of the criteria, overall values for the alternatives, ranking of alternatives, sensitivity analyses. The process of constructing decision models - value function models – should be constructive rather than prescriptive, with the emphasis on using the model to assist decision makers in understanding their own preferences and the impacts these have on the available choices. The process may involve some technically sophisticated procedures aimed at identifying models which are most consistent with the available information and the uncertainty in a decision situation. It is possible to standardize the method and the preference model to be used in a specific decision context and software can be used to support such standardized procedures.

Commercial software is available to support the application of one or several MCDA methods. The software can be used both by decision makers to support their personal decision making as well as by groups of decision makers and stakeholders to support participation, systematic evaluation and synthesis of different views and preferences.

However, MCDA software is easy to use – wrongly. For example, weight elicitation is much more than just assigning numbers to the criteria. The focus should be on explaining to the software users what the software is supposed to model – e.g. the meaning of the weights and scores prescribed by each value modeling method used. Behavior biases and mistakes are often made and therefore quality control by external MCDA experts is again recommended in cases where stakes are high and project decisions entail hard multi-attribute trade-offs

It is also possible to develop application specific software aimed at specific user groups that are not necessary very familiar with the MCDA methodology. Such software would come with comprehensive guidance and user support and perhaps in-built information which are domain specific. This would make decision processes –that are repetitive in some aspects - more transparent and homogenous and nevertheless support collaborative decision making.

On MCDA practice

Elements of MCDA are present in the existing water management assessment practices in Norway. We present a review of the main guidance documents on conducting Environmental Impact Assessment (EIA - konsekvensutredning) and Social Economic Analysis (samfunnsøkonomisk analyse) in Norway and discuss which aspects of MCDA are already in use.

Norwegian guidance documents on social economic analysis refer to three forms of analysis: cost-benefit, cost-effectiveness and cost-impact analysis. Cost-impact analysis is equivalent to multiple criteria decision analysis as understood in the research literature. While cost-impact analysis is one of the three main approaches to social economic analysis no cross-sectoral guidance document is currently available in Norway on how to carry out analysis.

The Roads Authority Handbook 140 is referred to as the leading source of guidance on impact evaluation, in particular for unpriced impacts. Unpriced impacts are pervasive in most projects and particularly those that affect ecosystem services from land use (NOU 2013:10).

Handbook 140 has standardized the approach to scaling different impacts to a common comparable indicator, and then comparing the relative importance of impacts. What is notable in the Handbook 140 methodology relative to formal MCDA methods is that:

(1) value judgments regarding the scaling of individual impacts using a value function are completely standardized by the guidelines so as to be invariant across projects. Little empirical or theoretical justification is given for this standardization.

(2) value judgments regarding the weighting - relative importance of impact categories - is completely unstandardized. Weighting across impacts is by default as uniform or determined by the subjective preferences of technical experts delegated as representatives of different social interests.

The mix of approaches may be a reflection of a mix of governance rationalities operating in parallel in Norwegian impact assessment. While the Finance Ministry and Roads Authority Guidelines cross reference each other's' methodology on social economic analysis, they have (until recently) had quite different theoretical starting points, and established practice.

Standardised value scaling in the HB140 'signficance matrix' methodology has built in biases which are not well documented. For example, the standardization of value scaling seems to give greater weight to positive, as opposed to negative impacts for some of the impact ranges. HB 140 explains the asymmetry between the scaling of positive and negative impacts by the difference in importance of gains versus irrevesible losses. Why this implies greater value for large positive versus large negative impacts for parts of the value function is not explained.

In a decision support process it is important to separate technical assessment of impacts from the value judgments and priorities. HB 140 establishes many roles for technical experts. They conduct value scaling and also implicit weighting of impact sub-criteria. However, the role of interests and decision-makers is not clearly defined in the Impact Assessment (KU).

To our mind more discussion could be made of the advantages of using MCDA to structure the evaluation process to involve stakeholders in the impact assessment(KU) itself, and not only in hearings once the KU has been conducted.

Here to there seems to be disagreement in the approach taken by different institutions. For example, impact value scaling is carried out by technical experts in Handbook 140, while Finance Ministry's guidance would have impacts valued based on consumer preferences where possible. HB140 also puts weighting of sub-criteria, and to a great extent also main assessment criteria, in the hands of technical experts by asking them to recommend project rankings based on technical criteria only (which requires default uniform criteria weighting). Finance Ministry guidance recommends that criteria weighting and project ranking be left to decision-makers as they are value laden political decisions.

From case studies reviewed in appendix (e.g. Optipol) we see that value scaling can be conducted with stakeholders, and not only technical experts. There may be good reasons to construct project specific value functions with stakeholders, rather than use standardised homogeneous criteria across projects as is current practice with HB140.

Formal MCDA potentially brings in structure, analysis and transparency to value judgments needed in comparing unpriced and priced impacts. However, to achieve greater transparency regarding MCDA will require more effort on consultation with stakeholder than is currently undertaken in Norway's impact assessment practice according to the Planning and Building Act.

There may be time saving advantages to using formal MCDA if it can be shown that this reduces project approval delays due to conflicts with stakeholders. A similar question is being discussed regarding greater use of "physical compensation" measures in transport projects (Samferdselsdepartementet 2013). There seem to be potential advantages to structuring the evaluation of "physical compensation" measures versus other mitigation measures using formal MCDA techniques.

On the potential of MCDA in improving hydropower and water resource planning in Norway
MCDA methods have potential as problem structuring techniques, and tools for promoting communication and deliberation with stakeholders about social impacts of water resource and hydropower projects. MCDA potential is greatest where the project evaluation process is least structured at present.

Simple MCDA value scaling and weighting have mainly been used to integrate unpriced impacts into quantitative comparisons with power loss. MCDA techniques have not been used to document and structure value elicitation. Multiple stakeholder interests are acknowledged as important, but this intention is not formalized in value scaling and criteria weighting methods currently promoted by state-of-the-art EIA guidelines such as the Roads Authority Handbook 140. To some extent conflicting decision support rationalities are proposed in Guidelines prepared by the Ministry of Finance and the Roads Authority regarding social economic analysis. The extent to which subjective value judgments of stakeholders in the Public Hearing process of projects are well reflected in the subjective value judgments carried out by technical experts conducting EIA, is not known. However, we think experts ability to represent social interests is limited, given the standardized approach the guidelines have to value scaling and criteria weighting.

The extent to which project evaluation is regulated by existing guidance and established appraisal practices may also be an indicator of where MCDA has the greatest likelihood of being integrated in management practices.

The screening of hydropower concessions that are coming up for revision is a challenging task for energy authorities. A standardised screening methodology is being applied (as yet unreported) which can screen projects much faster than they can be evaluated and approved. Formal MCDA could therefore potentially provide decision-support in two ways:

1) MCDA 'thinking' can be used to evaluate the valuation assumptions implicit in the screening methodology
2) Formal MCDA methodology could be used to structure the concession evaluation process of projects prioritised by the screening. This might have advantages if stakeholders express a current lack of participation or transparency in the evaluations as they are undertaken by authorities. If this is the case pilot testing would be relevant - with some form of parallel evaluation with a 'control group' of concession revisions using a non-MCDA structured approach.

Regarding individual hydropower projects, our hypothesis is that the MCDA might be most easily applicable in the short to medium term in hydropower concession revision and the evaluation of disproportionate costs. It might be harder to integrate the principles of MCDA into the appraisal of new hydropower concession because they are subject to long standing EIA practice and established guidelines.

MCDA is perhaps the most difficult to integrate into the evaluation of programmes of measures under the WFD. Detailed guidance on selecting measures have recently been written in Norway, using a cost-effectiveness rationale focused on compliance with a single objective – good ecological status (GES). Relative rankings of measures are less important in this process than the identification of cost-effective portfolios of measures (not needing ranking) that attain the single target of GES. It seems to us a less fertile regulatory context for MCDA.

Ecosystem services and MCDA in EIA

The concept of ecosystem services is being discussed for its relevance to Norwegian environmental and natural resource management. Framing an appraisal in terms of *impacts on ecosystem services* implies exploring how a project affects specific beneficiaries' well-being through its impacts on ecosystems. This is not far from the concept of appraising interests ("interessenter") or users ("brukere") in current Norwegian practice. However, distributional impacts across different interests are usually treated as a separate chapter in Norwegian guidance on EIA and social economic analysis.

Assessing impacts on ecosystem services means that specific groups' value judgements are directly integrated in the methods for ranking alternatives – from the definition of alternatives, through definition of impact indicators, to value scaling of indicators, and finally criteria weighting. Although the ecosystem services framework is promising, it should not form a rigid 'checklist' for assessments. It can be used to widen perspectives about potential issues in linking ecosystem properties to multiple human benefits and *acknowledging diverse value judgements*. An ecosystem services approach provides further theoretical justification for determining value functions on a case-by-case basis that is specific to local multiple user preferences.

MCDA techniques offer a methodology for structuring and documenting how each affected group's value judgements may affect the ranking of alternatives. The information is used to support public hearings as a process of dialogue between opposing interests. This is quite different from the current appraisal guidance in which impact indicators, value scaling and criteria weighting are standardized and delegated to technical expert groups.

A future challenge is to combine the ecosystem services framework with a social and communicative MCDA approach. A shift would be needed in the methodological focus of EIA from the technical towards the social; or from *aggregation to agreement* as formulated by Vatn (2009). This need is greater the larger the project, or to quote Funtowicz and Ravetz (1991), "where facts are uncertain, values in dispute, stakes high and decision urgent".

2 Introduction

By 2022, around 430 hydropower licenses in Norway may go through a process of revision with respect to the environmental requirements. In addition, every year new hydropower projects are proposed. Both existing and new hydropower projects must undergo standardized procedures before a concession can be granted.

The act which has (and will have) important implications on hydropower development in Norway is the EU Water Framework Directive (EU WFD) (2000/60/EF) adopted in the Norwegian Law by the approval of "Forskrift om rammer for vannforvaltningen" normally referred to as Vannforskriften (The Water Regulation)

The primary objective of the EU WFD is to ensure that all European water bodies reach good ecological status in natural water bodies, and good ecological potential in heavily modified water bodies (HMWB), within a defined time period (2015 / 2021). The Directive (Art 4.7) or (Vannforskriften §12), specifies that a deterioration of status may only be allowed as an exception, following some basic principles. EU WFD introduces an ecosystem-based and holistic river basin management of the water resources throughout Europe, and requires a simultaneous focus on water quantity, water quality and biology. The EU Water Framework Directive (EU WFD) (2000/60/EF) was adopted in the Norwegian Law by the approval of "Forskrift om rammer for vannforvaltningen"

Extensive work is now carried out in Norway and the rest of Europe in order to implement The WFD requirements. A number of activities have already been carried out to form the basis for developing plans to reach the environmental goals in those water bodies that required by EU WFD, including defining typologies for lakes, river, coastal waters and groundwater and developing classification system to all the different water body types. An extensive job has also been to carry out a characterization and classification of water bodies, i.e. to assess the ecological status of all water bodies. Based on the characterization, those water bodies being "at risk" or "potentially at risk" have been identified and plans to improve the standard are made.

The processes the existing hydropower owners and developers have to go through, together with NVE as the administrative counterpart and ultimately OED as the issuing body (NVE (2010), NOU (2012) and may quickly become complicated when there are many interests and stakeholders involved. Improved decision support approaches may be an important supplement in order to make the processes easier to handled by authorities and the decisions made more clear and transparent for all parties involved.

The focus in this report is on the potential of Multi-Criteria Decision Analysis in improving the water management processes. MCDA is especially relevant in those steps and investigations that are related to the assessment of the environmental impacts, mitigating measures and the design of the environmental monitoring programs accompanying the concession agreement.

The investigation of MCDA was a supplementary activity funded by the Norwegian Directorate for Nature Management (DN), under the CEDREN EcoManage project.

For this purpose, a workshop on multi-criteria decision analysis (MCDA) was organized on 27-28 February 2013. The main objective of the workshop was to provide a forum for discussing MCDA tools and methods in the context of hydropower regulation and environmental impact assessment. The workshop involved representatives of DN, NVE, experts and researchers in the fields of hydropower concession revision, environmental impact assessment, hydrological modeling, GIS, and environmental economics from Finland, Italy and Norway.

This report first introduces the MCDA methodology to an audience with technical background in hydropower and environmental impact assessment. MCDA underlying theory, methods, software and general application principles are discussed.

Although not formally named, MCDA methods are present in the existing practice with respect to decision processes and decision support systems in water management processes in Norway. Section 4 discusses elements of MCDA in formal guidance documents for socio-economic analysis impact evaluation.in Norway. We conduct a review of the main guidance documents on conducting Social Economic Analysis ("samfunnsøkonomisk analyse"), choice-of-concept studies and Environmental Impact Assessment (EIA – "konsekvensutredning") as prescribed in the Roads Authority Handbook140.

Section 5 gives an overview of the water management processes in Norway, describing the steps in granting concessions to new hydropower projects as well as the process of revision of terms for single hydropower projects and the steps in implementing the EU Water Framework Directive (EU WFD),

Section 5 summarizes experiences with MCDA in water resource management in Norway, Finland and the Alps region. This section reports on the main findings and recommendations from the case studies presented and discussed during the workshop. This section is complemented by the Appendix that includes more details about the reviewed case studies.

Section 7 gives general recommendations for the application of MCDA to water resources management in Norway. The chapter gives recommendations both on MCDA value modeling to improve the existing social economic analysis guidance in Norway. We discuss how MCDA can be used as decision support to improve the whole management process for individual hydropower concessions – new projects and revisions – as well as some ideas on how MCDA can be used in the implementation of EU WFD at river basin level.

3 Multi Criteria Decision Analysis

All problems and decisions are multi-criteria in nature. When a decision matters enough, formal modeling can be used for decision support and documentation.

Multi-Criteria Decision Analysis is the discipline that provides methods and procedures by which concerns about multiple conflicting criteria can be formally incorporated into the analysis of the decision. Wider in scope than traditional decision analysis theories, MCDA offers means for structuring the decision complexity, helping decision-makers to gain a deeper understanding of the decision problem.

MCDA addresses the whole process of decision making, from identifying and structuring complex multi-criteria problems, choosing the methods to assist the decision process and up to the point a decision is made. MCDA methods seek to support the modeling of both the reality independent of the decision-makers as well as their way of thinking about the problem.

Applied in the right way, MCDA should lead to 'better' and 'justifiable' decisions, in the sense that the decision-makers better understand their problem and their own contribution to the solution and are capable of justify and sustain their decisions.

3.1 What is multi-criteria decision analysis

Multi-criteria decision analysis aims to address all the intentions of decision support process. Figure 1 illustrates three main steps in a multi-criteria decision support process:

Step 1. Problem identification and structuring

A decision aid process starts with the identification and structuring of the complexity that exists in a decision situation. Aspects that must be clarified at this first step are: who is involved in the decision process, what decision has to be made and what uncertainties exists in a given decision situation (what is known and not known about the problem and what are the main difficulties for the evaluation).

Identification of the decision-makers and stakeholders –the interaction between them, how and when are they involved in the decision process.

Decision support is developed to help the decision-maker(s) and therefore it should be always clear who has this role in a decision process.

A decision-maker is the person (or persons) that is (are) confronted with a problem and is (are) in charge with solving it, or making a decision regarding it. The decision-maker can be:

- a single individual with sole responsibility for a personal decision or for a decision that might affect others (companies, organizations, etc.)
- a relatively small and homogeneous group of individuals sharing more-or-less common goals
- a larger group representing different points views
- highly diverse interest groups with very different agendas. This group may share corporate responsibility for a decision, it may have the task of investigating an issue with the goal of making a recommendation to a decision making authority, or it may have been assembled for the explicit purpose of exploring alternative perspectives without any executive power.

In complex decision situations, when large amounts of information must be processed and modeled, the multi-criteria analysis is usually conducted under the guidance of one or more expert facilitators (or decision analysts).

An analyst must be one that has a broad overview of the existing multi-criteria methods and experience with their practical implementation. Since the analyst may have an important contribution throughout the decision process (structuring the information, formulating the decision-problem, presenting this information to the decision maker and finally interpreting the result and issuing a recommendation) it is required that this person knows enough about the problem but also that he plays a neutral and objective role.

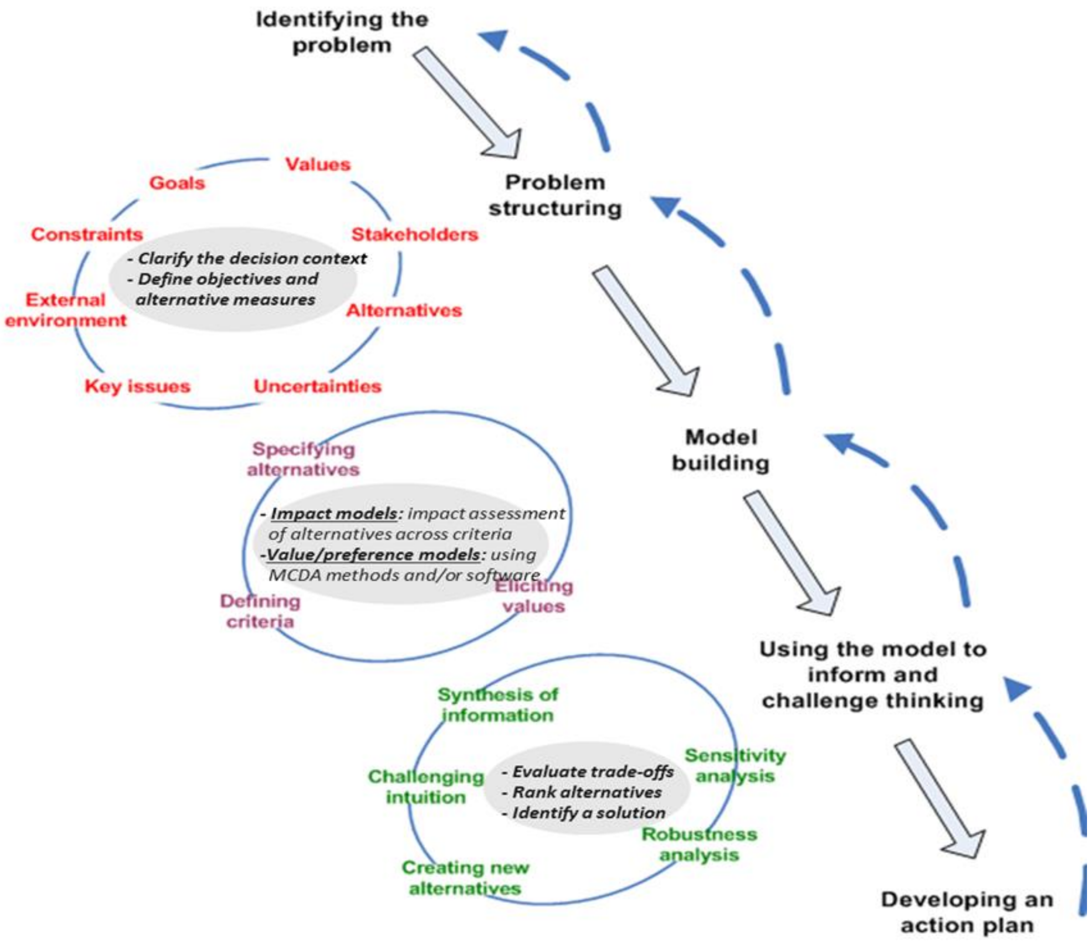


Figure 3.1 An illustration of a multi-criteria decision analysis process, based on Belton and Stewart (2002).

Beside decision analysts, the input from scientific and local knowledge experts may be needed. Their expertise is critical when conducting Impact Evaluation Assessments of the criteria used in the MCA, especially when new impact evaluations are required. In some methodologies (e.g. PIMCEFA) expert knowledge is required in specifying the form of value functions normalizing impacts to a common scale.

Identification of the decision problem: what exactly is to be solved and why, what is to be achieved, deadlines for decision, (time allocated for decision support), etc. Multi-Criteria Analysis can be applied to:

choice problems, sorting problems, ranking problems, learning (descriptive) problems, design problems, portfolio problems.

Problem definition requires the definition of:

- Goals and criteria relevant for the decision: or standards for judging that a decision makers and stakeholders may have. Overall criteria can be explained through a set of sub-goals (objectives, or criteria) that give a picture of the different facets of a decision situation.
- Possible alternatives or courses of action.
- In many environmental management contexts alternatives are usually complex sets of actions that need to be created rather than discovered, Gregory et al (2012). The number and diversity of alternatives can be overwhelming in the context of multi-stakeholder, multi-issue environmental problems. This requires methods for helping groups to come up with a range of creative alternatives, organizing them to facilitate effective evaluation, iteratively simplifying and improving them.

Step 2. Model building

In the MCDA context, the decision is aided by evaluating each alternative on the set of criteria.
Model building refers to models to estimate the impact (consequence) of each alternative with respect to each of the relevant criteria (impact models), as well as approaches to model decision maker's way of thinking about the problem (value/preference models).

Impact models can be for example economic models (information) or environmental impact assessment models.

The impact information is then structured and presented to the decision maker for evaluation. It is here where most MCDA approaches are visibly used and often many people perceive that this is MCDA. However, the whole process matters because the choice of a MCDA approach essentially depends on the information available about the decision problem and specifically the way uncertainty presents itself in the given decision context.

The modeling of impacts and preferences can be assisted by software tools. If separate software/models (sources of information) are used for the assessment of different impacts, then the information has to be gathered under a common platform for further evaluation of alternatives, by the decision maker.

Impact and preference models can be integrated, to a certain extent. Generally, the MCDA software is applied on top of the impact information and there is almost no integration between the impact assessment tools and the preference evaluation software (MCDA). However, it is possible to customize the MCDA software (to a certain extent), to be repeatedly used in the analysis of similar problems (for example problems which may address the same criteria- see the REGAIM and PIMCEFA).

Moreover, some impact assessment software may be extended with additional modules that will allow for a dedicated MCDA analysis.

Many MCDA software allow the preference modeling using several techniques (for value and weight elicitation) – as they are often designed to be flexible and applicable to as many applications (types of decision problems) as possible. However, using several MCDA preference modeling methods, on the same problem, is like using different diagnostic techniques and not as tools to tell decision makers what to do Belton (2002).

Step 3. Using the model to inform and challenge thinking, and develop an action plan

The purpose of modeling is to help in synthesizing the information in a decision-process, and to inform the decision-maker about his options. The whole MCDA process is dynamic and iterative, helping the decision-maker to gain better understanding of the problem and of what are the alternative solutions.

Decision support software is especially useful for sensitivity and robustness analyses – how the ranking of alternatives change when the input information (impacts or preferences) change. Often MCDA with different stakeholder interest will uncover different ways of structuring the problem, which in itself is useful in achieving negotiated solutions – defining new alternatives not previously considered.

During a MCDA decision support session, it is always possible to return to the previous phases because the process usually contributes to a better problem understanding (less uncertainty) which may lead to the identification of new alternatives, new criteria or new preferences.

The result of the process will usually be a ranking of alternatives with a recommendation – the analyst/facilitator (nor the MCDA software) cannot tell a decision maker what to do (what is the preferred solution to their problem) and can only help them find it out for themselves. It is the decision-maker who owns both the problem and the solution.

3.2 Multi-criteria analysis methods

There is a variety of MCDA methods available and, as described in chapter 3.1, their application implies three main phases as described in Figure 3.1 and by Belton and Stewart (2002):

1. Problem identification and structuring
2. Building and use of the preference model
3. Developing the actual action plans

Jordanger et al. (2007) reviewed Norwegian MCDA practice in large infrastructure projects. They distinguish between 3 main classes of methods. The choice of method depends on the type of decision needed, the complexity of the problem, assumptions about preference and the availability of methods formalized in software (Table 3.1).

Table 3.1 Main classes of MCDA methods reviewed for large Norwegian infrastructure projects.

	Value function methods	Outranking	Elementary methods
Single best alternative	x		x
Ranking alternatives	x	x	
Sorting alternatives into classes	x		
Preference assumption	Cardinal preferences;	Ordered preferences;	Cardinal, independence of attributes
Complexity	mixed qualitative quantitative scoring	qualitative scoring	Mixed, simple
Available software	Many	Some	None, manual approach (e.g. Even Swap)

Elementary methods are recommended where the impact matrix has dominated alternatives that can be easily eliminated. Furthermore, elementary methods assume that decision-makers can compare one-by-one the unpriced qualitative impacts with the NPV of quantitative priced impacts and determine what adjustment in NPV would compensate for the difference in unpriced impact between alternatives. Each unpriced impact is addressed in this way in a stepwise fashion until all alternatives can be compared across an adjusted NPV score only. The authors provide an example of this approach which they call “Even Swap”. Even Swap formalizes the evaluation that decision-makers are encouraged to make in assessing unpriced against priced impacts in social economic analysis using the Guidance FIN2005. The Even swap method depends on strong assumptions that criteria can be evaluated independently, and that the order in which criteria are addressed does not affect the adjustment of NPV (that valuation are path-independent). In more complex trade-off problems Jordanger and colleagues recommend using multi-attribute value theory and value functions in more complex trade-offs where assumptions of independence of criteria cannot be assumed.

Multi-attribute value theory (MAVT) is the MCDA method that is perhaps most often used in complex environmental assessment applications. The MVAT application and model building is fairly easy and the method is implemented by the majority of MCDA software available. A long research tradition and large number of real-life cases on MAVT has produced a good understanding of how to carry out a structured decision process in practice Marttunen et al. (2013). However, other MCDA approaches, as for example the Analytic Hierarchy Process (AHP) and outranking methods can also be used Belton and Stewart (2002).

In MVAT the problem is constructed as a tree-like hierarchy of criteria and alternatives.
The criteria are weighted according to their importance and the alternatives are evaluated with respect to each lowest level criterion (i.e. attribute). As a result, one gets overall values of alternatives that reflect the preferences of the decision makers as well as the performance of the alternatives with respect to each criterion.

The essence of applying MAVT is to understand the meaning of the weights, which describe how important or significant the decision makers consider the value changes in the attributes from their lowest to their highest level compared to the corresponding changes in the other attributes. In other words, the weights can be seen to describe the trade-offs between the attributes Marttunen et al. (2013).

However, in practice the decision makers often seem to neglect the ranges of the attributes, and instead give the attribute weights on the grounds of some ‘general importance’ of the attributes.
In such cases they might have some attribute ranges, at least unconsciously, in their mind, but if these differ significantly from the ranges used in the model, the results are likely to be biased. There are also many other phenomena related to, for example, the structure of the value tree, that can cause biases to the modelled preferences. Thus, in the practical application of the methods, certain decision analytical expertise is always needed to assure the correct use of the methods and consequently to minimize the biases Marttunen et al. (2013), Barton and Berge (2010).

3.3 Value judgments in MCDA

The main types of value judgments needed to compare alternative actions over multiple attributes with different impact scales are discussed in this section from a conceptual point of view. This chapter describes what value judgments are required in formal MCDA analysis. This is a backdrop for the analysis in the next chapter of the extent to which formal MCDA is recommended in guidance documents as well as part of current project appraisal practice. We will argue in the next chapter that MCDA methods, although perhaps not officially named in this way, are already a part of Norwegian guidance on social economic analysis.

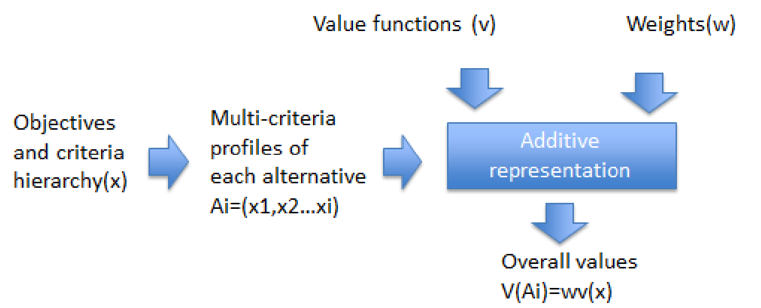


Figure 3.2 Subjective components of MCDA model structure. Source: based on Beinat (1997).

The Roads Authority Handbook 140 proposes a methodology that scales priced and unpriced impacts to a commensurable impact scale. The Handbook 140 guidelines are similar to MCDA approaches that use cardinal compensation between criteria and are based on multi-attribute value theory (MAVT). Value functions are needed in order to carry out the scaling of impacts in MAVT. Figure 3.2 from Beinat (1997), below illustrates the formal steps of an MCDA up to value model building. Subjective judgments are required in defining an additive representation of the decision problem which can be handled by decision-makers.

1 objective hierarchy
2 definition of alternatives
3 representation of objectives with evaluation criteria and their scales
4 value functions that normalize individual impacts to a common scale of comparison
5 weights for criteria that allow comparison of alternatives

Guidelines prescribe the role of subjective judgement in project appraisal. In choice-of concept studies step (1) project objectives and step (2) alternatives definition are subject to political control in larger projects. Sectoral guidance documents on impact evaluation such as HB140 broadly prescribe how impacts are to be scored. The next section discusses the steps of determining (4) value functions and (5) weighting. The Norwegian guidance documents on social economic analysis stop at this point, leaving room for much subjective interpretation by consultants carrying out the assessment.

Value scaling approaches

There are two fundamentally different methodological approaches to scaling and weighting multiple criteria in MCDA. (Beinat, 1997) classifies them as (i) decomposed scaling and (ii) holistic scaling (Figure 3.3).

The distinction is useful in clarifying possible methodological differences between guidance documents by the Ministry of Finance and the Roads Authority regarding how to conduct social economic analysis as part of impact assessment procedure in Norway

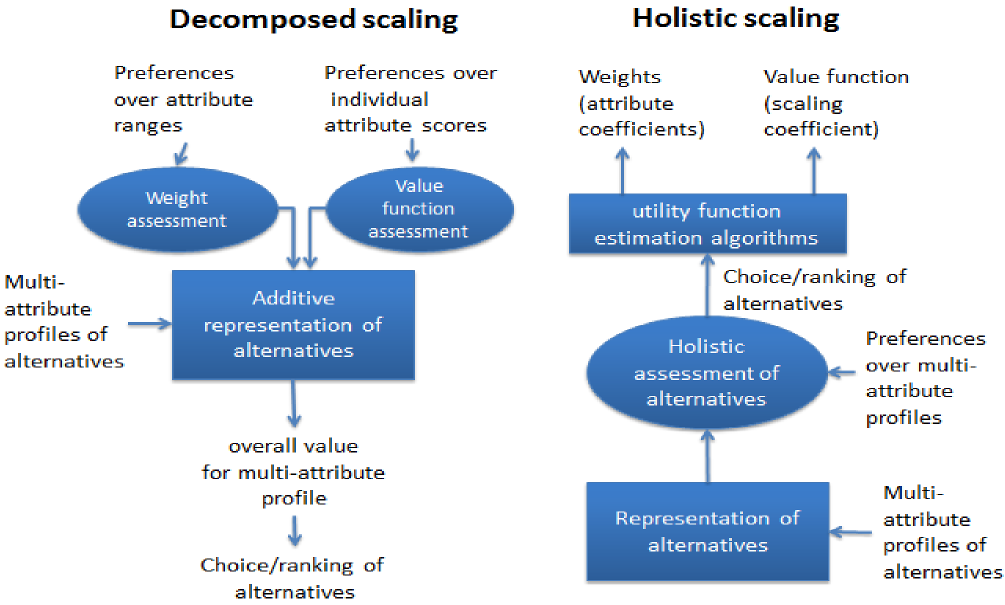


Figure 3.3 Two basic value scaling and weighting approaches in MCDA. Source: based on Beinat(1997).

Decomposed value scaling

Decomposed scaling is the approach explicitly taken in e.g. Roads Authority Handbook 140. Decomposed scaling requires explicit scaling of impacts and determination of weights. Holistic scaling reveals value scales and criteria weights implicitly through choices made by the decision-makers. Holistic scaling is consistent with rationality of individually revealed preferences.

The basic steps of a decomposed scaling methodology are (adapted from Beinat, 1997):
1. check attributes in multi-attribute profile for independence to avoid double counting
2. estimate marginal value functions for each attribute separately
3. assess weights for all attributes
4. specify the additive representation of alternatives as the weighted additive combination of individual value functions and weights.
5. compute overall utility of each alternative
6. choose or rank alternatives in order of highest utility

The decomposed scaling approach to MCDA requires that value functions be specified for each impact attribute. The impact indicator can be described in terms of cardinal biophysical units, intervals or as ordinal categories. A value function scales the impact indicator to a normalized/scaled impact indicator that can be compared across attributes (Figure 3.4). The scaled impact is often a number range representing either costs or benefits [0,1] or cost and benefits together [-1,1].

Crucially, value functions are *subjective* scalings of impact scores which are normalised to a common scale of impact. Value functions are based on a subjective evaluation. The value function may have different shapes for different attributes, and for positive versus negative changes in the attribute. The value function will have different ´steepness´ depending on the utility or importance of the type of impact. Different value functions are expected to be held by different types of stakeholders affected by the alternative projects. Decision-makers, stakeholders affected and technical experts on that particular impact may not express the

same value functions during consultation processes. Value functions may also be more difficult to elicit directly from stakeholders than from decision-makers, or technical experts.
In Roads Authority HB140 impacts are scaled to an ordinal indicator. This is discussed in greater detail in section 4.3. Several examples of cardinal or quantitative value scaling functions are presented in the following.

The Optipol project (Bevanger et al. 2012) developed a tool for optimal siting of power lines across a landscape using multiple siting impact criteria. Researchers used ‘accept functions’ to scale map layers to a normalized [0,1] value function. The accept function was then inverted to create a normalized ‘cost surface’ map layer for each siting criterion (see Appendix for further details). Degree of accept curves were determined in consultation with stakeholders and experts (Thomassen et al. 2012). (Figure 3.4)

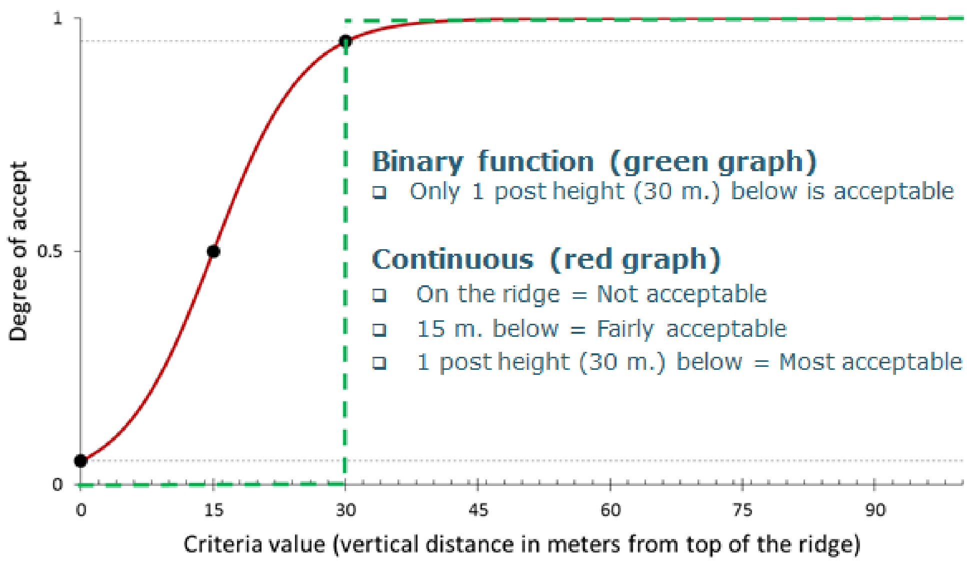


Figure 3.4 Degree of accept scaling of impact criteria for optimal siting of power lines. Source: Roel May (pers.com) Optipol project.

The STRIVER project used MCDA to evaluate optimal environmental flows in the Øyeren river delta across a number of impact criteria, including fish and bird habitat, farming, recreational boating and hydropower production (Barton et al., 2009) .So-called ‘pressure-impact curves’ were used to scale the importance of water level (horizontal axis) for a specific use to a standard or normalized range [0..1]. Pressure-impact curves are drawn based on discussion in thematic expert groups. Value scaling involves subjective judgement of importance of incremental changes and cannot be value free. Nevertheless, the authors argue that the method[1] with ‘pressure-impact’ curves helps technical experts to focus on evaluating biophysical impact, with as little value judgement as possible. Value judgements regarding the relative importance of the impacts are delegated to decision-makers in a separate step of MCDA using criteria weighting.

[1] PIMCEFA: Pressure-Impact Multi-Criteria Environmental Flow Assessment

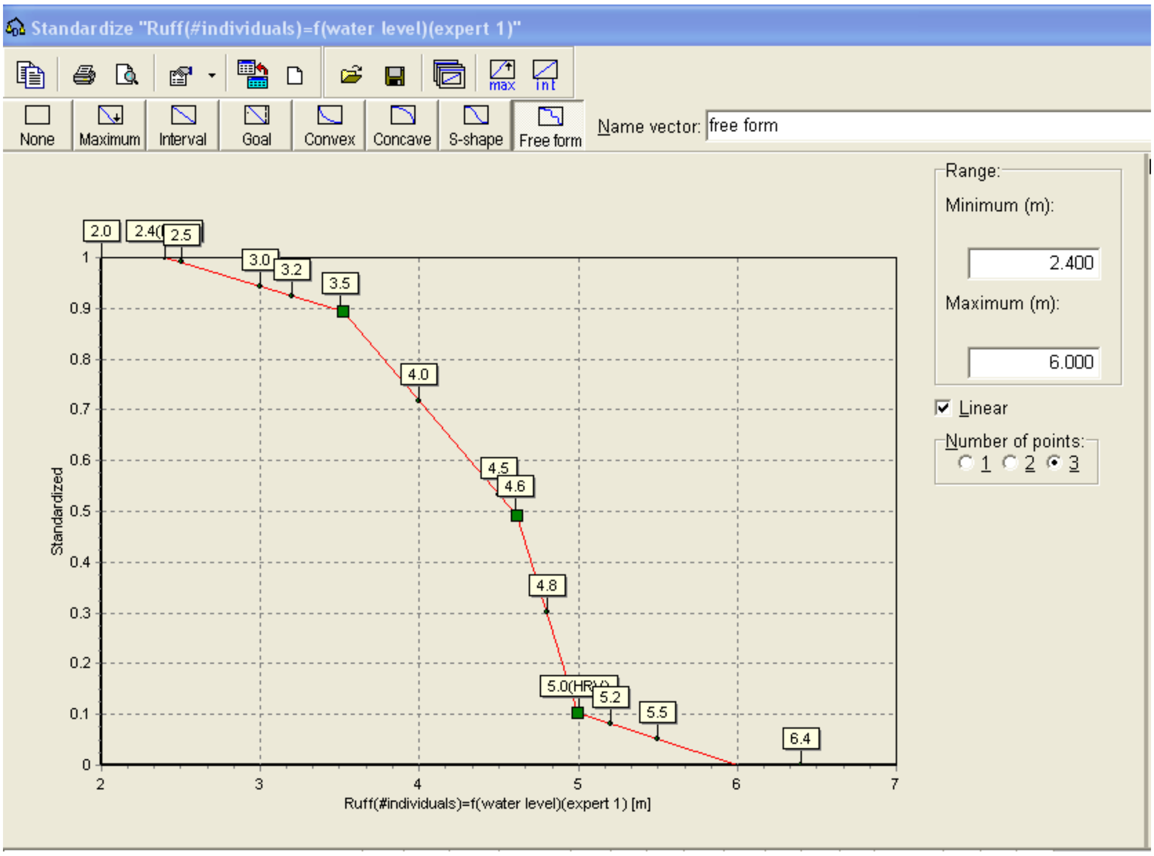


Figure 3.5 Pressure-impact scaling of water level to a normalized impact score (duck species "Ruff") Source: Barton et al. (2009).

Note: water level (horizontal axis). Vertical axis standardized range [0..1] where 0=100% loss of the attribute, and 1=no loss of the attribute in question

Holistic value scaling

Holistic assessment is based on overall value judgements of multi-attribute profiles across alternatives. The typical steps of holistic scaling are as follows (adapted from Beinat 1997):

1. check attributes for independence to avoid double counting
2. design a set of real or hypothetical multi-attribute project profiles
3. assess preferences over multi-attribute project profiles
4. estimate the multi-attribute utility function which best reproduces the preferences

Holistic value scaling avoids the complications involved in defining the value function directly as shown above for decomposed scaling. Instead decision-makers are asked to choose or rank different alternative project profiles. A large number of hypothetical project profiles are generated by the analyst. Enough combination of attributes must be put to the consideration of decision-makers in order to generate enough choice data that a utility function can be estimated using statistical techniques. The drawback of the method is that a large number of hypothetical project profiles have to be considered by decision makers.

Trade-offs made by decision-makers in choosing particular project profiles will also reveal how unpriced impacts are implicitly valued relative to priced impacts. Trade-offs and implicit valuation of unpriced impacts is delegated to whomever is considered to be the decision-maker.

It is worth noting that the increasingly popular monetary non-market valuation methods called 'choice experiments', which are used for pricing environmental impacts, use holistic scaling. The information burden placed on decision-makers is resolved by randomly assigning sets of choices across decision-makers. This works well when decision-makers are a population of households. However, the information burden would be expected to become challenging when designated decision-makers are only a few individuals. The choice experiment method of value scaling is also a method based on individual choices, rather than choice s deliberated in a group.

The holistic approach is consistent with recommendations in the Ministry of Finance´s Guidance on social economic analysis (FIN 2005), where weighting of unpriced effects is discouraged and implicit valuation is left to the decision-maker and political process.

To summarize, MCDA techniques are available to use in both decomposed and holistic valuation. Guidelines that propose using cost-benefit analysis may discourage decomposed valuation because it discourages direct value scaling and explicit weighting, preferring values to be revealed by decision-makers actual or hypothetical choices. These two focuses are not mutually exclusive. In Section 4 we will see that CBA and MCDA techniques are in practice combined in social economic analysis of projects in Norway.

3.4 How can MCDA be applied

MCDA is increasingly used in environmental planning projects to evaluate the alternatives and to support stakeholder involvement. This chapter is based on Marttunen et al. (2013), article summarizing 20-year experience of using MCDA to engage stakeholders in real-life environmental planning projects in Finland.

MCDA can be helpful in many situations:

- As a framework for the whole planning and decision making process
- In the identification and structuring stakeholders' objectives
- In the development of new alternatives
- For comprehensive evaluation/ranking of alternatives
- For incorporating stakeholders' values and knowledge in decision making
- For describing stakeholders' values and their impacts on outcomes
- For facilitating interaction and learning between experts, authorities and stakeholders
- For understanding the implications of uncertainties
- For creating shared understanding and commitment among stakeholders
- For finding widely acceptable (consensus/compromise) solutions

MCDA is a process structuring tool, in which MCDA modelling is only a part of. MCDA can be helpful although it does not result in the use of preference modelling. MCDA can even be realized without formal quantitative preference modeling for example in projects where the preferred management plan becomes clear directly after careful structuring Marttunen et al. (2013).

The application to and integration of MCDA in environmental planning and decision making requires an assessment of:

- When MCDA should be introduced into the process
- How MCDA affects the design of the decision process
- How are MCDA and the decision process integrated
- How should the decision makers and stakeholders (advisory boards, steering groups) be engaged in the MCDA process
- How the results of MCDA will be used in decision making

According to Marttunen et al. (2013) the integration of MCDA into the planning process works out best if MCDA experts participate in the decision support process. This is not always possible and examples have been reported where MCDA has been mainly used at the end of the process, as a tool to summarize information and describe for example how different stakeholders perceive alternatives.

However, the more integrated and interactive the process is, the more resources it will require and therefore a trade-off has to be made between the quality of the process and the needed workload.

Table 3.2 summarizes several approaches to MCDA in practice, differing in terms of the levels of integration and interaction in the decision process.

Table 3.2 Levels of integration and interaction in the MCDA process, Marttunen et.al (2013).

Level	Integration of MCDA	Interaction of MCDA
Low	MCDA is a separate process, it is unclear how the results of MCDA are used in planning or decision making.	MCDA is realized by the experts.
Moderate	MCDA has some links/impacts to planning or decision making.	Stakeholders participate to the process, but their participation is limited to certain phases and weight elicitation is realized without personal support using e.g. a questionnaire.
High	MCDA brings structure to the planning. The phases of planning and MCDA are well synchronized	Stakeholders are involved in some phases of the process, personal interaction in weight elicitation and analysis of the results, group discussions of the results.
Very high	MCDA provides the framework and roadmap for planning or decision making. MCDA's principles and practices are largely used when designing the planning process	Stakeholders are actively involved in different phases of MCDA, face-to-face personal or small group computer-aided interviews, seminar after the interviews

The requirements of the project as well as the possible constraints and the available resources, affect what kind of objectives it is reasonable to set for MCDA and how to realize the MCDA process, Marttunen et al. (2013). Many of the decision contexts that will be further described in chapter 3 imply public participation as an important component in environmental planning and management. However, meaningful participation requires that the involvement of the public and all interest parties is integrated directly in the phases of the decision process. MCDA is a versatile and flexible approach to engage stakeholders and incorporate their values and knowledge in the decision process.

Figure 3.5 presents five approaches for the design and realization of a participatory MCDA.

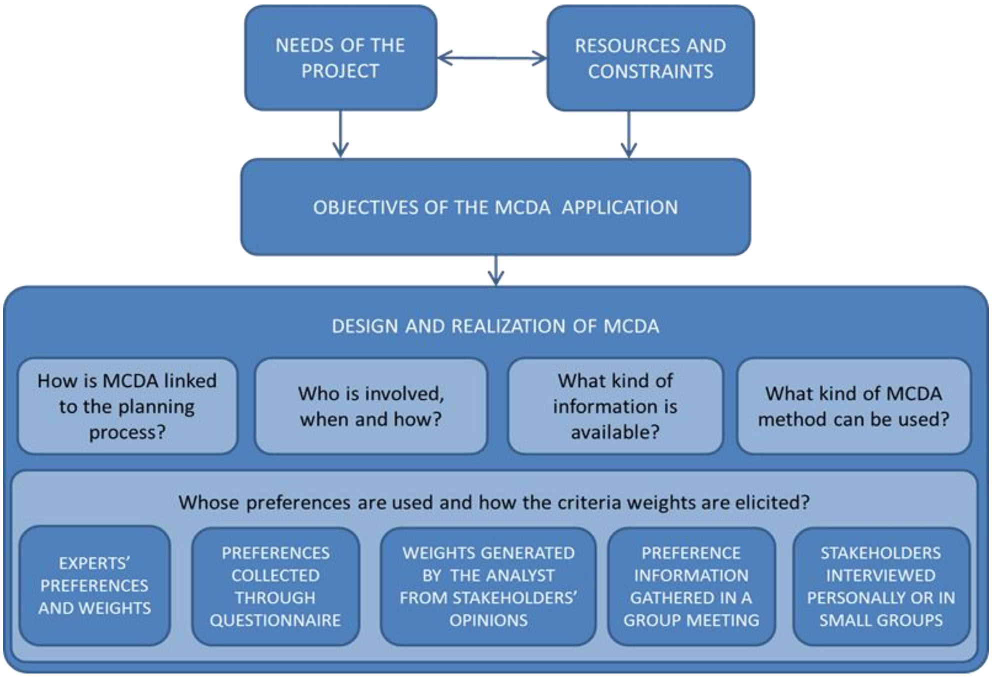


Figure 3.5 The framework for designing and realizing the stakeholder preference elicitation in MCDA process, Marttunen et al. (2013).

These approaches represent different practices for eliciting preferences or criteria weights from an expert-driven to a personal interview approach. These approaches can also be used in complementary ways.

- Expert MCDA: approach in which experts apply the MCDA method on their own, using their own preference information or hypothetical preferences. The results are discussed by the experts and may be presented to selected stakeholders or decision makers. The approach can be used to synthesize a large amount of information. It is especially applicable if the primary aim is to give experts a better overall understanding of the problem and of the strengths and weaknesses of preliminary alternatives or to identify data gaps and information needs.
- Postal questionnaire: approach in which stakeholders are asked to give their preferences in postal questionnaires. The approach is applicable in situations where input is needed from a large number of people.
- Generated value profiles developed by the MCDA experts: approach in which experts formulate some typical views on the basis of the available information about people's values and interests collected by e.g. interviews, questionnaires or public meetings. For each view, a plausible value profile is then generated by the experts. A value profile means here a specific combination of criteria weights which reflect a given perspective, such as a recreational user, a farmer or a representative of a hydropower company. The views and value profiles can be discussed and refined with stakeholders. This approach can be used as a complementary approach, if some points of views are missing.
- Weights elicited in a group meeting: approach in which preference information is gathered and analysed in a workshop under the guidance of a decision analyst. The elicited criteria weights can be those of individual group members or common weights of the whole group. The use of the former is often recommended, as these also reveal the variation in the preferences among the group members.
- Personal interviews: approach in which interactive personal interviews of stakeholders are carried out using MCDA software and the results are discussed in a group meeting. This approach is recommended when the primary aim is stakeholders' learning, commitment and joint solution finding in a controversial issue.

Further, Figure 3.6 provides an illustration of the role of decision analytical expertise and other roles in an MCDA of water level regulation in Øyeren, Norway. For more information about this case study please see Appendix.

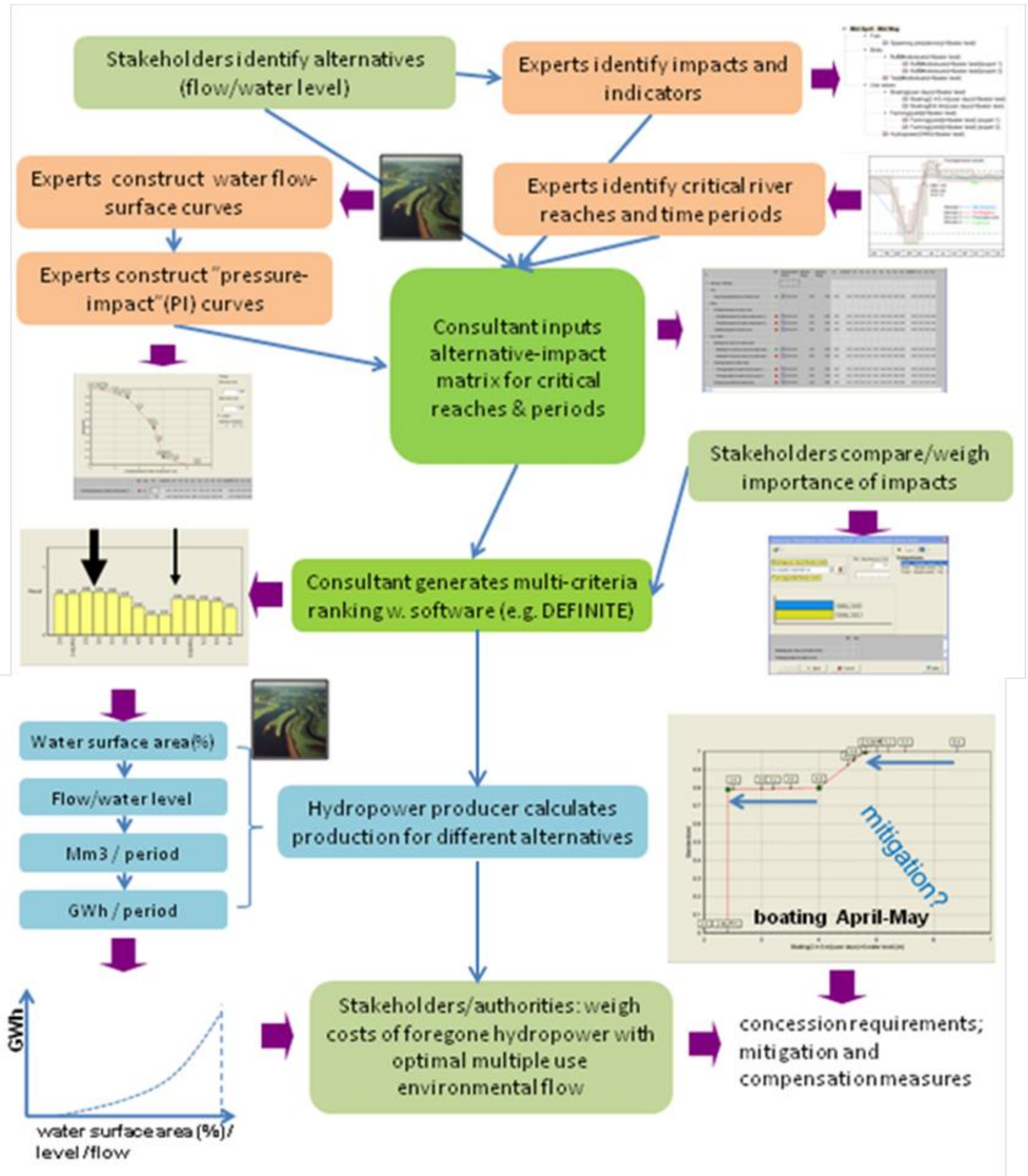


Figure 3.6 The role of decision analytical expertise and other roles in an MCDA of water level regulation in Øyeren, Norway. Source: Barton et al. (2009).

3.5 Multi criteria decision support software

Various multi-criteria software or decision support systems (DSS) have been developed to support the use of MCDA methods in practice. Besides computational support for implementing the methods and the calculation of the results, the software usually provide various ways to also support other phases of the process, such as the construction of the model and analysis of results (Mustajoki and Marttunen, 2013).

The structures of the different software are similar, following the general structure of the MCDA process as described in this chapter. However different software implements different MCDA method(s) and provide different ways to present the results.

A general trend is towards multi-purpose software providing different methods that would adapt to various decision situations. On the one hand this allows the application of software to a wide variety of different decision situations, but on the other hand this freedom also requires certain expertise from the user.

Criteria for selecting MCDA software will depend on the application context and resources available. Some consideration in choosing software is as follows:

- The software provides accompanying (online) guidance or decision wizards on how to carry out MCDA process
- The software provides the possibility to use various value elicitation methods and is flexible with respect to the definition of the value function
    - weighting methods available
    - benefit-cost analysis capability
- The software allows (graphical) comparison of a large number of alternatives
    - spatial scale of applications
    - spatial explicitness
- The software provides possibilities for uncertainty /sensitivity analysis
- The software provides possibilities to compare different stakeholders' preferences types of outputs/user interface
- The software allows the analysis of time-specific impact assessments.

In the case studies discussed in the report/workshop the following software has been used:

- DEFINITE
- Web-HIPRE
- REGAIM – customised decision support tool, not available on the Internet
- SESAMO-SHARE

For more information on how the software has been used see Appendix 1 and the references provided.

Table 3.3 lists also other software tools that are relevant for supporting the environmental impact assessment process.

The software presented here has been evaluated recently in Mustajoki and Marttunen (2013). In searching for ideas to develop a general purpose tool for EIA, the authors have identified the following needs of EIA for MCDA software:

- The software has to be easy to use. The target users of such software are EIA practitioners or consultants who are going to apply MCDA methods in their assessment process but not necessary have much experience on m Mustajoki, Marttunen (2013) MCDA. However in practice a certain expertise in MCDA is a must in order to use the software properly. They believe that due to the specificity of EIA it will be possible to develop software that will guide the user hand-in-hand through the process. Although the application areas for EIA can vary considerably, the principles of applying EIA are quite similar. Their work is in progress.

- MCDA has to be included in the EIA process in a very early phase of the process because already in the assessment program phase choices have to be made that will affect the whole decision process.
- Process support: often MCDA software count just as calculation and visualization tools for supporting the mathematical modelling of the methods. However in practice MCDA is more than that and therefore some support for a structured progression in the decision process is needed.
- MCDA has a lot of potential in providing methods that could make the impact significance assessment more structured and transparent. Implementing the process in practice should be carefully planned so that all special characteristics of the EIA are taken into consideration.
- Visualization of the results: often in EIA the overall impacts are formed of different dimensions, (e.g. magnitude, sensitivity) so that multi-dimensional graphs are very useful in helping decision makers understand the overall impacts. The graphical user interfaces of most of the listed software can provide various possibilities to visualize the process and the results, and consequently make the understanding of the results more transparent.

Table 3.3 Software having potential for supporting the environmental impact assessment.

Software	Web page
1000Minds	http://www.1000minds.com
Analytica	http://www.lumina.com/why-analytica/
Craft	http://www.fs.fed.us/psw/topics/fire_science/craft/craft/
Criterium Decision Plus 3.0	http://www.infoharvest.com/ihroot/infoharv/products.asp
DecideIT	http://www.preference.nu/?l=decideit&lan=en
Decision Tools	http://www.palisade.com/decisiontools_suite/
DEFINITE	http://www.ivm.vu.nl/en/projects/Projects/spatial- analysis/DEFINITE/index.asp
D-Sight	http://www.d-sight.com/
GMAA	http://www.dia.fi.upm.es/~ajimenez/GMAA
Hiview 3	http://www.catalyze.co.uk/
Logical Decisions	http://www.logicaldecisions.com
M-MACBETH	http://www.m-macbeth.com
MakeItRational	http://makeitrational.com/multi-criteria-evaluation
MCDA-Res	http://www.aegean.gr/environment/energy/mcda/MCDA_default.htm
MESTA	http://mesta.metla.fi
OnBalance	http://www.quartzstar.com/
PlanEval	http://heureka.resgeom.slu.se/wiki/index.php?title=PlanEval
Promax	http://www.cogentus.co.uk/products/
PUrE2	http://www.pureintrawise.org/
SESAMO-SHARE	http://www.sharealpinerivers.eu/tools-and-resources/our-softwares-1/sesamo-share
TESLA	http://www.quintessa.org/software/tesla.html
The Decision Deck project	http://www.decision-deck.org
V.I.S.A. Decisions	http://www.visadecisions.com/
Web-HIPRE	http://www.hipre.hut.fi
WINPRE	http://sal.aalto.fi/en/resources/downloadables/winpre
VIP Analysis	http://www.uc.pt/en/feuc/ldias/software/vipa

MCDA software functionality is generally easy to use, increasing the risk of using it wrongly! Almost all the software have some kind of help pages providing overview of the process, but the responsibility to follow and understand this guidance is still left to the user. In this respect, one approach towards more profound process guidance support is to provide on-line guidance during the process so that on each task, appropriate guidance is brought to the user automatically. A good example in this respect is the software V.I.S.A Decisions (see the table above), which provides a decision wizard that tells the user what to do on each phase and after this guides the user to the next phase.

3.6 Choosing a method for environmental appraisal - CBA or MCDA?

Vatn (2009) discusses how appraisal methods are institutional structures in themselves because they are rules concerning (a) who should participate and in which capacity, (b) what is considered data and which form data should take, and (c) rules about how a conclusion is reached.

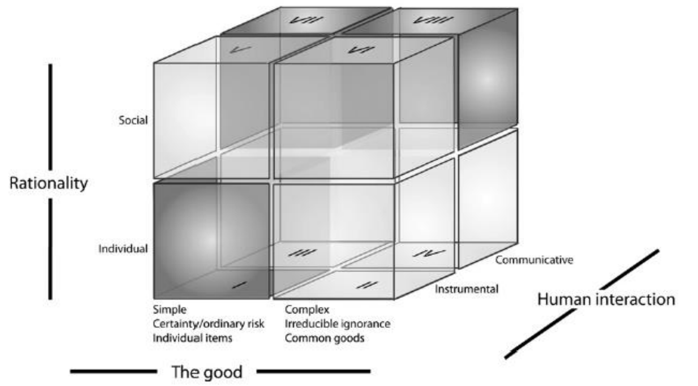


Figure 3.7 Dimensions of appraisal methods as value articulating institutions. Source: Vatn (2009).

In chapter 4 we will review how multi-criteria assessment is a part of social economic appraisal in current practice in Norway. In practice national guidelines determine which methods of appraisal are to be used in evaluating projects. Project appraisal methods used in practice are 'hybrid' approaches reflecting the mix of decision rationalities present in environmental governance.

The framework for analyzing value articulating institutions (Figure 3.7) provides useful dimensions for discussing national guidelines on project appraisal. Appraisal rationality may be characterized according to individual-social rationality; simple-complex types of environmental goods and communicative-instrumental types of human interaction in the appraisal.

Cost-benefit analysis (CBA) aims to assign monetary values to impacts derived from individuals´ or households´ observed or hypothetical choices. The favourable criteria values are summed as the benefits of an alternative while the unfavourable values are summed up as costs. The most desirable alternative is the one with the highest net present value (time discounted benefits minus costs). Simple goods can be easily demarcated and priced in monetary terms. Impacts are valued based on observations of the individuals' choices and their rationality. The preferred project alternative is identified based on an instrumental calculation of net present value of all priced impacts (rather than through communicative deliberation of the relative importance of impacts). In this sense the theoretical ideal CBA is of type I in Figure 3.7.

As we have seen multi-criteria decision analysis (MCDA) can be practiced in a number of different ways. However, some broad characteristics of the decision problem clearly set it apart from the ideal CBA as described above. Environmental goods are complex and not easily demarcated and so not easily valued. A decision therefore considers both priced and unpriced impacts. If the stakes and conflict potential are high the decision problem requires that value judgements and priority-setting be achieved through agreement rather than aggregation (Vatn 2009). In this case, MCDA is a communicative tool used to structure human interaction that is required to agree on priorities. Priorities and values in deliberative processes are likely to be determined by the social rationality of a group with different stakes, rather than based on individual rationality. In this setting MCDA belongs to Type VIII in Figure 3.7 and is clearly and alternative assessment technique to CBA.

In practice CBA is also applied to complex problems where impacts are hard to demarcate and/or very expensive to value using willingness-to-pay based surveys of the population. A hybrid approach is needed. MCDA methods are used to scale and weight impact of different dimensions and MCDA algorithms are used in an instrumental fashion to obtain a project ranking. Weighting is based on the individual judgement of experts. Here CBA is the theoretical starting point, and MCDA is applied in what might be called a 'technocratic approach' without the social or communicative dimensions that were described above. In this case CBA would fall in Type II.

CBA in practice may approach MCDA even further. Unpriced impacts may be left as qualitative descriptions in a disaggregated impact matrix. Guidance documents may recommend leaving to the decision-maker to compare this multi-attribute information with the net present value of priced impacts of each alternative. Ranking of alternatives by the decision-maker may be carried out, but the value judgments regarding the relative importance of unpriced impacts as left to the decision-maker are implicit and undocumented. In this case it is also assumed that there is a decision-maker who is able to represent multiple interests in a social welfare function and to which the technical experts can leave all value judgements. However, the implementation of the appraisal is not communicative because it does not recognize that there may be disagreement about who's stakes count and who are the legitimate decision-makers. In this case CBA – approaching MCDA still further - would fall in the Type VI.

Vatn (2009) points out that some 'hybrid' appraisal methods will be internally inconsistent in their rationality (for example aiming for a social welfare function without being participative, discursive and communicative in the value elicitation methodologies used). However, this may be a reflection of a mix of governance rationalities operating in parallel through multiple institutions which have their own appraisal norms and guidance. This may be the case of Finance Ministry and Roads Authority Guidelines on social economic analysis, discussed in the next chapter.

MCDA potentially brings in structure, analysis and transparency to value judgments needed in comparing unpriced and priced impacts. MCDA software have user interfaces that try to address different parts of the problem structuring process in a more explicit way than can be done in spreadsheet models.. However, to achieve greater transparency regarding MCDA requires much more effort (and time to analyze trade-offs) from the decision maker than classical CBA (which might be used only to inform and not to involve the decision-maker).

MCDA provides a structure whereby subjective judgements about the importance of criteria can be formally included in the analysis of a decision. A consultant or analyst having MCDA expertise can play a technical supporting role. This can be very important at least in the first phases of the method learning and implementation process. In a decision support process it is important to separate technical assessment of impacts from the value judgments and priorities. In the current impact evaluation and social economic analysis methods already used in Norway, some of the value judgments are assumed to be implicit to the impact evaluation methodology and carried out by technical experts rather than political decision-makers, or based on data on consumer preferences. Some value judgments are carried out by technical experts while economists would ideally have based them on consumer preferences.

In summary, MCDA can cover the whole decision process; it is a problem structuring tool, as well as a modeling tool and is increasingly reported as a viable tool to support stakeholder involvement in real life decision processes. MCDA can be helpful even though it might not always be used for preference modeling. CBA may be used in parallel to, or as a complement to MCDA (and vice versa). Rationalities from CBA and MCDA may also be mixed in one and the same appraisal guidance. In any case, the legitimacy of any hybrid appraisal method depends largely on how well the analysis is documented, verifiable, comparable and replicable across appraisal situations.

4 Elements of MCDA in formal guidance documents in Norway

The aim of this section is to identify the extent to which MCDA is already used as decision support in Norwegian water management practice. We start with description of general guidance on policy decision support in evaluating alternatives.

We first discuss the guidance document on social economic analysis FIN(2005).[2]. Next, we review guidance on ´concept screening of projects´[3] (FIN,2010) to see how the definition of social economic analysis has been broadened most recently to consider also formal MCDA techniques. Finally, we discuss the Roads Authority´s guidance on Impact Evaluation (Statens Vegvesen Handbook 140) which has been the basis for the development of applied methods of MCDA in practice in Norway.

These three guidance documents need to be considered together to understand the formal basis for applying MCDA in Norway. This provides the backdrop for discussing the potential for increased MCDA application to water management processes in the following section. Below, we discuss each in turn as stand-alone documents in order to emphasize potential methodological challenges that have existed in practical project evaluation.

Cost-impact analysis (FIN , 2005)

”An assessment of costs of different measures which are focused on the same problem, but where the effects of the measures are not exactly the same. In such cases we cannot choose the lowest cost alternative (without further analysis)”
”Calculation of costs of measures alongside a description of the different benefits can nonetheless provide valuable information for decision-makers” (p. 10. FIN2005).

4.1 Social economic analysis of projects

This section discusses whether MCDA is present in the official Norwegian Guidance on social economic analysis.

NVE(2003) has developed a Handbook for social economic analysis of energy projects . The NVE Handbook is based largely on the 2000 guidance document by the Ministry of Finance on social economic analysis.The guidance was revised (FIN 2005) and has also been the subject of a recent white paper (NOU 2012:16).

NVE’s guidance on social economic analysis refers mainly to cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) as the two most common forms of social economic analysis. In addition, the Finance Ministry’s guidance refers to a third main type of social economic analysis called “cost-impact analysis”[4] or CIA.

The aim of social economic analysis is to clarify and make explicit the consequences of alternative measures before a decision is taken. Social economic analysis is a systematic approach to organizing impact information. The analysis is meant to be decision-support, rather than to represent any form of decision rule. The definition of a ‘complete CBA’ is that all impacts are valued monetarily (FIN2005). However, cost and benefits are to valued monetarily only as far as it is technically possible and defensible (NOU 2012). The 2005 Guidance on social economic analysis refers to Roads Authority Handbook 140 for all

[2] ‘samfunnsøkonomisk analyse’
[3] ‘konseptutvalgsvurdering’,
[4] “kostnadsvirkningsanalyse”

recommendations of how unpriced impacts can be systematically compared and evaluated as part of a social economic analysis.

MCDA methods in social economic analysis

The cost and impact information used to evaluate alternatives in a CIA is equivalent to what is commonly handled in our conceptual discussion of MCDA discussed in Chapter 2. It is also similar to the priced and unpriced impact information as referred to in Handbook 140 of the Roads Authority discussed below.

The consequence matrix as a combination of "value" and "scope" of impacts from Handbook 140 is the only example of a method for systematic evaluation of unpriced effects provided. Regarding aggregating unpriced impacts FIN(2005) notes that some positive and negative impacts may cancel one another out in the comparison of sub-criteria across alternatives. It notes that such comparisons have to be made based on "technical guidance" and strict requirements for documentation. In cases where such aggregation and comparison of unpriced impacts cannot be undertaken without carrying out judgments of political prioritization, criteria aggregation should be left to the decision-maker. It emphasizes that all criteria may not have the same weight. It goes on to recommend that if unpriced impacts can be aggregated, alternative measures can be ranked by the alternative with the highest aggregate positive score (on a 3 level scale). FIN(2005) does not recommend further aggregation of priced and unpriced effects. It concludes that if a decision-maker chooses an alternative that is different from the one with the highest social economic return without unpriced effects, then the upriced impacts are implicitly valued through the decision-makers choices.

With a view to focusing on guidance on multi-criteria decision-making our reading of FIN(2005) is as follows:

- It recommends by default to use standardized value functions implicit in the ´consequence matrix´ of Handbook 140.
- It recommends using direct summation of criteria to rank alternative measures, while also emphasizing that criteria may not necessarily have equal weights.
-
- It recommends separating technical evaluation from political judgement in the aggregation of impacts of alternatives across unpriced criteria

We find it notable that the FIN(2005) guidance on social economic analysis devotes considerable discussion to potential biases in the choice of discount rate, risk adjustment and valuation of non-market impacts, while no guidance is offered on the potential biases in scaling, normalizing and weighting unpriced impacts. FIN(2005) refers the reader to sector specific guidance documents for more specific methodology, such as the Road´s Authority Handbook 140.

FIN (2005) refers to NVE(2003) for social economic analysis of energy projects. NVE (2003) provides some additional guidance on treatment of unpriced impacts, but focuses on pricing of environmental impacts, rather than how do deal with qualitative unpriced impacts. It concludes that available non-market valuation estimates of environmental impacts are too sparse to apply a full CBA. It recommends using a "simplified environmental assessment" with an "environmental index" describing the environmental cost at which project economic return becomes negative. No further guidance is offered on how the decision-maker may go about evaluating whether the combination of unpriced impacts exceeds the critical economic return needed by the energy project, as represented by the environmental index.

NVE has also developed and regularly applies simplified multi-criteria assessment for natural hazard control projects, principally flood and slide control works following a Handbook (NVE 2001). This methodology follows a simple spreadsheet-based summation of scores of unpriced impacts.

4.2 Choice-of-concept in major projects and social economic analysis

Public project planning in Norway has since 2005 required that large projects (>500 MNOK) be subject to evaluated by the Parliament before further planning can take place (KS1). This “Choice-of-concept stage ” should contain an assessment of alternatives which should be structured as a social economic analysis according to the Ministry of Finance Guidance (FIN 2005). The steps of a concept evaluation are outlined in FIN(2010) Guidance , and outlined in the table below.

Table 4.1 Steps in choice-of-concept studies.

Steps in the process	Description
Needs	Societal needs to be addressed by the project
Objectives	Overall political objectives and assumed consequences
Requirements	Indicators for societal goals and impact indicators
Assessment of alternatives	Priced and unpriced impacts.
Recommendation	Recommended project alternatives based on interdependencies, method of analysis, decision context, value of options

In terms of guidelines for handling multi-criteria assessment problems FIN(2010) complements FIN(2005). Choice-of-concept guidance has also been developed for power transmission lines, although these are less specific regarding methodology for multi-criteria comparison of alternatives.

MCDA methods in choice-of concept studies

Jordanger et al. (2007) conducted a detailed review of formal MCDA techniques in the context of Norwegian infrastructure and building projects. Projects reviewed included the relocation of the National Art Museum, a new stretch of E39 roads project, and relocation of the Norwegian School of Veterinary Medicine. Two principal findings from their review of published reports were:

- imprecise attributes - the attributes of project alternatives are not sufficiently concrete and precise, making it difficult to evaluate the scoring of each alternative’s impact on the attribute.
- inconsistent calculations are routinely carried out in relation to how impacts are measured. In particular unpriced impacts may be evaluated using qualitative or ordinal indicators, but these are then weighted in the same was as priced (cardinally measured) impacts. The ‘weighted sum’ approach to the overall scoring of each alternative reinterprets the original ordinal measure of the indicator as a cardinal measure, even when the original evaluation explicitly stated that the evaluation is qualitative.

Jordanger and colleagues also evaluated the potential for different MCDA approaches in the Norwegian context. They recommend the value function approach as the most flexible and able to handle different types of decision contexts (choice of single alternative, sorting of alternatives in classes, ranking).

Subsequently Minken et al. (2009) conducted a detailed assessment of MCDA methods in social economic analysis of roads projects in particular. FIN(2010) recommendations regarding MCDA methodology refer to the methodological evaluation by Minken and co-authors. We focus on Minken and co-authors' discussion of value scaling and weighting of impacts as these are key distinguishing feature of MCDA relative to CBA with only priced impacts.

Indicators. Indicators for unpriced impacts in the choice-of-concept studies cannot be as detailed as Impact Evaluation studies detailed in HB140, while they must be more specific than national level targets. Minken et al. recommend simple indicators and subjective judgement in ranking alternatives per indicator.

Consequence matrix. Minken et al. call for a more systematic approach to how impact matrices are presented, in particular the comparison between priced and unpriced impacts. In order to make impacts comparable they suggest two alternative methods for scoring impacts.

Method 1 consists in scoring the discounted net benefit/cost ratio (B/C) on a scale of -1 (B/C<0.1) to +2 (B/C>1.5). Unpriced impacts are similarly scaled from -1 to +2. Through this subjective scaling impacts are made comparable. The authors recommend that in determining ranking of alternatives, all unpriced impacts should be equally weighted, and the discounted priced impacts should be weighted higher than the combination of unpriced impacts. The authors suggest that priced impacts should be allocated 2/3 of the overall weight.

Method 2 resumes to introducing simple distributional analysis to the choice-of-concept study. Priced impacts are disaggregated into the net present value for project operators, traffic, public and society at large. These priced impacts are scales from -4 to +4. Unpriced impacts are scaled by assigning -4 to the alternative with the worst indicator value and +4 to the alternative with the best indicator value for the impact in question. The seven categories between the two extremes are scaled with equal intervals relative to the impact indicator. Alternatives are then ranked using the unweighted sum of criteria across alternatives.

Alternatives weighting and ranking. Minken et al. emphasise that indicators per impact theme in a choice-of-concept study may have different importance because they represent impacts for few people or many, and indicators may be aggregates of a few subimpacts or many. For both reasons it is therefore a mistake to give them equal weighting. Informal methods for ranking can be used where there are clearly dominant alternatives. More formal MCDA techniques for to structure more complicated trade-offs and are useful to quality assure the rationality of project rankings.

Discussion. The authors go on to discuss how project rankings can be quality assured in choice-of-concept studies. We focused our quick outline of Minken and co-authors' recommendations regarding scaling and weighting impacts in order to underline some challenging issues concerning MCDA.

Value scaling. In both methods proposed values are scaled or normalised linearly relative to the impact indicator. In concept-of-choice studies indicators are less detailed and more subjective than in project impact evaluation and non-linear value scaling may be impracticable. However, even linear scaling has importance implications. In method 2 the authors recommend disaggregating net present values for four types of interests (project operators, traffic, public sector, all other societal interests) before being scaled from -4 to +4 according to the extremes of NPV for each stakeholder group. If the extremes of NPV are much wider for one interest than another, this approach to scaling will tend to reduce the importance of interests with large ranges in NPV across alternatives.

How interests are grouped then assigns implicit weighting to the members of the group. This might be the case for all other societal interests, where we would expect aggregate NPV to have larger variation because it composed of many interests, and impacts for each individual other societal interest would have lower implicit weight relative to project operator, traffic or public sector.

Criteria weighting. In both methods authors propose a fixed approach to weighting. In method 1 priced impacts are given a greater weight as a standard for all analyses. Standardized and invariant scaling and weighting across impacts is familiar from The Roads Authority's HB140 (discussed below). The recommendations for fixed weighting across criteria also seem contradictory with the authors' reasonable observation that criteria may vary in their importance.

We agree with Minken and co-authors' final recommendation that there is " a large need for systematization of the final phases of choice-of-concept assessments, priority setting between alternatives and recommendations for a single alternative". They recommend that "comparison of significant impacts (impact matrix)" and "evaluation of the impact matrix" be given its own chapter in the conclusions of concept-of-choice assessment reports.

In addition we would add that "systematization" should include recommendations on formal methods for value scaling and weighting that reveal analysts versus stakeholders value judgements explicitly and avoid implicit value judgements as far as possible.

4.3 Impact evaluation Handbook 140 for road projects

As there are no Norwegian guidelines of more general nature, the standard procedure for qualitative analysis is often based on the Roads Authority Handbook140 (Statens Vegvesen, 2006), also outside the road sector.

This chapter discusses the methodology for comparison of impacts (Step 5) and choice of alternatives (Step 6) in the HB140.

The handbook provides a method to take into consideration unpriced impacts i.e. how they should be evaluated in a uniform way. Unpriced impacts categories are defined by HB140 as

- landscape and urban scape esthetics
- local environment and recreation
- natural environment
- cultural environment
- natural resources

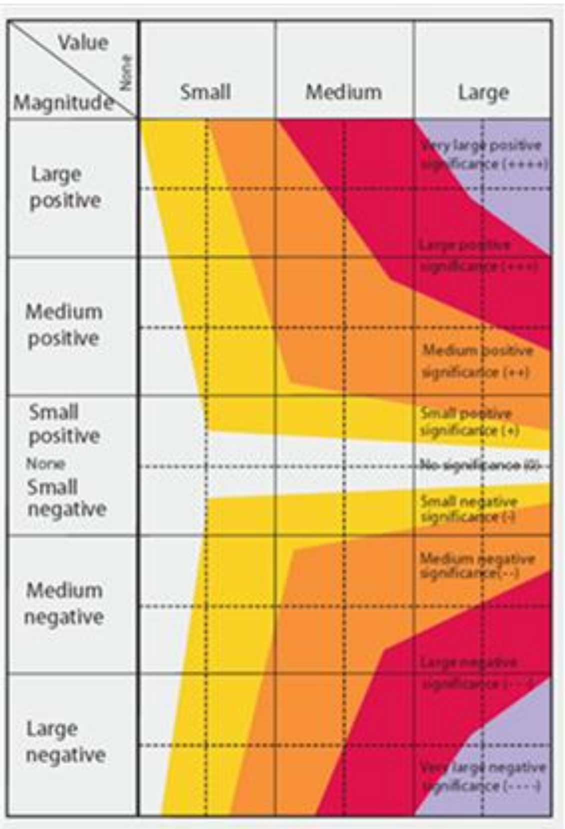


Figure 4.1 Significance matrix – the tool for assessing environmental impacts proposed in Handbook 140, Statens Vegvesen 2006.

The impact significance matrix

Biophysical quantification of impacts has been systemized for EIAs in the transport sector using the software EFFEKT. However, such models are not applicable for general use and rare in other sectors.

The impact ‘significance matrix’ discussed here is an approach to standardise unpriced qualitative impacts.

These impact categories are defined as unpriced independently of whether monetary valuation studies are available or not for the impacts. Unpriced impacts are assessed using a standardized qualitative evaluation method focused on the terms “value”, “extent” and “impact”.

Value: this aspect describes how valuable the affected area is. The value is determined for all the individual environmental themes to be assessed, according to for instance the EIA-program. The valuation assessment is made based on a 3-level system, i.e. assigning the values of the areas as being small, medium or large.

Magnitude: The magnitude is used to describe the biophysical extent of impact of planned alternatives relative to a status quo or “no project” alternative. This is evaluated individually for all the investigated environmental topics. Magnitude is given on a qualitative scale ranging from small, medium to large. The scale includes both a negative and a positive axis.

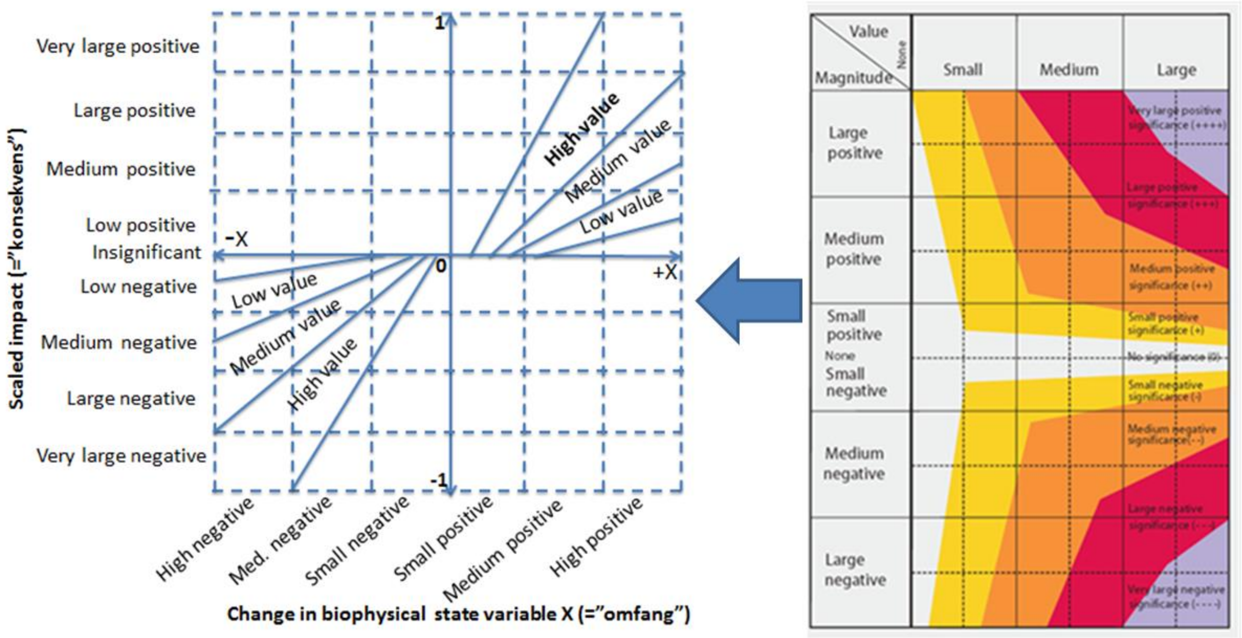
Significance: The combination of the magnitude and the value gives the significance of the planed project, again differentiated for each environmental topic assessed, and with ‘no project’ as the basis for comparison. The combination of value and extent give a 9-level scoring system ranging from ‘very negative impact’ to ‘very positive impact’. The so-called ‘significance matrix’[5] used by Statens Vegvesen (2006), is presented in Figure 4.1.

The significance matrix is a standardized tool that is to be used in all EIAs for hydropower projects. It is a visual presentation of impacts that is easy to understand and communicate. Despite the clear advantages of using this matrix, several weaknesses or short-comings were identified in a comparative review of hydro and wind power projects Bakken et al. (forthcoming).

- The scales are qualitative making it difficult to compare the impacts across specific projects.
- As the scales are qualitative, it is also problematic to aggregate impacts of several projects of differing magnitude
- The matrix is sensitive to subjectivity in assessment of both “value” and extent”. When comparing or aggregating projects a ‘calibration’ exercise is needed across experts using the matrix and across projects
- HB140 makes it clear that mitigation measures are to be noted, but excluded from the evaluation of alternatives using the significance matrix. However, in practice it is not clear what measures in the mitigation hierarchy[6] have been included in the assessment of magnitude.

[5] ‘Konsekvensvifte’

[6] The mitigation hierarchy specifies the order in which mitigation measures should be undertaken ; each successive type of mitigation measures will reduce the net impact of the original project design: (1) Minimization/redesign; (2) Mitigation on-site; (3) Off-setting (off-site), (4) Compensation



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- **Figure 4.2 Decomposed value scaling using multiple value functions (high, medium, low).**

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- Note: The left hand panel shows an approximation of the three value scaling functions used
  - in Roads Authority HB140 assessment matrix shown in the right hand panel

Value scaling

Figure 4.2 is an approximation of the significance matrix used in HB140, emphasising that the 'value' criteria along the columns of the matrix are in fact three different value scaling functions (high, medium and low). Value scaling was discussed in Section 3, for impacts that are quantitative.

Value scaling is more complex for impacts that have not (or cannot) be quantified in biophysical terms. Additional impact 'sub-sub-criteria' are needed to determine the choice of value function. In the HB140 Guidance these criteria reflect - in the language of economists - a mixture of marginal or per unit utility, and total use. For example, use intensity per individual, total use and use for specific social groups are criteria for selecting which value scaling function to employ (Table 4.2).

	Low value	Medium value	Large value
Public meeting places and other urban outdoor areas (squares, parks, playgrounds etc.)	-little use	- frequent use/by many - important for children and young peoples' physical development	- very frequent use/by very many - important for children and young peoples physical development - important for surrounding area
[..]			
Recreational areas	-little use for recreation	- used by many for recreation - especially well suited for outdoor recreation	- use by very many - part of connected multi-day trail network - national and international attraction and of importance of quiet and nature experiences

Table 4.2 Value scaling for selected 'unpriced' impacts in Roads Authority HB140.

The steepness and shape of each of the value functions in the "significance matrix" – i.e. the colour shading in Figure 4.1, 4.2 - represent what economists call social preference or welfare functions. For example, a 'large' impact (positive or negative) using the 'medium value' scaling function has a higher probability of being of 'large consequence' if it is a 'large positive' than if it is 'large negative' impact. This can be understood by looking at the area of each significant colour in each cell of the matrix.

Here the value function is 'giving more value' to positive impacts than to negative impacts (when they are large). A similar 'preference' for positive over negative impacts can also be seen for the 'small value' scaling function.

HB 140 explains this asymmetry between the scaling of positive and negative impacts by the difference in importance of gains versus irrevesible losses (p.142). Why this implies greater value for large positive versus large negative impacts for large parts of the value function is not explained. This standardization of value scaling would seem to give greater weight to positive as opposed to negative impacts for a large part of the impact range.

HB140 makes it clear that value scaling and joint assessment of impacts using the 'significance matrix' is a matter for technical evaluation (rather than a stakeholder or decision-maker issue). However, we saw from the Optipol examples above that value scaling can be conducted with stakeholders as well. There may be good reasons to construct project specific value functions with stakeholders, rather than use standardised homogeneous criteria across projects as is current practice with HB140.

Criteria weighting

Unpriced impact categories are composed of a number of sub-criteria. When each sub-criterion has been scored according to the impact significance matrix the following step is to aggregate scores to a single indicator for each unpriced impact category (Figure 3.3).

Technical experts are asked to rank each alternative according to each impact topic. Compensation between subcriteria is to be used and the technical expert must justify how the ranking was reached and the trade-offs undertaken between small and large impacts on sub-criteria. The ranking is to be undertaken from a technical point of view only.

The team of technical experts is then asked to discuss and justify a single ranking of alternatives taking into account all the unpriced impact categories. This is to be done iteratively, starting if possible with the identification of the worst and best alternatives. Any technical disagreements or uncertainty which can make a ranking between two alternatives difficult is to be discussed in the final report. For both aggregation of sub-criteria and the main impact categories no further guidance is given on any formal MCDA methods that could be used by the technical experts to document their assessment. HB140 emphasizes that there is no objective 'best' approach to aggregating impacts in order to rank projects.

MCDA process in HB140

Weight assessment in HB140 follows a non-standardised consensus-based discussion approach. Within the main impact categories sub-criteria are weighted equally and simply summed to obtain a single score for that impact category. The overall scores for each alternative are presented in a matrix of unpriced impacts alongside the net present value of priced impacts. Technical consultants are asked to determine a consensus on single overall score for unpriced impacts using discussion in interdisciplinary groups. Interdisciplinary groups should have one technical expert for each type of unpriced impact. The group is also asked to try to obtain consensus on whether priced or unpriced effects weigh more heavily in order to reach a recommendation on preferred alternative. Lack of consensus in the interdisciplinary group on what impacts are most valuable for society is to be explained in detail.

What is notable in the HB140 methodology is that:

1. value judgments regarding the scaling of individual impacts in a value function are completely standardized by the guidelines so as to be invariant across studies; and
2. value judgments regarding the weighting - relative importance of impact categories - is completely unstandardized, and determined by the subjective preferences of technical experts delegated as representatives of different social interests.

There is no guidance on formal approaches the group of technical experts could use to elicit and document the preferences of individual experts and that of the consensus position of the group, upon which the consultant makes recommendations.

Pricing the unpriced impacts

Based on the HB140 guidelines there is no flexibility to assess e.g. natural resource impacts as priced impacts should monetary valuation studies be available.

Magnussen and Linhjem (2013) review the arguments for pricing loss of farm and forest land in Impact Evaluations based on Handbook 140. They recommend that the fixed evaluation categories / criteria for unpriced impacts used in Handbook 140 be more flexible in terms of what impacts are grouped together. Flexibility will make it possible to employ valuation techniques that ´bundle´ or jointly value several different ecosystem services associated with loss of particular farmland or forest. This is relevant for the discussion of different methods for assessing values and preferences in MCDA versus CBA.

Furthermore, the find that current impact categories can lead to double counting of impacts. They recommend that pricing of hitherto unpriced impacts may reduce double counting, because pricing requires more rigour in the definition of what biophysical impacts are included in the analysis. This recommendation is echoed in the MCDA literature which aims for a clearer separation of technical evaluation of biophysical impacts from subjective value judgements of those impacts Beinat (1997).

5 Water management processes and MCDA relevance

This section aims at describing processes and tasks in project evaluation as part of management of water and energy resources in Norway. This section is complemented by Section 7.2 which provides further recommendations on how MCDA can be integrated in water management processes as described here.

5.1 The process of granting concessions to new hydropower projects

Many hydropower projects must undergo a standardized procedure before a concession can be granted. NVE requires that projects having the following characteristic require a standardized application, including an EIA, (NVE, 2010):

- Annual production > 40 GWh. Projects between 30 GWh and 40 GWh are evaluated individually with respect to the need for an EIA.
- Reservoirs with storage capacity > 10 mill. m3.
- An increase in generation/extension (upgrade) larger than specific criteria given in MD (2009) Attachment I.
- Power lines carrying a higher voltage than 132 kV or more, and longer than 20 km.

The process the developer has to go through, together with NVE as the administrative counterpart and ultimately OED as the issuing body is comprehensively described in NVE (2010) and NOU (2012). The focus in this report is on those steps and investigations that are related to the assessment of the environmental impacts, mitigating measures and the design of the environmental monitoring program accompanying the concession agreement.

The relevant concession steps are described in Table 5.1. In the table we also indicate at which steps in the existing decision process a formalized MCDA (as described in the previous chapter) can be used.

Table 5.1 Steps in the current process of granting concessions to new hydropower projects and similarities and relevance to steps in a multi criteria decision analysis.

Steps in the concession process	Description	Governing body	MCDA similarities and relevance
Announcement of a hydropower project ('melding')	An official announcement must be first made and quality assured by NVE. This announcement should include a description of the planned project(s) and its likely impacts - 'a mini-EIA'.	Project developer ('tiltakshaver')	
Receiving comments on the announcement and specification of the EIA-program	Based on the announcement and the received comments from interested/affected parties, the formal EIA-program is specified. NVE 3/2010 provides a list of typical environmental and socio-economic aspects that are relevant to include in the EIA-program. The list of topics is discussed in Table 2.	NVE	Impact criteria selection
EIA-investigation	The EIA is developed according the EIA-program. The EIA, as part of the full application, should be prepared by competent personnel (e.g. an experienced consultant) and should be presented in a form that is relevant for decision-making.	The project developer, with assistance from consultants and researchers.	Impact evaluation (magnitude, value) Does the EIA contain a ranking of alternatives (implicit trade-off

Steps in the concession process	Description	Governing body	MCDA similarities and relevance
			analysis)?
Submit the application	Application for concessions is submitted, including the EIA, technical solution, hydrology, etc. to NVE for quality control.	The project developer	
Hearing	Hearing among affected and interested parties locally, regionally and nationally.	Co-ordinated by NVE	New impacts; revision of impact evaluation;
Decision proposed by NVE	Decision regarding the application for concession and the terms is proposed, and distributed for a new hearing	NVE	Impact comparisons and trade-off judgments (implicit weighting)
Approval of application by OED	OED approves (or not)	OED	
Approval of application by the Government /King	The Government ultimately approves (or not) the project(s).	The Government/ King	

Table 5.2.provides a list of environmental and socio-economic aspects that should be investigated as part of the EIA. An EIA of a specific project will include an assessment of impacts on all or a sub-set of the topics in this table, as specified in the EIA-program.

Table 5.2 Environmental and socio-economic aspects that should be investigated as part of the EIA.

Overall theme	Sub-theme
Hydrological conditions	• Hydrology (surface hydrology, flooding, water temperature, ice conditions, groundwater) • Sediment transport and erosion • Avalanches
Landscape, nature and cultivation	• Landscape • Geophysical condition • Flora • Fauna • Freshwater biology (invertebrates, zoo plankton) • Fish • Protected cultural heritage sites • Sami cultural heritage • Cultivated landscape
Pollution	• Water quality • Other pollution, including air quality and noise
Natural resources	• Soil and forest resources • Reindeer husbandry • Freshwater resources • Marine resources • Minerals and other land resources
Society	• Industry, commerce and employment • Demographic trends and housing construction • Services and local economy • Social aspect • Health-related aspects • Hunting • Fishing • Recreation, including tourism
Other aspects	

5.2 The revision of hydropower licenses

By 2022, around 430 hydropower licenses in Norway may go through a process of revision with respect to the environmental requirements. For prioritized regulated rivers, the revision process may lead to changes in requirements related to instream flow and on how to operate the reservoirs.

A few licenses have already been revised to include modernized environmental requirements that have been tested under a trial period for several years. Per September 2013 ca 30 licenses are under a revision process.

In May 2012, The Norwegian Government, OED, launched a final national guidance for the revision of hydropower terms. At the same time, NVE and the Norwegian Environmental Agency have been assigned to carry out a national screening to prioritize between the 430 hydropower projects.

The criteria for prioritization are:

- Specific environmental qualities in river systems, defined by OED (2012):
    - Fish and game fishing **-** mostly salmonid fish and especially in National salmon rivers.
    - Biodiversity
    - Landscape qualities and recreation
- Reduced power production
    - Minimum flow restriction
    - Reservoir restrictions
- Other aspects
    - Potential for upgrading/extension ('O/U-prosjekt')
    - Changes in inflow
    - Security of el-supply
    - Degree of regulation
    - Risk of flooding
    - Geographical distribution

The screening process was considered a 'one-time' job and was finalized during 2013. The result was a set of recommendations for which projects must be prioritized in order to:

- Maximize environmental improvements, ecosystem services.
- Keep production loss at acceptable/moderate level.
- Comply with the national policy guideline to inform the WFD process (not binding).
- Signalize the ambition level and prioritized sites

The second level of revision will focus on the concession terms of the individual plants. The main purpose is to improve/update the environmental standard in the regulated river system. Only the terms (environmental requirements) for the hydropower operation are revised and not the concession agreement as such. Typically, a revision might change the requirements for minimum flow releases and other mitigation measures in the bypass sections, but not the highest and lowest regulated water levels (in the reservoirs). The revision process is outlined in Table 5.3 as a stand-alone process

The table also indicates at which steps in the existing decision process a formalized MCDA (as described in the previous chapter) can be used.

Table 5.3 Steps in the process of revising the environmental terms of for single hydropower projects similarities and relevance to steps in a multi criteria decision analysis.

Step of the revision process	Description	Governing body	MCDA similarities and relevance
The request for a revision	Party representing the public interest has to document the need for changes in the terms of the concession of a specific hydropower project. The revision request is submitted to NVE. Alternatively NVE initiate the process themselves.	Party representing the public interest (often the municipalities or NVE)	Problem identification and structuring resulting in: 1) a proposal for indicators that can be used to represent impacts/societal benefits of the proposed measure. 2) a proposal for criteria hierarchy to be used to compare alternative measures.
The project owner's comments to revision request	NVE asks the project owner to comment on the documented needs for changes in the terms of the concession.	Project owner (power producer)	project owner's criteria included in the criteria hierarchy.
Opening of a revision of terms	NVE decides whether a formal revision process should be opened or not.	NVE	Specification of environmental objectives (WFD GEP) for revision of terms. Specification of permitted scope for offsetting abatement measures (within concession, across concession, across watersheds)
Develop revision documentation	The project owner develops a revision document according to the format specified by OED (2012). If upgrading/extension plans exist, these plans should be coordinated with the revision process. With respect to environmental conditions, special attention should be made to degradation (caused by the regulation) on the following topics: fish, recreation, landscape, biodiversity, cultural heritage and 'other issues'. Already installed measures to mitigate the impacts should also be described. The power producer should evaluate the proposed changes in terms, including the consequences for the power production and improved environmental conditions.	Project owner (power producer), possibly with assistance from a consultant	Impact evaluation of alternative abatement measures. Preferred abatement alternative, with documentation of weighting criteria across societal benefits and MCA/trade-off method used
Hearing of revision document	The prepared revision document is distributed for an external hearing.	Interested/affected parties	Stakeholders' proposed changes to criteria hierarchy, abatement measures, and weighting
Comments on the response received during the hearing	NVE forwards the received comments to the project owner who has the possibility to comment on the received feedback.	Project owner (power producer)	Owners revised criteria hierarchy, abatement measures, and weighting. Revision of preferred alternative
Proposed decision from NVE	If relevant, NVE proposes changes to the terms of the concessions which are then sent to OED for approval.	NVE / OED	
Approval of application by the Government /King	The Government ultimately approves (or not) the revision of terms. A new set of terms/environmental requirements are then linked to the existing concession.	The Government/ King	

The Norwegian Government - OED (2012) emphasizes the need to coordinate the revision process with the implementation of EU Water Framework Directive (WFD) and plans for upgrading and extensions of hydropower plants ('O/U-projects').

However, OED (2012) does not provide a complete set of which environmental topics that should be assessed/investigated as part of a revision process, but mentions fish, recreation, erosion, landscape, biodiversity, cultural heritage and other environmental aspects as relevant during the revision. Furthermore, OED (2012) refers to 'standard nature management requirements' available on the web-pages of NVE a basis for a more extensive list.

As important measures, OED (2012) points out changes in the minimum flow releases and changes in reservoir management, but underlines that the highest and lowest regulated water level (HRV and LRV) are not subject to revision. Additional relevant mitigating measures include erosion protection, building of weirs (to increase the water level in minimum flow sections), habitat adjustments, fish stocking, egg planting and fish ladders.

5.3 Implementing the EU WFD in river basin district level

The EU Water Framework Directive (EU WFD) (2000/60/EF) was adopted in the Norwegian Law by the approval of "Forskrift om rammer for vannforvaltningen". Extensive work is now carried out in Norway and the rest of Europe, in order to implement its requirements and improve the ecological status where needed. The primary objective of the EU WFD is to ensure that all European water bodies reach good ecological status in natural water bodies, and good ecological potential in heavily modified water bodies (HMWB), within a defined time period (2015 / 2021). EU WFD has introduced an ecosystem-based and holistic river basin management of the water resources throughout Europe, and requires a simultaneous focus on water quantity, water quality and biology.

A number of activities have already been carried out to form the basis for developing plans to reach the environmental goals in those water bodies that required by EU WFD, including defining typologies for lakes, rivers, coastal waters and groundwater and developing classification system to all the different water body types. An extensive job has also been to carry out a characterization, i.e. to assess the ecological status of all water bodies. Based on the characterization, those water bodies being "at risk" or "potentially at risk" have been identified and plans to improve the standard are made. The further description of the management process of the EU WFD (see Table 5.4) starts at this point, and is to a large extent based on Direktoratsgruppa for gjennomføringen av vanndirektivet (2007) ("Tiltaksveileder").

In the tables below we also indicate at which steps in the existing decision process a formalized MCDA (as described in the previous chapter) can be used.

Table 5.4 Steps in the process of developing river basin and actions plans in line with the EU WFD and similarities and relevance to steps in a multi criteria decision analysis.

Steps in the EU WFD implementation		Description	Governing body	MCDA similarities and relevance
Local planning level ("vannområde")	Describe current status and environmental goals	The current status is assessed during the characterization, which also describe the pressures. The water type and the corresponding classification system defines the environmental goals (for natural water bodies)	Local authorities, often municipalities	
	Description of user interests and pressures	In the case of other prominent user interests, these should be described and different environmental goals than those outlines by EU WFD might be defined. The main factors/pressures causing water bodies being "at risk" is assessed during the characterization, which also gives a clear indication about the pressures.	Local authorities, often municipalities. Close cooperation with affected interest groups.	Definition of objectives and criteria hierarchy
	Sector-wise assessment of potential mitigating measures	A set of measures to reach the environmental goal must be defined. It is important that the planning of the measures is carried out in collaboration with the sectors that are supposed to implementing them in order to create commitment and ownership. The sectors also hold important knowledge about the relevance and efficiency of the various measures under different conditions.	Local authorities, often municipalities. Close co-operation with involved sector authorities.	Definition of alternative measures
	Assessment of costs and effectiveness of measures	The costs and effectiveness of the proposed measures should be assessed. It might be difficult to quantify the exact effect of all measures and the guideline proposes to use a relative scale of some types of problems. The measures should be ranked and priority given to those measures with the best cost-efficiency ratio.	Local authorities, often municipalities. Co-operation with sector authorities.	Impact evaluation across criteria. Weighting. Scoring of alternatives based on cost and effectiveness
	Rough assessment of socio-economic aspects	The first assessment of the societal benefits from implementing the mitigating measures is done at local level. This will form the basis for the regional assessment, where also the final decision regarding the selection of sets of measures within the various sectors, balancing energy production and the environment (in regulated rivers), and ultimately applying for exemptions are made.	Local authorities, often municipalities.	Re-evaluation of alternatives including benefits.
Regional planning level ("vannregion")	Compilation of local action plans	The local analysis and action plans are compiled in order to provide the basis for the regional plan.	Regional authorities ("VRM/VRU – vannregionmyndighet/-utvalg")	
	Development of regional action plan	This is regional action plan including a set of measures to reach the requirements of EU WFD, overview of which water bodies that will not reach the objectives (where derrogations are needed – permanently or temporarily), which water bodies that are classified as HMWBs, etc). The regional plan can deviate from the local plan. This plan will also include a plan for monitoring and involvement of sector interests, stakeholders and the general public.	Regional authorities ("VRM/VRU – vannregionmyndighet/-utvalg")	
	Adoption of regional management plan	The management plan is ultimately approved by the regional authorities.	Regional authorities ("Fylkestinget").	

Those water bodies that are assigned as HMWB undergo a different approach of setting the environmental goals (good ecological potential), as their ecological standard cannot be defined based on their water body type and the corresponding classification system.

According to Direktoratsgruppa for gjennomføringen av vanndirektivet (2007) ("Tiltaksveileder") the process of defining good ecological status is as follows:

Table 5.5 Steps in the process of defining good ecological potential in HMWBs. Primary source: Direktoratsgruppa for gjennomføringen av vanndirektivet (2007) ("Tiltaksveileder").

Steps in the process	Description	Governing body	MCDA similarities and relevance
Screening of relevant measures	Based on the local action plans those measures that give a significant negative consequence on other uses (e.g. in some cases power production) or the environment, should be omitted. The distinction between significant or not-significant is determined from case to case and by national/regional policies.	Local and regional authorities	
Ecosystem effect of the realistic measures	The effects of implementing the remaining measures should be investigated with respect to ecological response, i.e. what ecological conditions can we expected given that the proposed measures are all introduced, based on expert judgments and experiences from similar systems.	Local and regional authorities	
Describe the environmental goals	Describe the expected ecological condition when all measures that do not have significant negative consequences on other water uses are implemented	Local and regional authorities	
Assess derrogations	Are the total costs of proposed measures disproportionate to the benefits to other water users? If yes, considered exemption.	Local and regional authorities	Assess multi-attribute benefits against costs.

6 Experiences with MCA on water resource management from Norway, Finland and the Alps region

MCDA is increasingly used in environmental planning projects to evaluate the alternatives and to support stakeholder involvement. The workshop brought forward mode than 40 examples from:

- Water course regulation projects in Finland, Norway and the Alps
- River restoration projects in: Finland, Norway and the Alps
- Flood risk management in Finland, Norway
- Other applications:
  - Optimal routing of power lines: Norway (the Optipol project)
  - Spillway locations of hydro power plants (Finland)
  - Forest management in Lapland (Finland)
  - Risk of peat production to water use and protections (Finland)
  - Optimal location and characteristics of new power plants: the Alps
  - Recommendations for the development of cantonal conservations and exploitation strategies for small hydropower plans: the Alps region – Switzerland

This chapter summarizes experiences with MCDA in water course regulation, river restoration, flood risk management and optimal routing of power plants. For more detailed information on specific case studies please consult Appendix 1. There, the case studies have been analyzed in terms of:

1. Decision context:
   - Decision makers, stakeholders, experts and analysts involved
   - The decision problem

2. Description of how MCDA was applied
   - The stage(s) in the decision process at which MCDA was applied
   - The MCDA approaches used
   - Software tools used for impact evaluation and for preference modeling
   - How where the decision-makers, stakeholders and experts involved
   - Possibilities to integrate MCDA in 'established' management processes.

3. Resources used
   - The total 'budget' of an MCA study – for example, how long did the MCA studies take to carry out and report (start-finish).
   - Which steps in the MCA may be skipped when budgets and time is constrained?

MCDA was applied in many ways, the case studies varying from expert multi-criteria (desktop) assessments of environmental impact to laborious participatory decision processes involving many decision makers, stakeholders, experts and analysts. This chapter summarizes the main lessons learned from the examples as expressed by the researchers involved in the studies.

6.1 On the MCDA decision-support process

MCDA is increasingly used in environmental planning projects to evaluate the alternatives and to support stakeholder involvement. MCDA can be realized in many ways and with many techniques.

MCDA is a process structuring tool, in which MCDA modeling is only one part. MCDA can be helpful although it does not result in the use of preference modeling. MCDA can even be realized without formal quantitative preference modeling for example in projects where the preferred management plan becomes clear directly after careful structuring

The MCDA approaches that are most often used: simple linear weighting, Multi-attribute value theory (MAVT), Outranking methods .
MAVT is very often used because:

- value function elicitation is fairly intuitive and transparent
- the method is implemented by the majority of MCDA software available.
- weights can be determined using preference elicitation methods that break trade-off decisions into smaller problems, such as analytical hierarchy process (AHP)
- a long research tradition and large number of real-life cases on MAVT has produced a good understanding of how to carry out a structured decision process in practice

The ease of application of MAVT approaches also leads to its misuse, for example through default assumptions of linear value scaling functions and equal weights.

However, the choice of MCDA approach depends on the decision required and the complexity of the alternatives. One aspect usually discussed in the case studies analyzed is that every time the MCDA support process should be tailored to the case specific needs. For example, the choice of method depends on basic assumptions regarding the compensability of impacts.

- MAVT assumes that impacts may be compensated or off-set against one another in ranking alternatives
- Outranking methods do not assume compensability and should be used in cases where relative rankings of impacts cannot be scaled, compared and compensated

Structuring an available impact evaluation report ex post into a MCDA, provides little information on whether MCDA would actually support or complicate the decision process, relative to existing practice.

Ex post application of MCDA provides more impact evaluation data than is available during the process. In ex post applications of MCDA stakeholders assign weights to criteria with 'near full knowledge' of impacts, rather than under uncertainty and in a strategic bargaining situation typical of an MCDA process

It is important to clearly establish from the beginning, the scope of using MCDA in aiding the decision making process and how the outcomes of the process should be used. (MCDA as technical advice vs. MCDA as a legally binding tool). Carrying out and MCDA decision-process provides impact evaluation with replicable methods that can be scrutinized by third party review. This is of particular importance when concessions come up for review (the ability to return to the original analysis).

The MCDA applications discussed during the workshop revealed that the time to carry out the studies varied from 2 months (but based on 6 years of formal Impact Evaluation Assessment studies-Øyeren) to over 6 months (25 weeks- needed to carry out a rather extensive and complete MCDA decision support process - Pirkanmaa).

When the resources are scarce MCDA may easily be used as a synthesizing tool. Information from impact matrices are used as input and the criteria weights are based on the experts' judgments. Value functions are assumed to be linear. In such cases limited resources might be used on discussing the criteria and structure of the value tree in cases where one has reason to suspect that the choice of the attributes has been superficial.

On the other hand, lack of time/resources may also increase the risk that criteria weights are arbitrarily defined. A common mistake is that main criteria (economic, social and ecological) are given equal weights with the argument that this balances different objectives or is an indication that principles of sustainable development have been taken into account. However, this violates the theory of MCDA because impact ranges should be taken into account in determining weights. Equal weights can lead to situation where small disadvantages are weighted as much as large benefits.

6.2 On MCDA relative to generic alternatives of EIA and CBA

Ideally CBA is limited to those aspects that can be priced in a non-controversial manner – all conflicting goals are assessed on monetary scales derived from observed behaviour in markets. When all impacts can be scaled monetarily, CBA provides a consistent methodological approach.

In practice CBA often includes unpriced impacts which are acknowledged but not included in the formal analysis. This concerns environmental goods which are difficult to demarcate and for which market valuations are impossible or very expensive to undertake.

MCDA has potential in providing methods that could make the impact significance assessment more structured and transparent.

MCDA is increasingly used to support stakeholder involvement. MCDA techniques can be helpful for structing the decision process although the methods are not used for preference modelling.

Uncertainty analysis is increasingly carried out in both CBA and MCDA.

MCDA thinking is already embedded in Norwegian guidance of both EIA and CBA. In fact, repeated revisions of guidelines for EIA and CBA have led to a 'hybrid' approach to social economic analysis of projects which combines different types of rationalities of decision support.

6.3 On MCDA software

There are many multi-criteria software or decision support systems (DSS) developed to support the use of MCDA methods in practice. They offer:

- computational support for implementing the methods and the calculation of the results,
- various ways to also support other phases of the process, such as the construction of the model and analysis of results.

A good supporting software which can synthetize information and judgments and effectively present the options and preferences to the decision makers is important

For a meaningful and relevant use of MCDA software it has to be included in the EIA process in a very early phase of the process because already in the assessment phase choices have to be made that will affect the whole decision process.

In practice a certain expertise in MCDA is a must in order to use the software properly. However, due to the specificity of EIA it can be possible to develop customized software that will guide the user hand-in-hand through the process.

Visualization of the results: often in EIA the overall impacts consist of different dimensions, (e.g. magnitude, sensitivity). Software offering possibilities to present results in multi-dimensional graphs are very useful in helping decision makers understand the overall impacts.

6.4 Resource constraints and how to address them in MCDA

The integration of MCDA in existing management practices will likely increase the time needed for specific management phases, at least in the initial phase. The time is however expected to decrease once those in charge of the MCDA application gain experience. Substantial resources and time is often needed for impact assessment studies which are defined by some authors as external to multi-criteria modeling, although it should be definitely considered as a part of the MCDA process as a whole.

If a decision has been made to use MCDA to structure the decision process this can be expected to have repercussions on how the impact assessment is conducted. For example, stakeholder consultations regarding the criteria hierarchy and its indicators may identify the need for the assessment of impacts that have not been defined by formal guidance documents. Stakeholders may wish other indicators to be evaluated than those commonly used by experts.

The MCDA applications discussed during the workshop revealed that the time to carry out the studies varied from 2 months (but based on 6 years of formal Impact Evaluation Assessment studies-Øyeren) to over 6 months (25 weeks- needed to carry out a rather extensive and complete MCDA decision support process - Pirkanmaa).

When the resources are scarce MCDA may easily be used as a synthesizing tool. Information from impact matrices are used as input and the criteria weights are based on the experts' judgments. Value functions are assumed to be linear. In cases where one has reason to suspect that the choice of the attributes has been superficial limited resources might be used on discussing the criteria and structure of the value tree.

On the other hand, lack of time/resources may also increase the risk that criteria weights are arbitrarily defined. A common mistake is that main criteria (economic, social and ecological) are given equal weights with the argument that this balances different objectives or is an indication that principles of sustainable development have been taken into account. However, this violates the theory of MCDA because impact ranges should be taken into account in determining weights. Equal weights can lead to situation where small disadvantages are weighted as much as large benefits.

7 Recommendations

7.1 General recommendations on MCDA in social economic analysis of projects

Implementing MCDA in practice should be carefully planned so that all special characteristics of the EIA as part of the Plannning and Building Act are taken into consideration. The current approach used in Norway for conducting assessments of the environmental impacts of hydropower regulations projects is based on the approach used in the road sectors (Statens Vegvesen, 2006). The approach allows a uniform and qualitative evaluation of both priced and unpriced impacts. The consequence matrix's visualization of value scaling of impact may be a useful tool in also supporting weight elicitation among different stakeholders.

However, a number of challenges to the impact matrix methodology could be addressed in ongoing revisions:

- The scales are qualitative making it difficult to compare the impacts across specific projects,
- As the scales are qualitative, it is also problematic to aggregate impacts of several projects of differing magnitude
- The matrix is sensitive to subjectivity in assessment of both "value" and extent". When comparing or aggregating projects a 'calibration' exercise is needed across experts using the matrix and across projects
- HB140 makes it clear that mitigation measures are to be noted, but excluded from the evaluation of alternatives using the impact matrix. However, in practice it is not clear what measures in the mitigation hierarchy have been included in the assessment of magnitude.

Current HB140 guidance has a more explicit and detailed emphasis on MCDA methods than FIN2005, while both are termed 'social economic analysis'. Choice-of-concept guidelines are the most explicit in recommending the formal use of MCDA.

Further clarification is needed across guidance documents on the formal role of MCDA methods in cost-impact analysis when applied at sector level, i.e. regarding

- Partly conflicting rationalities can be found in the application of guidance documents when .
- Currently, there is a lack of clarity on whether value judgements regarding trade-offs within unpriced impacts and between unpriced and priced impacts are to be undertaken by experts or by decision-makers.
- Current impact matrix methodology assumes standardized value scaling, while weighting is unstandardized.
- Value judgements in scaling, weighting of sub-criteria and to a certain extent weighting of major impact categories are mainly carried out by expert panels. This conflicts with the declared intention of the guidance documents that value judgements be carried out by decision-makers representing stakeholder interests.
- Formalization of uncertainty analysis using e.g. Monte Carlo simulation techniques for scoring, value scaling and weighting

There is an assumption that stakeholder interests will be addressed during the Public Hearing Process as specified in the Planning and Building Act. However, further evaluation is needed on the extent to which stakeholder interests expressed during the Public Hearing process are formally integrated in MCDA methods currently implemented in the guidance documents, in particular regarding the different subjective components of the analysis (objective hierarchy, value scaling, weighting).

Future revisions of the guidelines should specify how the different parties should be involved and their role in the decision-making (where expert opinion/independent expert evaluations are needed and where and how the stakeholder should express their views/preferences and how to aggregate these views).

A number of commercially available MCDA software packages have features that may be adapted to existing project appraisal practice in Norway. These should be evaluated and compared to designing a bespoke application.

7.2 Recommendations regarding the potential for MCDA in assessment of hydropower and water resource regulation

This section presents recommendations on using MCDA decision-support for different decision-making contexts in hydropower and water resource regulation in Norway, as described in Section5.

Granting concession to new hydropower projects

Figure 7.1 summarizes the process of granting concessions to new hydropower projects as described in Table 5.1. The figure shows the main responsible with each part of the process and when a decision has to be made.

The decision process for granting concessions to new hydropower projects covers mainly one decision to be made by NVE although all cases can be revisited at governmental level. The main background for decision is the description of the technical solution and all other aspects related to hydropower production and the EIA.

As discussed in Section 5.1, NVE provides a list of typical environmental and socio-economic aspects that are relevant to include in the EIA-program. The EIA, as part of the full application, should be prepared by competent personnel (e.g. an experienced consultant) and should be presented in a form that is relevant for decision-making.

Experiences from real-life cases suggest that MCDA can support EIA processes in many ways (Karjalainen et.al, 2013). 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.

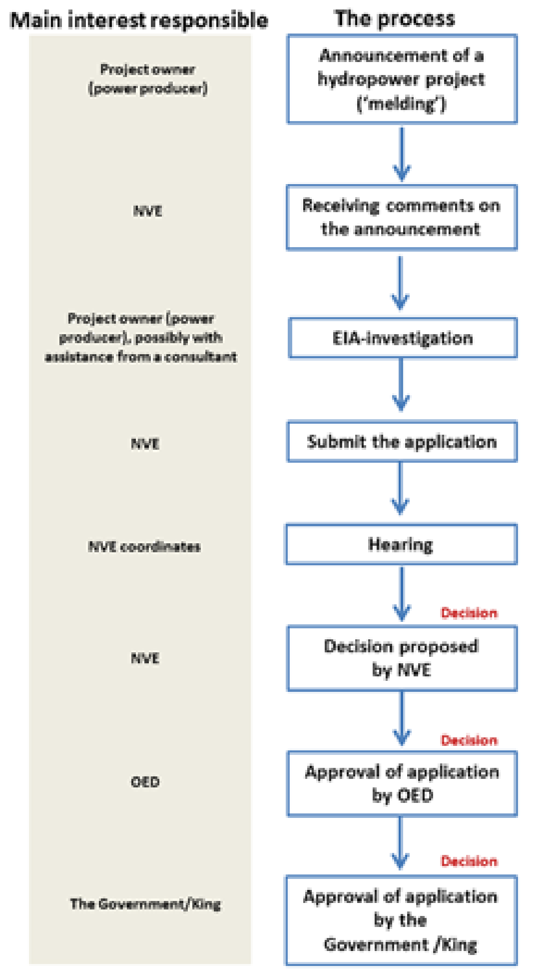

Figure 7.1 The process of granting concessions to new hydropower projects.

However, it might be difficult to integrate the principles of MCDA into the appraisal of new hydropower concession because they are subject to long standing EIA practice and established guidelines.

As a general recommendation, MCDA techniques for problem structuring can be used by both the project developer and NVE to structure the documentation and information needed for the decision of granting concession for a new hydropower project. For example, the 'traditional' analyses like technical assessment and social economic evaluation of a new hydropower project, CBA (or other methods that are in use today) can benefit from MCDA problem structuring techniques such as value focused thinking (Keeney, 1992) or techniques for structured problem solving (Gregory et.al.2012).

Individual concession revisions at local level

As discussed in section 5, around 430 hydropower licenses in Norway may go through a process of revision with respect to the environmental requirements, by 2022. The main purpose with the revision is to improve/update the environmental standard in the regulated river systems. For prioritized regulated rivers, the revision process may lead to changes in requirements related to instream flow and on how to operate the reservoirs

The revision concerns only the environmental requirements and not the concession agreement as such. Typically, a revision might change the requirements for minimum flow releases and other mitigation measures in the bypass sections, but not the highest and lowest regulated water levels (in the reservoirs).

The revision process is a stand-alone process as outlined in Figure 7.2 and described in Table 5.3 The figure indicates the main interest responsible specific parts of the process and when decisions should be made.

The revision process covers two main decisions to be made by NVE and the Gouvernment: 1) decide whether the revision of terms is necessary and 2) decide how the terms should be changed.

MCDA can be integrated in the revision process from the very beginning that is from the phase a request for revision is made

The start of the revision process consists of an assessment of the current situation for the hydropower project (alternative 0). When integrating MCDA at this stage there will be perhaps no major changes to the way the documentation for such requests are usually made. This will mainly imply a different way to structure information and present the case. MCDA techniques for problem structuring can be used both in the documentation which is the background for revision request as well as in the preparation of the case for hearing and discussions involving all interested parties. Value focused thinking (Keeney, 1992) or techniques for

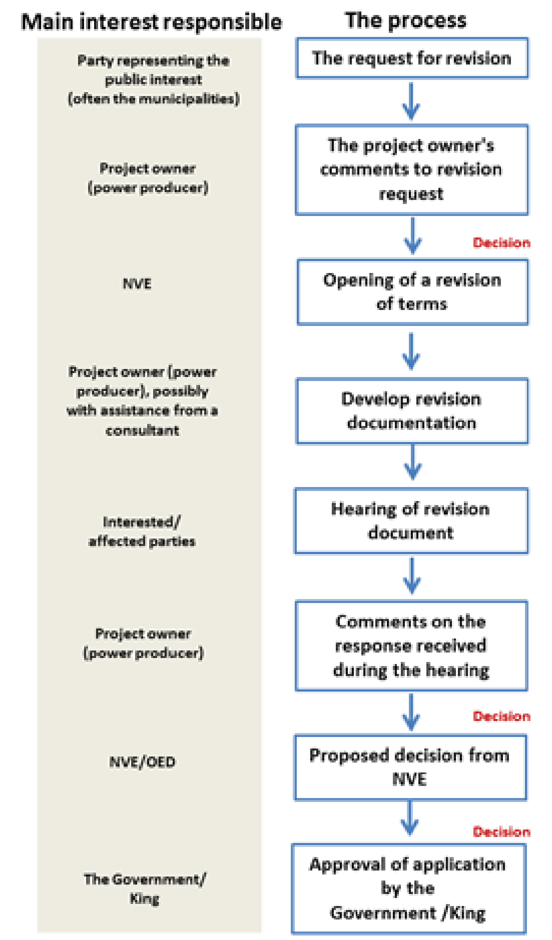

Figure 7.2 The process of revising the environmental terms for hydropower projects and the potential for MCDA decision support.

structured problem solving (Gregory et.al.2012) are especially useful when important environmental aspects have to be considered.

It is expected that the assessment criteria for of the present situation (alternative 0) will be relevant for the whole process (including the decision for revision of terms) although the criteria hierarchy may expand or become more detailed to include new assessment aspects that will be specific to the alternatives for revision.

In the next phases, both the project owner's opinion as well as other stakeholders' views will also have to be included in the case documentation. The assessment of impacts of a project - economic, environmental or social - would reflect specific decision makers' or stakeholders' value judgements and is directly integrated in their ranking of alternatives – from the definition of alternatives, through definition of impact indicators, to value scaling of indicators, and finally criteria weighting. MCDA techniques offer a methodology for structuring and documenting how each affected group's value judgements may affect the ranking of alternatives. The information can be used to support public hearings as a process of dialogue between opposing interests. This is quite different from the current appraisal guidance in which impact indicators, value scaling and criteria weighting are standardized and delegated to technical expert groups. Experiences with real life participatory processes as reported from Finland (see appendix) are be very useful to have in mind.

Simple MCDA value scaling and weighting have mainly been used to integrate unpriced impacts into quantitative comparisons with power loss. MCDA techniques have not been used to document and structure value elicitation. Multiple stakeholder interests are acknowledged as important, but this intention is not formalized in value scaling and criteria weighting methods currently promoted by state-of-the-art EIA guidelines such as the Roads Authority Handbook 140. To some extent conflicting decision support rationalities are proposed in Guidelines prepared by the Ministry of Finance and the Roads Authority regarding social economic analysis. The extent to which subjective value judgments of stakeholders in the Public Hearing process of projects are well reflected in the subjective value judgments carried out by technical experts conducting EIA, is not known. In general, experts ability to represent social interests is limited, given the standardized approach the guidelines have to value scaling and criteria weighting.

To improve the current practice, a model of the decision to be made and the opinions and preferences of decision makers and stakeholder. Commercial or customized MCDA supporting software can be used by NVE to:

- Structure, model and present the decision alternatives and criteria and improve the existing decision support practice for revision of terms.
- Model the opinions (values) of different stockholders and decision maker(s) – facilitate participatory decision processes. The existing practice should change in order to clearly separate the technical assessment of impacts from the value judgments and priorities. The Roads Authority Handbook 140 methodology can be improved in order to eliminate existing biases, e.g. to allow project specific value functions with stakeholders, rather than use standardized homogeneous criteria across projects- (see section 4.3).
- Make changes in the decision model - update the problem to include new criteria, alternatives or points of view.
- Structure and present the revised terms and all aspects that lead to the decision.

There may be time saving advantages to using formal MCDA because it can efficiently facilitate participatory processes which may reduce project approval delays due to conflicts with stakeholders. As reflected in the case studies and reviews of similar decision processes, it is preferable that MCDA is integrated with the process from the beginning that is from the phase a hydropower project is evaluated and a request for revision is made until the terms are finally revised.

As a recommendation, a procedure for carrying out the MCDA analysis can, for example, be established, detailing:

- How data and information from both those asking for revision as well as from the project owner should be structured. It is important that all alternatives, criteria and initial points of view are summed up in a structured way. The procedure should allow for adding new information to the decision process, e.g. new alternatives based on project owners' documentation for revision, including upgrading and extension plans.
- How the interested parties and experts and will be involved in the decision process
- The MCDA value modeling method(s) and software to be used

River Basin Management Plans under the WFD

As discussed in section 5.3, an extensive work has been done to assess the ecological status of all water bodies as an important step in the implementation of the EU Water Framework Directive. Water bodies being “at risk” or “potentially at risk” have been identified and plans to improve the standard are made. The further description of the management process of the EU WFD is illustrated in Figure 7.3.and Table 5.4.

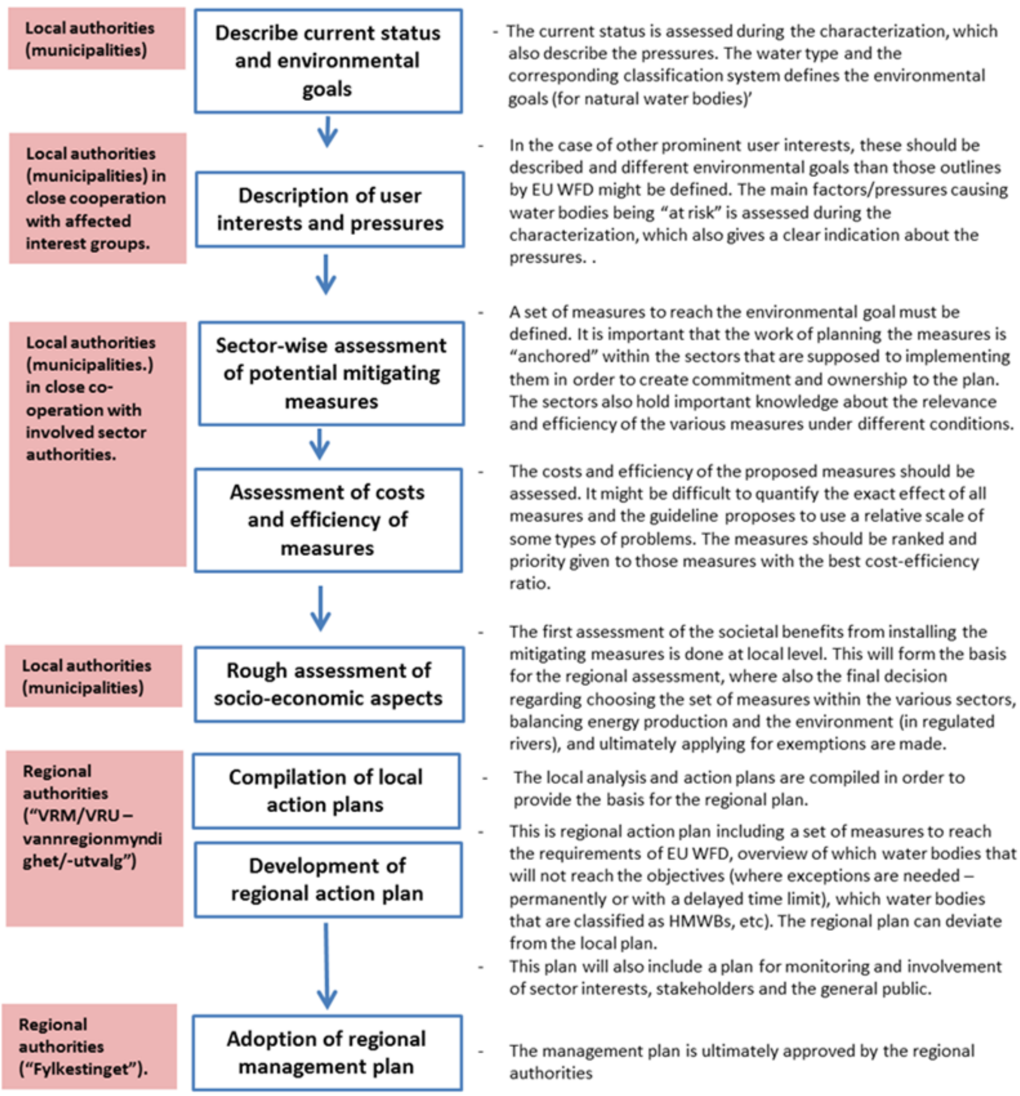

Figure 7.3 Steps in the process of developing river basins and action plans in line with EU WFD.

Several observations can be made on the existing practice regarding the WFD definition of programmes of measures.

The first aspect regards disproportionate costs and that not all criteria are evaluated simultaneously. Costs and effectiveness are assessed first to rank a set of measures that will attain GES at least cost. Societal benefits are then assessed. This diverges from MCDA where all criteria are assessed simultaneously. The sequential evaluation of benefits is meant to employ the disproportionate costs criteria as an alternative to NPV of CBA. The concern has mainly been that monetisation of societal benefits would not be possible and could not be placed on an even footing with the analysis of costs of measures. This does not consider the possibility that societal benefits could be assessed qualitatively or using non-monetary measures and that other weighted utility-based measures of MCDA might be used to rank (sets of) measures.

The disproportionate cost article (9) of the WFD requires that societal benefits are assessed at least roughly in monetary units and compared to costs. This is rarely practiced explicitly in Norwegian implementation of the WFD and may not be an important technical issue for that reason. If MCDA is to be used in the evaluation of measures, implementation of disproportionate cost would have to be given a relative rather than absolute interpretation.

Regional plans do not require further comparison of measures across water bodies or local plans, so there is no need for a decision-support tool such as MCDA at the regional planning level. Worth noting is that this may over time lead to large differences in the practice of what is considered “disproportionate cost” between water authorities.

Another aspect is whether MCDA could provide complementary interpretations of ‘significant negative consequence’ on other water users. This consideration implies that major costs to other water users - in many cases foregone hydropower production - are assessed against ecological status and other non-commercial water uses. This is a multi-attribute problem.

Both ‘disproportionate cost’ in the case of derogations and ‘significant negative consequence’ in the case of defining good ecological potential imply a specific interpretation of the value tree (criteria hierarchy) of the decision problem. Experience from MCDA has shown that the way the criteria hierarchy is defined can determine (bias) which alternatives are selected.

On the other hand, the use of MCDA for ranking of individual measures within programmes of measures under the WFD might not be applicable for several reasons:

- Ranking of measures is to be conducted against a single rather than multiple attribute of “good ecological status”.
- While good ecological status is a composite indicator, the rules for the joint evaluation of sub-indicators in their contribution to achieving GES have been established and are not subject to trade-off analysis
- In programmes of measures absolute ranking of measures is not required, rather than identification of a portfolio of measures that is to achieve GES at minimum cost.

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Appendix

Case-studies

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Water course regulation

1 The Pirkanmaa case in Finland

1.1 Short summary of the case

The Pirkanmaa case concerns one of the main river basins in Finland that is heavily constructed and regulated for the purpose of hydropower production and flood prevention. The area has high recreational and fishing values. Dissatisfaction of local municipalities and fishery associations toward lake regulation (especially in winter and late spring) lead to a process to identify possibilities to diminish the negative impacts on aquatic ecosystem, fish stocks and the usability of shorelines and scenery. The case did not focus only on water level issues but also on other mitigation measures such as fish stocking and restoration measures. The case is described in (Marttunen and Suomalainen, 2005).

1.2 Decision context

1.2.1 Decision makers, stakeholders, experts and analysts involved
In the ***Pirkanmaa*** case one of the main goals was to reconcile the different views and interest in watercourse regulation and to compile widely accepted recommendations for watercourse regulation policy in co-operation with authorities, local stakeholders and experts. The case had its premises in a series of long term discussions and disputes over one of the largest (the forth in size) and most heavily constructed and regulated watercourse in Finland. MCDA was used to find consensus among conflicting interests and opinions considering the means and possibilities to diminish the adverse impacts of lake regulation.

1.2.2 Framing the decision problem
What proportion of the impact evaluations used in the MCA relied on existing studies/secondary data (conversely what proportion of the impacts required primary data)?

The ***Pirkanmaa*** project was comprised of 10 subprojects which produced information on the ecological (aquatic vegetation, bird life, fish, crayfish), social (recreational use, fishing) and economic (hydropower, flood damage) impacts of regulation. The impacts of current regulation were assessed based on field studies, various models and expert judgments.

1.3 How was MCDA applied

1.3.1 The stage(s) in the decision process at which MCDA was applied
In the ***Pirkanmaa*** case, MCDA was embedded in the decision support process, e.g. in: defining and framing the problem, impact assessment, evaluation of options and recommendations and realization and follow up.

A customized decision support tool, REGAIM was used in the process. The whole analysis has had seven phases (steps):

STEP 1: Construct a value tree

Goal: the most preferred water level profile
Main attributes: water quality, nature, recreational use and fishery, flood damage, navigation and hydropower production
Alternatives: minimum and maximum water level fluctuation zones

STEP 2: Define a range for water level fluctuation in different dates

Stakeholder's ideal water levels were defined for five dates (having high biological relevance and significant impact on the uses). First, for each date, a range of water level fluctuation was predefined based on hydrological simulations. Stakeholders where then asked if they preferred the predefined values.

STEP 3: Assess the impacts of water level fluctuation

Impacts were assessed based on field studies, mathematical modeling and expert judgment

STEP 4: Define the most appropriate water level for each attribute

Example: an alternative (water level) got the value 1if the highest value for the attribute was achieved at the maximum water level and 0 otherwise.

STEP 5: Define weights for the attributes.

Weights were defined interactively, during interviews with the stakeholders. The respondents had the possibility to compare and adjust different weights immediately using visual displays.

STEP 6: Calculate and analyse target water levels

STEP 7: Analyse the impacts and compare to current regulation

At this stage the results of the MCDA are further refined so it make sense for participants and for the consensus-seeking process. The target water levels calculated here take into account all objectives that were weighted by the participants. Some objectives 'raise' the target water level while others 'lower' it so the calculated levels can be considered as a compromise outcome between competing water level objectives.

In the ***Pirkanmaa*** study, steps 1-4 were undertaken before the interviews while steps 5-7 were carried out in the face-to-face computer aided decision analysis interviews.

1.3.2 The MCDA approach used

In the Pirkanmaa study basic principles of Multi-Attribute Value Theory (MAVT) were used to calculate priority values for alternatives. Linear value functions were assumed.

The approach was designed to find out those water levels that stakeholders prefer at certain dates, and by connecting these points to form a target regulation practice the impact of which were analyzed and discussed.

The approach deviated from our earlier MCDA applications because in the Pirkanmaa case we did not have specific alternatives which would have been compared to each other but each participant generated her/his own target regulation which impact were then analyzed.

The concrete outcome of the process was 36 target regulations for three regulated lakes.

Step 6: Calculate and analyse target water levels

For each of three dates the REGAIM model calculated the priority values for minimum and maximum water level alternatives ($V(WL_{upper})$, $V(WL_{lower})$). The conversion of alternative priorities into target water levels can be formulated as:

$$WL_{target} = WL_{lower} + (WL_{upper} - WL_{lower}) V(WL_{upper})$$

The basic idea in Step 6 is to further refine the results of multicriteria analysis in a way that makes sense for the participant and for the consensus-seeking process. The target water level is set in a way that it takes account all the objectives which respondent has given weights. Some of these objectives 'raise' target water level and some of them 'lower' it. As a result, the calculated target water level can be considered as a compromise outcome between competing water level objectives. For instance, in case where the priorities for lower level and upper level alternatives are both 0.5, the target water level is in the middle of the predefined water level zone.

1.3.3 Multi-criteria decision support software

In the Pirkanmaa study a customized MCDA based model, REGAIM, was developed. The name 'REGAIM model' refers to water level REGulation and to stakeholder's AIM. The REGAIM model is an Excel spreadsheet model consisting of three sub-models:

1) The value tree model is used to compute target water levels for five time points on the basis of the stakeholder's opinion of the importance of the related impacts and the optimal water level for each attribute. For each stakeholder, the target regulation is formed by drawing an adjusted line between the five target water levels
2) The hydrological model is used to calculate the impacts of the target regulation on the water levels and flows in different water years. The results show how well the stakeholder's target regulation can be achieved in different water conditions.
3) The impact assessment model is used to calculate the scores for the attributes describing the ecological, social, and economic impacts of the target regulation in different water years and summarises them in the impact matrix.

1.3.4 How were the decision-makers, stakeholders and experts involved

The participants or actors in the Pirkanmaa case can be divided in four main groups:

1) the research team which consisted of a project manager and key experts. The research team facilitated the whole process of MCDA implementation
2) the stakeholder group (or the steering group) formed by 40 representatives of various interest groups, organizations, local people and key experts. The group involving environmental and fisheries authorities, municipalities, fishermen and recreational users as well as hydro power companies was established at the beginning of the project. The group had 7 meetings. In the meetings information gaps, research plans, and the results of the economic, social and ecological studies were presented and discussed. In the steering group the content and structure of the value tree was also refined. Most of the members of the steering group also participated in the personal interviews in which preference information to the REGAIM model was gathered and the model was applied in order to calculate respondents' target regulations. The duration of the interviews varied from 2 to 3 hours.
3) Citizens – about 2500 summer cottage owners. Their input was used at the beginning and at the end of the project.
4) experts and scientists played a very important role in the impact assessment phase. They conducted the relevant impact assessment studies associated with ecological, social and economic aspects of the current regulation and different alternatives.

1.4 Possibilities to integrate MCDA in 'established' management processes

In the Pirkanmaa study MCDA was integrated into the planning process from the very beginning of the project. The regional environmental authority who was responsible for the realization of the project recognized the need to support stakeholders to structure and analyse the planning situation and to incorporate their values into the decision-making process, to support their learning and to facilitate group decision-making. One reason for the authority's willingness to work with MCDA approach was earlier positive experiences from another similar project.

In the study MCDA (the REGAIM model) was used to generate target regulations for each respondent. The REGAIM interviews produced 9-15 target regulations for each of the three study lakes. These regulations were compared and analysed, and the results were presented in a workshop. The variation in the target regulations and their impacts was so large that it was evident that there was no alternative accepted by all stakeholders. In the workshop, the later phases of the work were discussed and decided. Based on the REGAIM analyses, primary target water levels were set for each lake.

General objectives for an acceptable outcome were agreed on. E.g. flood damage should not increase and there should not be significant losses for hydro power production. In a next phase a simulation model was applied to calculate the hydrological impacts of new regulation alternatives.

The economic, social and ecological impacts of each alternative were assessed, analyzed and discussed and if the general objectives set in the workshop were not achieved, the target water levels of the regulation alternatives were revised. All in all, more than ten regulation alternatives were calculated and analyzed. The results were presented in the two steering group meetings. In addition, there were three meetings with hydro power companies.

1.5 Resources used

The total 'budget' of an MCA study – for example, how long did the MCA studies take to carry out and report (start-finish).

The REGAIM model was developed and applied to three regulated lakes (three applications). The development of the customized Excel spreadsheet model including impact assessment model and MAVT based model for three lakes (=3 models) took 8 weeks. Preparing the background information and "questionnaire forms" to the respondents took 3 weeks (1 week/lake). Altogether 35 interviews were realized. There were 2-3 interviews in a day, and the arrangements took 1 week, which makes 4 weeks. The analysis of the results took 3 weeks (1 week/lake). Writing the report took 6 weeks. There were two meetings. One meeting was held before the interviews in which the value tree and alternatives' impacts were discussed and one after the interviews where the result were presented and discussed.

The preparation and arranging these meetings took 1 week. The impact assessment phase has not been calculated here because MCDA was an integral part of the work. The whole process lasted 8 months and the efficient time needed for the REGAIM work was totally ca 25 weeks. It should be noted that in this project we developed a totally new approach and there were three cases realized parallel.

1.6 Steps in the MCA that may be skipped

When the resources are scarce MCDA may easily be used as a synthesizing tool. Information from consequence tables can be used as input and the criteria weights are based on the experts' judgments. Value functions are assumed to be linear. There is not enough discussion about the criteria and structure of the value tree. Perhaps the choice of the attributes has been superficial.

Maybe the lack of time/resources increases the risk that criteria weights are arbitrarily defined. There have been cases in which main criteria (economic, social and ecological) have all been given equal weights and the argument has been that this balances different objectives or is an indication that principles of sustainable development have been taken into account. However, this violates the theory of MCDA because impact ranges should be taken into account. Equal weights can lead to situation where small disadvantages are weighted as much as large benefits.

1.7 "Take-home" messages

Typically, early in the development project, distrust and disputes arose between stakeholders. Some people had strong negative emotions directed at the watercourse regulation project and the organization responsible for it. Discussions were easily dominated by general beliefs and personal experiences of the impact of the watercourse regulation.

Each stakeholder had his or her own perception of what constituted good water levels and flows, reflecting his or her interests and values. These images were often very different from the watercourse regulation practice then in place.

Our working style in the Pirkanmaa project can be characterized as a search for an acceptable compromise solution. The process aims at finding a regulation practice satisfying multiple objectives at the same time. The projects aimed to create a process during which participants' overall understanding of the watercourse regulation and its effects as well as hydrological and technical constraints and stakeholders' objectives improved. A simultaneous aim of the development projects was to find and present recommendations that alleviate harmful impacts of the watercourse regulation or increase its overall benefits. The conditions for finding a compromise solution were most favorable when both there were means to improve the existing watercourse regulation and a process providing good opportunities for individual and social learning could be developed.

The levels of integration and interaction have a crucial impact on the quality and effectiveness of the MCDA process and its outcomes. The following reasons emerged:

- Improved opportunities to identify contradictions between participant's views and the weights of the attributes and the outcome of the analysis.
- Greater fairness and transparency: Personal DAIs (decision analysis interviews) signaled that each participant's opinion was appreciated and taken into account.
- Sustained participant interest in the process: In projects lasting several years, keeping participants active and committed was a big challenge. The integrated, interactive use of the MCDA tools helped create conditions for meaningful and effective interaction, which has been found to be one of the key objectives for the design participation processes

The interactive and integrated MCDA approach is quite laborious. However, it does not mean that the approach automatically would delay decision-making process or increase planning costs. Rather, the participatory, systematic and structured approach supports the identification of the most significant impacts in the early phases of planning. This diminishes the risk of surprises in the later phases of planning as well as the risk for additional studies and extra costs. The developed approach and transparent planning process may also reduce citizens' complaints to different instances and thus speed up the decision-making process.

2 The Øyeren case in Norway

2.1 Short summary of the case

Most hydropower regulations in Glomma River Basin (if we omit the pure Run of the River Regulations and the oldest regulations), have some kind of minimum release, compensation flow, or environmentally motivated rules for water level variations in reservoirs. The approach can be roughly described as an expert judgment based on baseline studies of ecological and water use interests‘, often simply referred to as the Expert Panel Method‘ in Norway. In the old regulations there was often only one expert that assessed all environmental aspects, frequently the regional Fish Inspector from the Directorate for Nature Management. In more recent regulations several experts and river users are involved in assessing the minimum water flows and the water levels. This expert group is often called an Expert Panel. The panel is composed of different experts on a case-by-case basis. The assessment methodology underlying expert judgment is often not documented in concession documents. The purpose of the case study was to propose approaches to improve this process (expert recommendations).

2.2 Decision context

2.2.1 Decision makers, stakeholders, experts and analysts involved

The Øyeren study was a desk study, including expert workshops, but the analysis was not part of any formal decision support process. In that senses there were no stakeholders involved. The expert panel was composed of representatives from NVE, hydropower operator, bird, fish and macrophyte specialists.

2.2.2 Framing the decision problem

What proportion of the impact evaluations used in the MCA relied on existing studies/secondary data (conversely what proportion of the impacts required primary data)?

The impact information used in the Øyeren study was based on an earlier impact evaluation report (Berge et al. 2002) where alternatives had been identified by a steering committee composed of authorities, hydropower and researchers. The impact assessment evaluated 4 different monthly water regulation scenarios addressing different use and ecological interests. The PIMCEFA method was applied to evaluate water levels achieving an optimal balance between interests for two critical months; April-May and September. 3/4th of the impact evaluation work had been carried out in a formal EIA prior to the PIMCEFA study. The remaining information was collected from the Expert Panel regarding the shape of the ‘pressure-impact’ curves for each criterion. However, the experts – particularly in biology - would not have been able to carry out their evaluations without having also participated previously in the EIA. We therefore relied on a large amount of tacit knowledge that may not be available in other projects that have not been through a formal EIA.

2.3 How was MCDA applied

2.3.1 The stage(s) in the decision process at which MCDA was applied

In the Øyeren study, MCDA was carried out after the water regulation had been decided using the normal regulatory environmental impact assessment process. The aim of the study was to show how EIA documentation could be formatted, in combination with well-documented expert judgment, into a MCDA.

2.3.2 The MCDA approach used

In the Øyeren study - Analytical hierarchy process (AHP) with pairwise weighting of criteria was used because it was easier to explain the process than more complicated preference elicitation methods such as outranking and ENVALUE – combining approaches - which was also part of the software.
Software tools used for impact evaluation and for preference modeling. The steps in the MCDA are illustrated in Figure 1 below.

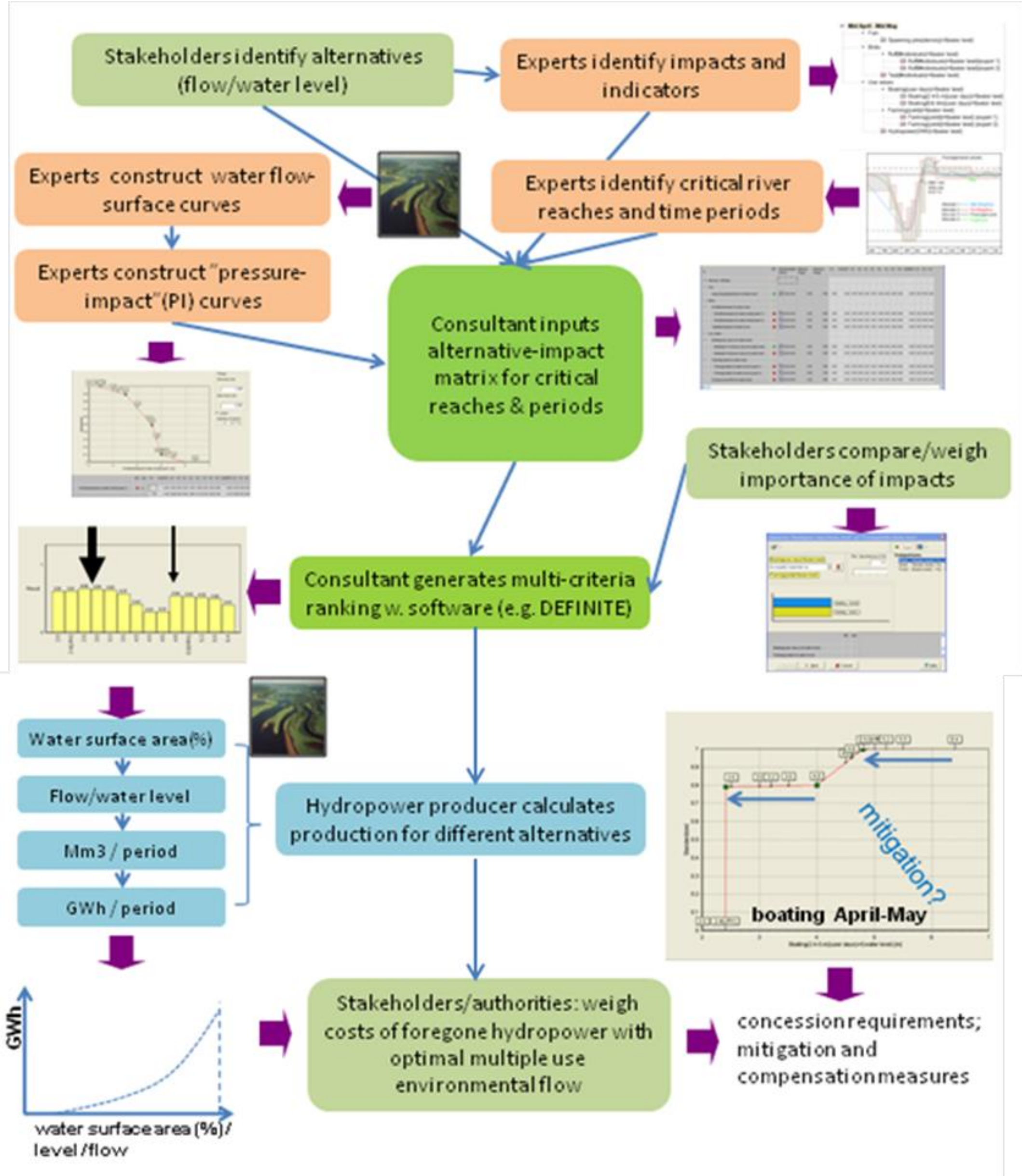

Figure 1. The role of decision analytical expertise and other roles in an MCDA of water level regulation in Øyeren, Norway. Source: Barton et al. (2009).

A key aspect of the methodology was simplifying 'value judgements' required in the analysis. Experts defined 'pressure-impact' curves which work as value scaling functions. Experts evaluated the impact of water level on different interests. Their judgement was supposed to focus on biophysical impacts and not include value judgements.

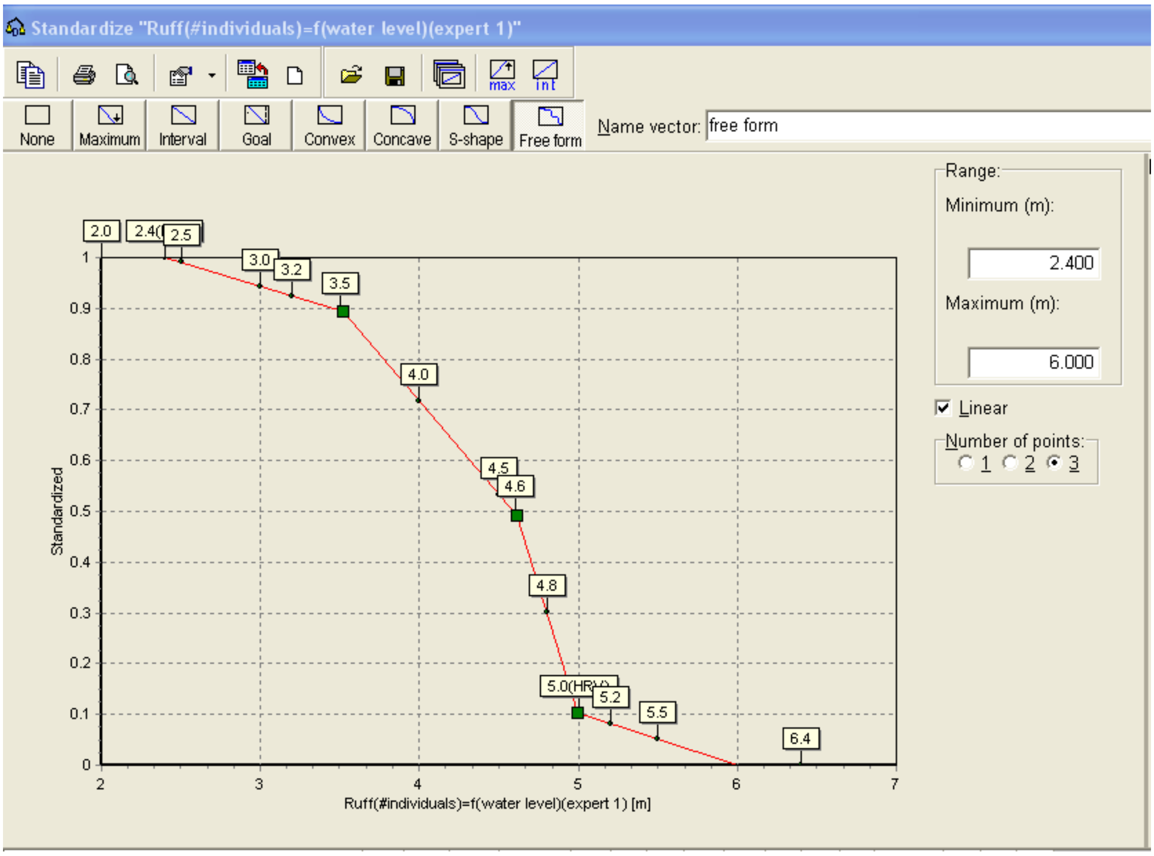

Figure 2. Pressure-impact curves scale the importance of water level (horizontal axis) for a specific use to a standard range [0..1]. 0=loss of the value in question (0 preservation); 1=no loss of the value in question (100% preservation).

In this case a duck species "Ruff" has the best wading conditions at low water levels; at 6 m water level there are no wading locations available and the site is completely unsuitable. The pressure-impact curve is drawn based on discussion in thematic expert groups. Experts can focus on evaluating biophysical impact, as a separate step from value judgements made by decision-makers in the criteria weighting step of MCDA.

2.3.3 Multi-criteria decision support software

In the Øyeren study the DEFINITE software (http://www.ivm.vu.nl/en/projects/Projects/spatial-analysis/DEFINITE/index.asp) was used to carry out the analysis. The value function Graphical User Interface was used to specify pressure-impact functions.

We also considered Expert Choice (http://expertchoice.com/), but selected DEFINITE because it

- Had several different MCA methods as functional options, while Expert Choice only had AHP. Nonetheless we ended up using AHP because it was the easiest to communicate.
- DEFINITE had a GUI for freeform definition of "value functions", while Expert Choice only had some standard functional forms (convex, concave and linear). The possibility to specify thresholds in the value function was seen as particularly important for implementing the pressure-impact modeling approach.

2.3.4 How were the decision-makers, stakeholders and experts involved

In the Øyeren study decision-makers were nominally involved as part of the Expert Panel to evaluate pressures and impacts.

2.4 Possibilities to integrate MCDA in 'established' management processes

Expert and stakeholder willingness to have their assessments and judgments made public and exposed to scrutiny may be the biggest limitations to the implementation of multiple criteria analysis for evaluating environmental flow in Norway. Regarding experts, PIMCEFA integrates and summarized a lot of their expert knowledge, and may be seen as a threat in that their expertise is 'captured' and may be used by others. A system of publication of expert opinions summarized in 'pressure-impact' curves may help to both recognize the source of expertise and expose it to public scrutiny. Regarding decision-makers, multi-criteria-analysis has a disruptive effect on the political economy of projects and policy. MCA documents where conflicts of interest may lie, both in relation to other stakeholders and in financial terms for specific stakeholders. Nevertheless, environmental impact assessment and public hearings are mandatory for large hydropower projects and major revisions of HP concessions. Viewed as an approach to jointly considering technical aspects of EIA with stakeholders' preferences as expressed in hearings – rather than as simply an MCA software application - PIMCEFA may offer some ideas for new approaches in Norwegian river basin management.

2.5 Resources used

The total 'budget' of an MCA study – for example, how long did the MCA studies take to carry out and report (start-finish).

3 expert Panel meetings and approximately 2 personmonths of consulting time to prepare the analysis, carry out meetings, analyse and present results. Approximately 3 personmonths in total, including expert panel time. 2 months, but based on 6 years of formal Impact Evaluation Assessment studies (1994-2000)!!

2.6 Evaluation of the MCDA process

In fact, the PIMCEFA study skipped the pairwise weighting procedure setting all criteria weights by default equal to each other. This was done because the analysis did not include a formal decision-conference with actual stakeholder interests. In other words, weighting – one of the key aspect of MCDA(!) was skipped, as the main aim of the study was to show how standard EIA information can be formatted at low cost into and MCDA.

Other simplification may be to evaluate the correlation of pressure-impact curves before conducting the multi-criteria weighting. This may significantly simplify the analysis as highly correlated impacts may mean that multiple impacts can be represented with a single ―proxy‖ pressure-impact curve.
Given the limitation on fixing the pressure-impact curve to three points, a good rule of thumb may be to ask experts to provide the 10%, 50% and 90% impact water levels, in addition to the end points. Our experience from the expert panels used to elaborate pressure-impact curves indicates that experts do not have the data or models to evaluate impacts with any more precision than this (even in the well documented Øyeren case).

2.7 "Take-home" messages

1. Carrying out and MCDA decision-process provides impact evaluation with a replicable method that can be scrutinized by third party review. This is of particular importance when concessions come up for review (the ability to return to the original analysis).
2. MCDA has traditionally placed much more emphasis on "getting the weights right", than "getting the value function right". The PIMCEFA approach places a lot of emphasis on eliciting and defining value functions based on expert knowledge of biophysical and economic responses expressed as pressure-impact curves. It is important that this expert knowledge is documented, and subject to third party review, as part of MCDA
3. MCDA can be useful for problem structuring even without weighting.

3 The Chalamy river case in the Alps region

3.1 Short summary of the case

The Chalamy River in North West of Italy is partially included in the Mont Avic Natural Park: its basin is characterized by a high degree of naturalness. In the upper part of the basin there's a hydropower withdrawal with a steady traverse collecting also the water of other four small torrents. Considering that until 2008 no MIF was released from the withdrawal point, the management alternatives involved the amount of increasing MIF releases. Experimental releases are gradually increasing from 2008 to 2015.
The experimental tests are feeding a MCA Decision Support System (DSS) supported by an indicator set defined by a technical panel. When possible, indicators deriving from regional and national set of laws have been preferred to allow compliance with normative requests. The expert group is composed by specialists mainly working in the public administration (PA) technical sectors and in the public hydropower company (CVA - Compagnia Valdostana delle Acque). For more information on the case and similar projects please check http://www.sharealpinerivers.eu/.

3.2 Decision context

3.2.1 Decision makers, stakeholders, experts and analysts involved
The Chalamy case has been considered both in the frame of SHARE cooperation project pilot areas and in an official experimentation process aiming to define the optimal MIF for the specific river system. Stakeholders involved are representatives of public hydropower company, regional environmental protection agency, fishermen association, PA technical services divisions for economy, landscape, tourism and water use concessions.
Starting from 2008, the same experimental management approach has been set up for 29 existing HP plants (big-medium size) in the same administrative region. Experimentation will continue till 2015.

3.2.2 Framing the decision problem
What proportion of the impact evaluations used in the MCA relied on existing studies/secondary data (conversely what proportion of the impacts required primary data)?

The ***Chalamy*** experimental approach has been proposed by the hydropower company involved and subsequently, discussed and assessed by the regional technical panel. Information needed to implement indicators to be used in the MCA frame has been collected from CVA HP experts, existing monitoring networks and previous studies.

3.3 How was MCDA applied

3.3.1 The stage(s) in the decision process at which MCDA was applied

Regional official MIF definition rules (NUTS2 level) allow the adoption of an experimental approach to define withdrawal sustainability. For the Chalamy case, MCDA was proposed by the public power company as a tool to manage and assess information related to sustainability criteria to be essentially considered (economy, energy, river environment, landscape, tourism and sport fishing). The explicit aim of the study is to define the optimal MIF to be released

3.3.2 The MCDA approach used

In the Chalamy study classical linear additive MCA approach has been used. Even if limits of this methodology are well documented in bibliography, the technical panel decided to adopt an assessment approach as simple as possible to avoid that stakeholders perceive MCDA as a "black box" not fully reflecting their own interests.

A pairwise weighting of indicators and criteria is going to be implemented.

3.3.3 Multi-criteria decision support software

In the Chalamy case study the software to support MCDA assessment is SESAMO-SHARE (http://www.sharealpinerivers.eu/tools-and-resources/our-softwares-1/sesamo-share) customized in the frame of SHARE cooperation project. The system is a stand-alone application which implements the classic multi attributes analysis, as described in Keeney and Raiffa (1993).

3.3.4 How were the decision-makers, stakeholders and experts involved

In the Chalamy case study decision-makers were formally involved in the technical panel from the beginning of the process to evaluate sustainability of releases at regional level.

3.4 Possibilities to integrate MCDA in 'established' management processes

Aosta Valley is an autonomous region holding the rights for water governance: official regulations include experimental approach to define MIF to be released from HP plants. MCDA is adopted as a "soft governance" tool integrated in the frame of normative compliance and sustainable river management. The experimentations results are legally binding.

3.5 Evaluation of the MCDA process

Our approach has been really simplified and essential as possible so it is difficult to think about cutting out one or more phases.

We have applied MCDA using two separate levels of implementation: the first is dedicated to decision makers and it is focused on weight assignment and ranking of general criteria, the second is single criteria focused practically involving only disciplinary experts. The second level could be simplified deciding to limit significantly the number of indicators to be considered but it would be a very thorny situation to manage because every stakeholder group wants to see their own interest reflected in a specific indicator / dataset elaboration.

3.6 “Take-home” messages

It is important to define clearly and from the beginning the real influence of MCDA on decision making process and viable expected outcomes (MCA - technical advice vs. MCA - legally binding tool)

The adoption of a communication protocol is strategic to “translate MCDA” in the right language for decision makers: no magic tongue, no black box allowed with decision makers, they want to hold the process. Before coming out with methodology presentation, it is hardly preferred do at least a test with collaborative decision makers.

Policy makers are not the main target group because they often adopt a shorter term decision making approach: it is better to focus on high level administrators because they need to be better equipped for decision making.

Focus on the profile of decision makers (age, studies background, priorities in decision making, hierarchy level, lobbies influence) because it strongly shapes their decision making attitude.

While presenting the potential of MCDA adoption to PA sectors and decision makers, it is important to put in evidence that it can be a significant support to be compliant with set of laws. For the same reasons it is suitable to prefer criteria, alternatives and indicators already defined / supported from set of laws.

When possible, prefer a MCDA stakeholder driven: criteria should correspond to stakeholders groups (including PA branches). Anyhow, ranking and weighting would be never easy and fair, there will be losers and winners …

MCDA allows hard & soft information respect: some indicators are coming from set of laws, some are valuable in euro, some are expert-based qualitative assessment but they are all dependent from data reliability and availability.

WFD community based indicators are not fitting enough to detect HP effects: they have to be supported and integrated by hydro morphologic indicators

HP concession usually last for several decades but global change already strongly affect water availability and flows patterns in a time scale coincident with concessions duration. This driver should be considered in MCDA approach.

River restoration

4 Restoration of the River Mustionjoki

4.1 Short summary of the case

Mustionjoki is a 25 kilometre river in the Karjaanjoki river basin in southern Finland. The river is harnessed by four hydroelectric power plants, which block migrating fish, for example salmon, from returning to the river. An endangered freshwater pearl mussel population of the river needs salmon for reproduction.
In 2009, the Finnish Association for Nature Conservation and the power company Fortum Ltd. started a project to compare the desirability and feasibility of different mitigation measures that would enhance freshwater mussel and salmon populations.

4.2 Decision context

4.2.1 Decision makers, stakeholders, experts and analysts involved

A steering group, MCDA experts, involvement of the public (through meetings)

4.3 How was MCDA applied

MCDA was as an integral part of the project in order to provide a systematic framework for gathering and presenting information, identifying objectives, interviewing key stakeholders, discussing the results and deciding on further actions. The main objectives of the project were

- to assist the steering group of the project and the respondents in getting a better overall understanding of the planning situation
- to assist participants in understanding the scale of the impacts and the uncertainties related to them
- to find out stakeholders' opinions about the desirability of the alternatives from each participant's point of view
- to identify and systematically assess alternative actions for enhancing freshwater mussel and salmon populations.

4.3.1 The stage(s) in the decision process at which MCDA was applied

This case can be seen as an example of a highly integrated and interactive application of MCDA with the help of the DAIs. Decision analysis interviews were carried out with the help of Web-HIPRE software. In addition, two public meetings were arranged. In the first, the project was presented and the objectives and evaluation framework were discussed. In the second, public meeting the results of the project were presented and future studies and actions were discussed.

4.3.2 The MCDA approach used

Value-focused thinking (Keeney, 1992) and decision analysis interviews carried out with the help on the Web-HIPRE software.

4.3.3 The multi-criteria decision support software used

The Web-HIPRE software was used (http://www.hipre.hut.fi).

4.3.4 How where the decision-makers, stakeholders and experts involved

There was close co-operation between MCDA experts and the representatives of the steering group, which was highly motivated and committed to MCDA process. There were six steering group meetings. Altogether 12 decision analysis interviews were carried out with the help of Web-HIPRE software. In addition, two public meetings were arranged. In the first, the project was presented and the objectives and evaluation framework were discussed. In the second, public meeting the results of the project were presented and future studies and actions were discussed.

4.4 Possibilities to integrate MCDA in 'established' management processes

The research team was responsible for designing the whole evaluation and participatory process. Therefore, it was quite easy to realize processes that were based on the phases and principles of MCDA.

4.5 Evaluation of the MCDA process

Based on the feedback from the steering group, the method aided in gathering and synthesizing information and in identifying knowledge gaps. It also provided a way to transparently present different viewpoints and the reasoning behind them. This was possible, because a lot of time was spent on structuring the problem to develop a common view of the key criteria. The main challenge was to assess alternatives' impacts, and too little time was spent on that due to time constraints. Because of this, the assessments were refined after the first interviews, which reduced the commensurability of the interviews. The interviewees considered the information booklet long, but they also found that it provided a good holistic view of the problem, if one found time to read it. Of the obtained results, the final scores of the alternatives were seen as less important than the understanding of the different viewpoints and identification of key knowledge gaps.

During 2013 most of the suggested research activities have been realized, but restoration measures and fish ways lack still funding.

4.6 Take home message

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 co-operation might have become easier. Consequently, this may increase the willingness of the stakeholders to accept compromise solutions to the problem and also the commitment to the decision to be made, even if this is not the best one from one's point of view.

5 Restoration of the River Iijoki in Finland

5.1 Short summary of the case

The River Iijoki is the sixth largest river in Finland. Until its damming for hydropower production between 1961 and 1971, it was one of Finland's famous salmon rivers. For several decades, five hydropower dams in the lower course have blocked the passage of migratory fish to their reproduction areas. Most of the upstream areas suitable for salmonids have been restored after the cessation of timber floating. Since the damming in the 1960s, salmon and sea trout stocks have been maintained in the River Iijoki through a broodstock program where the stocks are renewed using eggs stripped from returning fish and their genetic diversity is monitored

In the case of River Iijoki, a heavily modified river, restoration is inevitably a lengthy process, and long-term commitment of different parties to the project is necessary. Therefore, smooth co-operation and communication as well as mutual understanding between planners, authorities, stakeholder groups and citizens are of vital importance.

The case compares a real life process in which MCDA has been applied with a desktop analysis of how the ES approach could be integrated into MCDA. The comparison answers the following questions:

- Are some value or impact categories and criteria left out from EIA when applying the ES approach with MCDA in an assessment? Are some ecosystem services left out when applying the interactive MCDA approach in an assessment?
- Can we assess and value ecosystem benefits in a more understandable way for the stakeholders and public by using the ES framework than by using the theories and practices of multi-attribute valuation? Or, does the ES approach actually introduce a new form of expert assessment which hinders public and stakeholder participation and learning in EIA?

Please check reference (Karjalainen et.al, 2013) for more details on the case.

5.2 Decision context

5.2.1 Decision makers, stakeholders, experts and analysts involved

The impact assessment process in the River Iijoki case was coordinated by a project group of researchers, key stakeholders from fishing co-operatives, a hydropower company, a local environmental association as well as officials from the environmental and fishing administration.

5.3 How was MCDA applied

5.3.1 The stage(s) in the decision process at which MCDA was applied

The case compares a real life process in which MCDA has been applied with a desktop analysis of how the ES approach could be integrated into MCDA.

5.3.2 The MCDA approaches used

The project group had altogether six different meetings or workshops where the MCDA and EIA work was processed.

The first meeting was to agree that the rehabilitation of migratory fish populations into a regulated river in the presence of multiple interests (such as hydropower, recreational and amenity values, nature conservation and tourism) would be complex and span a considerable period of time. It was accepted that a time scale of 50 years would be an appropriate period for all the measures to have taken effect. There was also discussion about existing uncertainties, e.g., the future state of the Baltic Sea and its effect on the migration and rearing of salmons. It was important to clarify all the objectives of the stakeholders and the different policies for the restoration project

5.3.3 The multi-criteria decision support software used

Web-HIPRE software was used (http://www.hipre.hut.fi).

5.3.4 How where the decision-makers, stakeholders and experts involved; at which stages in the decision support

The project group had altogether six different meetings or workshops where the MCDA and EIA work was processed. The smaller expert group, which coordinated the research for the impact assessment, consisted of researchers from the University of Oulu, the Finnish Environment Institute and the Finnish Game and Fisheries Research Institute. The whole EIA process lasted one year.

The MCDA process provided a framework and a tool for integrating the different work packages, disciplines, studies and phases of the research and for collecting, processing, organizing and analyzing the information gathered from stakeholders, experts and scientists.

The participants' evaluation of the process and approach (through a feedback questionnaire) was positive: they thought that different viewpoints and alternatives were found and systematically analyzed

5.3.5 "Take-home" messages

The applied value-focused approach is appropriate and flexible in working with stakeholders and their often conflicting values and goals because it takes trade-offs into account in EIA. It focuses on the scoping stage where the key objectives and values of stakeholders are defined, and where the key ecosystem services (ES) can also be selected. To avoid the top-down process of identifying and valuating ecosystem services and important objectives, analytic–deliberative methods could foster a bottom-up way of forming value categories, including key ecosystem services and assessment criteria. Applying value-focused thinking during the scoping stage enables the identification of priority ESs according to the significance of the project's impact on each of them. In the EIA process, determining the impact's significance is recognized as a crucial, highly complex and little-understood activity.
The interactive MCDA approach can be used as an integrated impact assessment framework within which all dimensions of value could be considered, including ecological, socio-cultural and economic dimensions as well as the different costs and benefits.

6 Optimal routing of high-voltage power lines employing the least-cost-path approach – an example of geographically-explicit multi-criteria assessment

6.1 Short summary of the validation case study

Parts of the high-voltage power line corridor (300/420 kV), between Klæbu and Viklandet in Central Norway, has been used as a validation case to develop a Least-Cost-Path (LCP) toolbox for routing of high-voltage power lines (Bevanger et.al. 2011). The toolbox is being developed by the Norwegian Institute for Nature Research (NINA), and is one of several outcomes from the interdisciplinary research project OPTIPOL (Optimal design and routing of power lines) as part of the Centre for Environmental Design of Renewable Energy (CEDREN).

The high-voltage power line routed between Klæbu and Viklandet became operative in 2005, and the accompanying impact assessment reports (2001/2002) formed a reliable knowledge platform on the underlying restrictions, issues, concerns and routing criteria that the final routing decision was based on in 2002.

A multidisciplinary subset of these routing criteria were selected and reviewed by involved stakeholders, for the development of a geographically-explicit multi-criteria assessment in the LCP routing toolbox.

6.2 Decision context

6.2.1 Decision makers, stakeholders, experts and analysts involved

From the beginning of the OPTIPOL project (Bevanger et al. 2009, 2010, 2011, 2012) a broad range of stakeholders (the electrical power industry, consulting companies, NGO's, local/regional/national authorities and researchers) have been participating in the development of the LCP toolbox.

To ensure a relevant collection of criteria a standardized bottom-up dialogue approach has been undertaken where stakeholders were challenged to seek consensus on criteria selection and definitions, their values and mutual weights (Thomassen et al. 2012, 2013). In addition to this a national online survey was disseminated among relevant stakeholders throughout Norway in order to harvest additional inputs from other stakeholders. This national survey was closed in July 2013 and will be analysed in August/September 2013.

6.2.2 Framing the decision problem

How can we ensure optimal decisions, effective processes, stakeholder involvement and reduced conflict levels?

The main objective of our work is to develop a geographically-explicit MCA for environmental-friendly routing of high-voltage power lines based on a stakeholder consensus on ecological, societal, economic and technological criteria (including improvement of existing planning tools and conflict reduction through dialogue).

The intention of this work is to demonstrate how such multi-criteria analysis efficiently can be performed with LCP in early phase planning and decision making of power line routing. Use of LCP will not replace Environmental Impact Assessments (EIA), but it can be a powerful tool in assessing where the optimal corridor should be planned and can be viewed as part of the scoping process in EIA's.

6.3 How was MCDA applied

6.3.1 The stage(s) in the decision process at which MCDA was applied

In our approach MCA is applied at an early stage in the planning process. The LCP toolbox is not a traditional decision support system. But it is very flexible as it allows the stakeholders to individually re- run their choices of criteria values and weights based on the same Geogeo-databases.

6.3.2 The MCDA approach used

Least Cost Path has for many years been used in GIS-applications for routing of linear features and siting of man-made structures. This method demands a strict scheme for calibration and weighting of all applied criteria. Criteria based on legal requirements, personal judgements and best practices expressed by the stakeholders have to be normalized in order to be measured and compared.

Decision-making on routing of high-tension power lines is a multi-criteria problem where preferences from economic, technological, societal and ecological perspectives –with associated stakeholders– need to be balanced. The Least-Cost-Path (LCP) methodology helps to find the "optimal" route and/or corridor between two locations over a friction surface as a function of accumulated distance and user-defined criteria. To ensure relevant multi-criteria collection, a standardized bottom-up dialogue approach has been developed where stakeholders are challenged to seek consensus on criteria selection, associated quantifiable/geographical definitions, threshold values and criteria weights (Delphi process: Brown 1986, Berry 2007). Criteria deemed relevant for optimal routing of power lines may however not be directly comparable because of their character and measuring units. Also, categorization of criteria values into two or more classes are not realistic.

To standardize criteria into a continuously measured common unit, a fuzzy logic approach is employed (see figure 1). Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than accurate (Zadeh et al. 1996). Fuzzy logic variables (i.e. criteria) may have a degree-of-accept (figure 2.1) that ranges on a continuous scale between 0 (bad) and 1 (good). This scale may take various shapes (i.e. extreme / mid-point optimum and incremental / decremental) that may be managed by four specific mathematical functions (i.e. positive/negative Gaussian and sigmoid). Threshold values derived from the dialogue process are used to calculate the function parameters. Acceptance or rejection is assumed to be reached within pre-defined limits (e.g. inflection points or two-sided 90% confidence interval); this to avoid acceptance or rejection reaching infinity. A standardize and continuous approximation of "cost" is derived as 1 – degree-of-accept (i.e. degree-of-conflict) (figure 4).

These functions measuring the degree-of-conflict are converted to a non-monetary cost surface index based on the stakeholders' consensus on each criterion. In reality it may, however, be hard to obtain consensus from all stakeholders on specific criteria threshold values. For further scoping of the dialogue process it is therefore extremely important to identify geographical areas where disagreement for a given criterion exists. Simple statistics are used to measure mean costs and cost variation. While preferred areas (agreement on a low conflict level) are characterized by a low mean cost and a low cost variation, areas to avoid (agreement on a high conflict level) have a high mean cost and low cost variation. Areas with a high cost variation (indicating disagreement in criteria threshold value estimation) should be further assessed.

All thematic cost surfaces are calculated in the manner described above based on the degree-of-conflict. Thematic cost surfaces are weighted proportional to their relative importance and summarized into cost surfaces for each of the four perspectives (economic, technological, societal, ecological). Finally all perspective cost surfaces are weighted proportional to their relative importance and summarized into a total friction surface, from which the LCP methodology derives the "optimal" route and/or corridor. Restricted areas where routing of power lines is prohibited by law are excluded from the least cost path calculation.

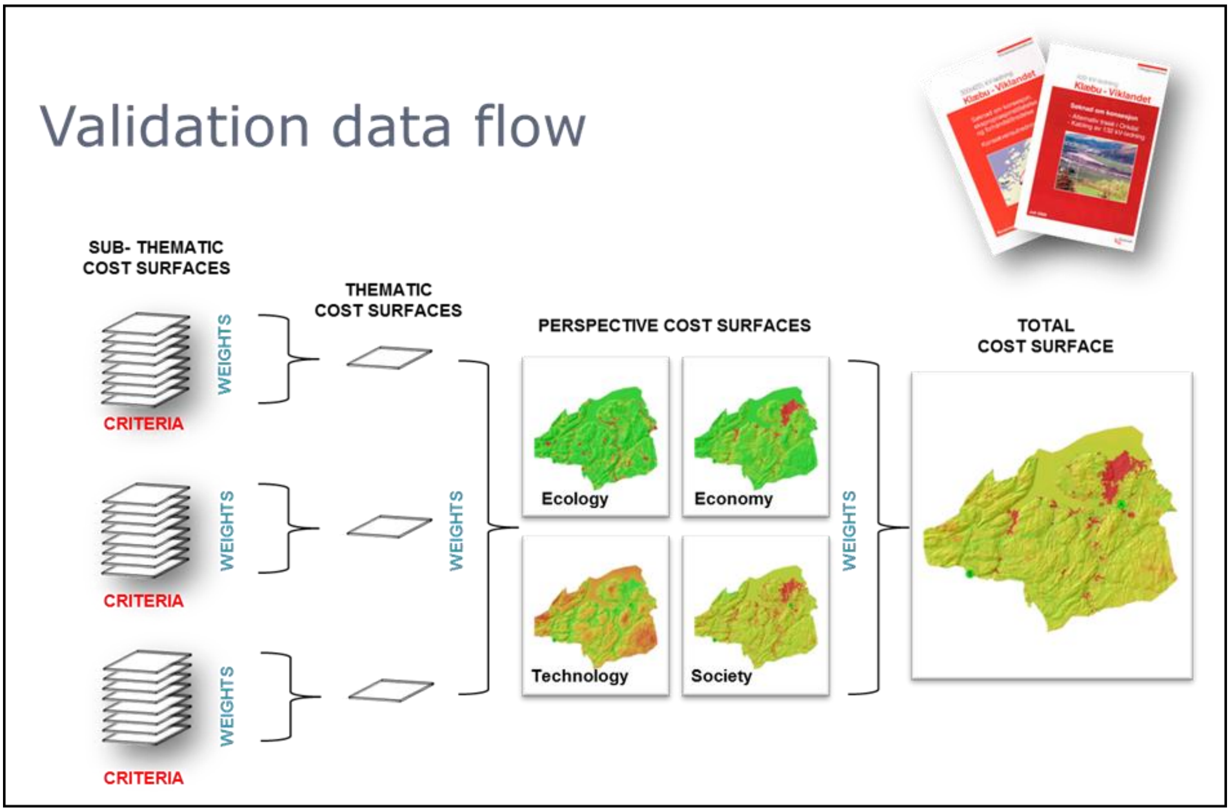

Figure 3: MCA Validation data flow.

Stakeholder's degree of consensus is a measure for criteria values by implementing basic summary statistics. The idea of this approach is to identify and visualize areas of consensus and conflict. This may in turn assist the further scoping of the dialogue process.

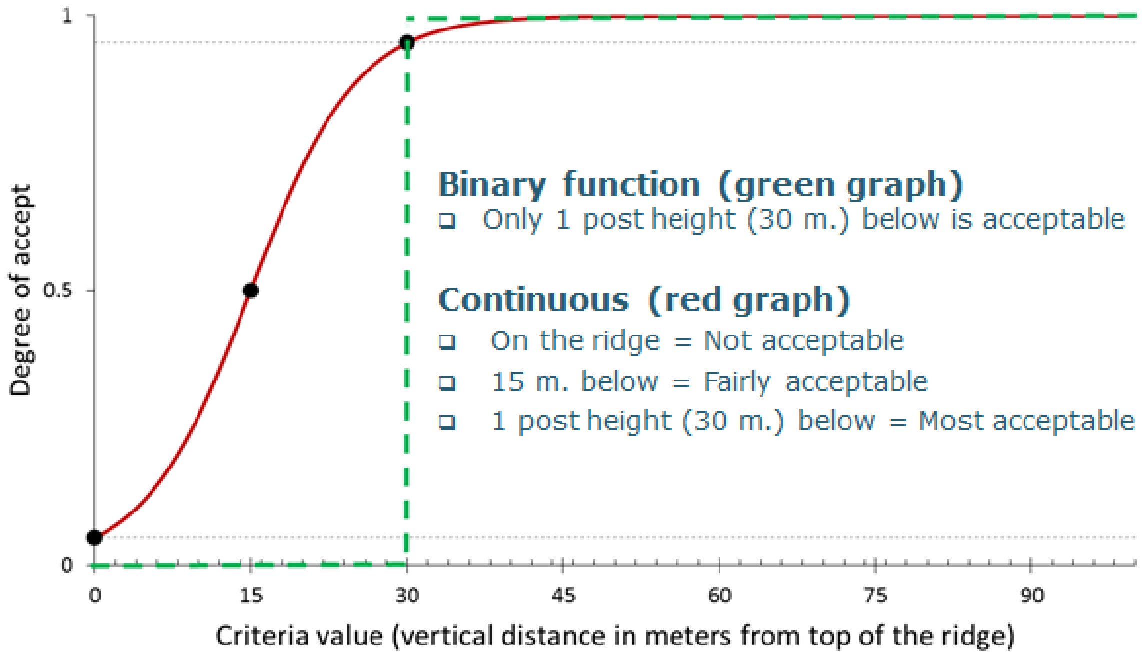

Figure 4.1 Degree of acceptance scaling of impact criteria.

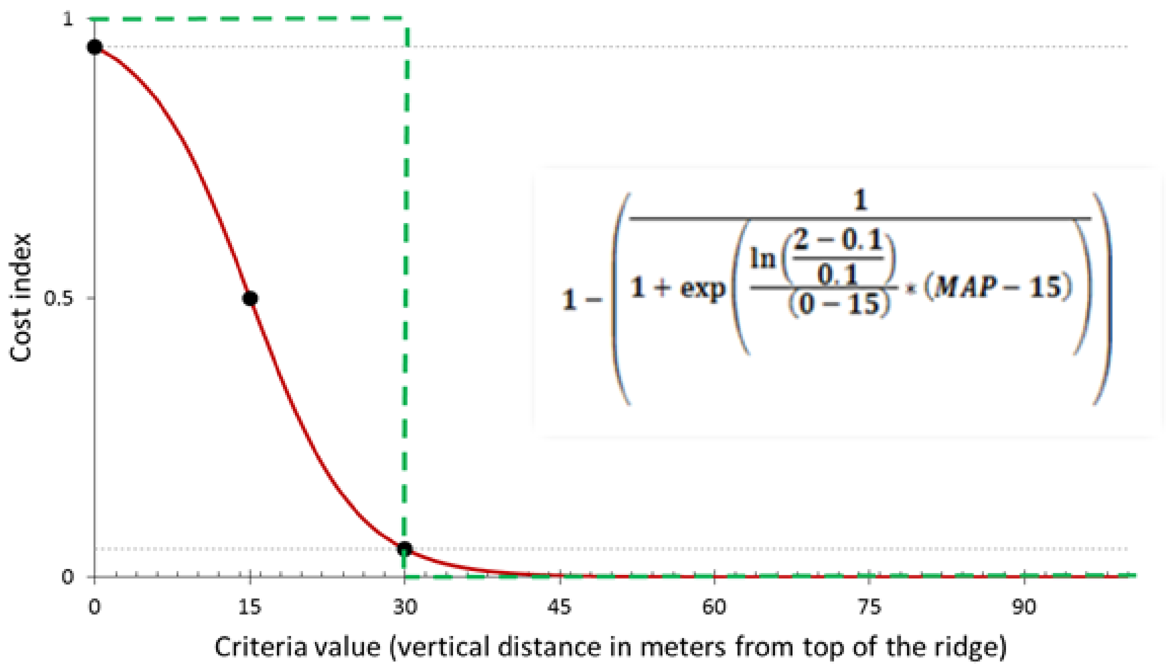

Figure 4. Transformation of degree of acceptance to a cost index.

6.3.3 Multi-criteria decision support software

To standardize the stakeholder's preferred values into mutually comparable criteria maps we have developed a dynamic Excel macro. The LCP toolbox is developed in ESRI ArcGIS 10.1 based on map algebra.

6.4 Possibilities to integrate MCDA in 'established' management processes.

There are clearly many possibilities to integrate our geographically - explicit MCA approach in established management processes. We are currently in dialogue with several stakeholders (the energy sector, the regional land-use planning sector and the wind-energy industry) concerning the application of this approach for other purposes. The national electrical grid-owner Statnett has indicated that OPTIPOL LCP could fit very well into the earliest stages of their project cycle when planning a new power line construction project.

6.5 Resources used

This question will be discussed in the final report of the OPTIPOL project in 2014.

6.6 "Take-home" messages

- Stakeholder involvement is very important
- Improved dialogue may reduce conflict levels
- Important to agree on a common knowledge platform early in the planning process
- Mapping of conflicts of interest enables both a thematic and geographical scoping of the study area
- The LCP approach offers a high degree of flexibility and verification
- More effective decision processes may lead to an increased return of investment
- Some stakeholder issues may be challenging to quantify in MCA
- Our toolbox is not an engineering tool

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